Health of the Bay of Fundy: Assessing Key Issues

Proceedings of the 5th Bay of Fundy Science Workshop
and Coastal Forum, "Taking the Pulse of the Bay"
Wolfville, Nova Scotia
May 13-16, 2002

Editors

P. G.Wells, G. R. Daborn, J. A. Percy, J. Harvey and S. J. Rolston

Environment Canada – Atlantic Region
Occasional Report No. 21
Environment Canada, Dartmouth, NS and Sackville, NB
March 2004

This publication should be cited as:

P. G.Wells, G. R. Daborn, J. A. Percy, J. Harvey and S. J. Rolston. (Eds.). 2004. Health of the Bay of Fundy: Assessing Key Issues. Proceedings of the 5th Bay of Fundy Science Workshop and Coastal Forum, "Taking the Pulse of the Bay", Wolfville, Nova Scotia, May 13-16, 2002. Environment Canada - Atlantic Region, Occasional Report No. 21, Environment Canada, Dartmouth, Nova Scotia and Sackville, New Brunswick, 416 pp.

Copies can be obtained from:

Ecosystem Science and Information Division
Canadian Wildlife Service
Environmental Conservation Branch
Environment Canada - Atlantic Region
45 Alderney Drive
Dartmouth, Nova Scotia, B2Y 2N6

Bay of Fundy Ecosystem Partnership (BoFEP)
Acadia Centre for Estuarine Research
Acadia University
Wolfville, Nova Scotia, B4P 2R6

Published under the authority of the Minister of Environment

ISBN 0-662-32818-3
ISSN 1195-664X
Catalogue No. CW69-12/21-2004E

Table of Contents

The Bay of Fundy Coastal Forum: “Taking the Pulse of the Bay”

Poster Session

A. Organizations

B. Projects

Preface

The 5th BoFEP Bay of Fundy Science Workshop, the most recent in a series of Fundy Workshops launched in 1996, was held at Acadia University, Wolfville, NS, May 13-16, 2002. Its theme was "The Health of the Bay of Fundy: Assessing Key Issues". This reflected a desire to continue examining issues in an integrated and ecosystem-based manner as they may affect the structure and function of the whole bay, its watersheds and adjacent waters.

Following a trend set by the 2nd and 4th Fundy Science Workshops, this meeting also involved a second major sponsor. GPAC (the Global Programme of Action Coalition for the Gulf of Maine) joined BoFEP in conducting, as part of the workshop program, a Bay of Fundy Coastal Forum entitled "Taking the Pulse of the Bay". The forum was a Canadian contribution to the joint, on-going, Gulf of Maine Council on the Marine Environment – GPAC initiative to report on the state of the Gulf of Maine-Bay of Fundy by late 2004.

The workshop had 16 sponsors, 180 participants, six concurrent paper sessions, four panel discussions, an on-going poster session, and 1.5 days of plenary discussion and working sessions as part of the Coastal Forum. It ran for 2.5 days. We were honored by the presence of two eminent guest speakers, Mr. David Phillips of Environment Canada, Toronto, and Dr. J. A. (Jack) Pearce of the Buzzards Bay Laboratory, Falmouth, Massachusetts. Some challenging Maritime spring weather notwithstanding, the workshop was judged a success by all who attended. It was especially encouraging that participants represented many sectors, from scientific institutions to communities and non-governmental groups, a true mixing of different interests. All were willing to share their ideas, knowledge, energy and thoughts of the future of the bay. More than 100 people contributed to the Coastal Forum.

These proceedings contain the abstracts and papers presented at the workshop and the papers presented at the Coastal Forum. The workshop papers highlight eight current key topics: coastal zone and information management; climate and sea level change; fish and fisheries; wildlife and habitat conservation; contaminants and ecosystem health; *Corophium* and mudflat ecology; Minas Basin; and ecotourism opportunities and impacts. The principal panel discussions are summarized herein. Posters featured organizations, specific projects on Fundy, and diverse management initiatives. A background paper on Fundy health, prepared as a working document for this meeting, is included. The Coastal Forum discussed and debated five key questions pertaining to the health of the Bay of Fundy. These discussions are being prepared as a separate Fundy Coastal Forum report in 2004.

P. G. Wells[1], G. R. Daborn[2], J. A. Percy[3], J. Harvey[4], and S. J. Rolston[5]
Workshop Chairs and Editors
March 2004
1 Environmental Conservation Branch, Environment Canada
2 Acadia Centre for Estuarine Research, Acadia University
3 Sea Pen Communications
4 Conservation Council of New Brunswick
5 Seawinds Consulting Services

Workshop Organizers

Workshop Co-chairs

Graham Daborn and Peter Wells

Workshop Program Committee

Peter Wells and Jon Percy (Co-chairs)
Mike Brylinsky
Thierry Chopin
Debra Dugas
Chris Greene
Diana Hamilton
Janice Harvey
Stephen Hawbolt
Pat Hinch
Barry Jones
Jeff Ollerhead
Nancy Roscoe-Huntley (Logistics Chair)
Maxine Westhead

Logistics Committee

Nancy Roscoe-Huntley (Chair)
Debra Dugas
Barry Jones
Jon Percy
Peter Wells
Maxine Westhead

Sponsors

The 5th Bay of Fundy Science Workshop and Coastal Forum were sponsored by:

Acadia Centre for Estuarine Research
Acadia University
Acadia University Bookstore
Bay of Fundy Ecosystem Partnership (BoFEP)
Conservation Council of New Brunswick.
Environment Canada, Environmental Conservation Branch
Fisheries and Oceans Canada, Bedford Institute of Oceanography
Global Programme of Action Coalition for the Gulf of Maine (GPAC)
Gulf of Maine Council on the Marine Environment
Huntsman Marine Science Centre
Nova Scotia Department of Agriculture and Fisheries
Nova Scotia Department of Environment and Labour
Parks Canada
Sodexho Canada
Town of Wolfville
World Wildlife Fund Atlantic Region

Acknowledgements

Many people and groups contributed to make the 5th Workshop and Coastal Forum a success. In particular, the authors of all contributions and the participants are greatly thanked for their interest and enthusiastic participation; the Fundy workshops are now a recognized biennial event reflecting their work and interests in the Bay of Fundy region. Members of the organizing committees worked long and hard, notably members of the logistics committee before and during the meeting, under the able hand of Nancy Roscoe-Huntley. The distinguished speakers David Phillips and Jack Pearce are thanked for their special efforts to attend the meeting. We had many sponsors and they were much appreciated. Acadia University hosted the workshop and made all participants very welcome throughout their stay in the residences and in the meeting hall. Finally, Susan Rolston is warmly thanked for her skilled work copy-editing the final Proceedings.

The Bay of Fundy Ecosystem Partnership (BoFEP)

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

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

To learn more about BoFEP visit: <http://www.auracom.com/~bofep>

Global Programme of Action Coalition for the Gulf of Maine (GPAC)

In 1995 more than 100 countries, including the United States and Canada, adopted a Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). The GPA is administered through the United Nations Environment Programme. It requires participating countries to develop action plans to reduce the effects on the marine environment of activities taking place on their lands.

Earlier, in 1993, the United States, Canada and Mexico had signed the North American Agreement on Environmental Cooperation, undertaking to work together to protect the environment in North America. The North American Commission for Environmental Cooperation (CEC) was set up to promote and coordinate the joint activities.

As one of these joint activities that also contributes to the GPA, the CEC created and provided resources for the Canada - United States Gulf of Maine Pilot Project from 1996 to 2000. The cross-sector working group known as the Global Programme of Action Coalition for the Gulf of Maine (GPAC), started in 1996, is continuing to work to reduce risks from land-based activities that affect the Gulf of Maine.

To learn more about GPAC visit: <http://www.gpac-gom.org>

Workshop Background Paper

ASSESSING THE HEALTH OF THE BAY OF FUNDY – CONCEPTS AND FRAMEWORK

Peter G. Wells,
Coastal and Water Science Section, Canadian Wildlife Service,
Environmental Conservation Branch, Environment Canada,
Dartmouth, Nova Scotia

A version of this paper was published as P.G. Wells, "Assessing health of the Bay of Fundy—concepts and framework," (2003) 46 *Marine Pollution Bulletin* 1059-1077.

Abstract

A discussion of health and ecosystem health concepts and a conceptual framework for assessing health of the Bay of Fundy are presented. The framework includes:

1. **Concepts** – What is health? What is ecosystem health (EH) and marine ecosystem health (MEH)? How does EH relate to other closely related concepts and principles, i.e. environmental quality (especially marine), ecosystem integrity and ecosystem sustainability ?
2. **Importance** – Why is EH important, and what are the linkages to people, i.e. human health?
3. **Approaches and Techniques** – How do we monitor and measure EH, and in that context, ecosystem or ecological change? What are the monitoring approaches and tools? What is an appropriate set of EH indicators and indices for the Bay of Fundy and Gulf of Maine? At the present time, can we make unequivocal statements about the status and trends in EH measures of the Bay of Fundy? Do we have adequate guidelines, objectives and standards for assessing environmental quality and EH?
4. **Connecting with Management Needs** – Do we have adequate mechanisms in place to address MEH, marine environmental quality (MEQ) and environmental sustainability in the Bay of Fundy? What is the role of periodic marine assessments (e.g., state of the marine environment reports) in this activity? What kinds of new directions and new ecosystem science should be given priority, given the above analysis and the collective answers of the workshop participants? What kinds of other new activities should be pursued?

For the Bay of Fundy Coastal Forum at this workshop, five core questions flowing from the health framework served to initiate and focus the discussions:

1. **Current State** – What is the present health or condition of the Bay of Fundy?
2. **Changes** – Are conditions improving or deteriorating?
3. **Indicators** – What kinds of indicators do we consider most useful in trying to answer these questions?
4. **Existing Resources** – Are there adequate resources (e.g., institutional, financial, scientific, regulatory) to protect or restore the health of the Bay?
5. **Needs** – What kinds of new information and approaches do we need to protect the health of the Bay?

The background information and ideas of this paper were intended to assist discussion at the workshop, and to help identify the next steps, both individual and collective, for assessing the health of the Bay of Fundy.

Contents

> For whoever knows the ways of nature will more easily notice her deviations; and on the other hand, whoever knows her deviations will more accurately know her ways.
>
> Francis Bacon 1620, cited in Sherman, B. H. 2000

1. Introduction

The Bay of Fundy is a large macro-tidal embayment, forming the north-eastern arm of the Gulf of Maine. It is closely linked oceanographically to the greater Gulf of Maine, the Scotian Shelf and North-western Atlantic, and receives the inputs of 44 major rivers and countless smaller ones. It is bounded by two provinces with 1.5–2 million people, is extensively used by the fishing, shipping, aquaculture and other industries, and has two moderate-sized cities and many towns and villages along its shores.

The workshop's theme was the "Health of the Bay of Fundy – Assessing Key Issues". The Bay of Fundy is faced with a number of major issues, 38 by our count at the first workshop in 1996 (Percy et al. 1997, Chapter 6). At this workshop, we wished to assess progress since 1996 (Percy et al. 1997) in identifying and clarifying the issues, and through panel and informal discussions to plot a path forward for research, monitoring and management action. A primary objective of the workshop, through the Coastal Forum, was to contribute to the state of environment (SOE) assessment activities of both the Global Programme of Action Coalition for the Gulf of Maine (GPAC) Summit process, and the third Action Plan (2001–2006) of the Gulf of Maine Council on the Marine Environment (GOMCME 2002).

For such SOE or health assessments, data and information are required from a large number of indicators used for monitoring and describing the health of the environment – in this case, the Bay of Fundy. Also required is a process (an outline or framework) for producing periodic, carefully prepared, peer-reviewed reports on the Bay's health, in the context of the greater Gulf of Maine. Such monitoring, analysis and reporting involves the contributions of many people and organizations (a consideration of many perspectives on the approach and necessary information), understanding of some key concepts, and the incorporation of the experiences and knowledge of people who know the Bay. It also requires commitment, time and some money!

The task of assessing the Bay's health is not simple. Many other 'state of the environment' reports have shown the task of objective analysis and synthesis to be challenging – ecosystems are complex, incompletely known and always changing, and the measures of health, ecosystem health and environmental quality are in their infancy. It is important to avoid the pitfalls of the recent tome *The Skeptical Environmentalist* (Lomborg 2001), where oversimplification, incomplete knowledge and bias colored the analysis, according to most reviewers. Once a credible approach is chosen for the Bay of Fundy, there is a very large literature and experience to distill. The north-west Atlantic and the Gulf of Maine benefit from more than 100 years of oceanographic study (from the works of Bigelow and Huntsman, to Plant 1985, Backus and Bourne 1987, and Percy et al. 1997, amongst many other sources).

The challenges notwithstanding, we should try to produce a current assessment of the Bay of Fundy, and in turn, a report for the greater Gulf of Maine. It is hoped that the current series of Fundy Science Workshops, the GPAC forums, and many other meetings occurring in the Gulf of Maine watershed will contribute substantially to this effort.

Given these objectives, this paper presents a brief review of current concepts of ecosystem health, environmental quality and ecosystem integrity; a summary of what is required in health measurements, e.g., the indicators of ecosystem health, for the Bay of Fundy; and a framework for the process of assessing the health of the Bay of Fundy and its key issues.

2. Concepts of Health and Ecosystem Health

Various conceptual frameworks have been presented for assessing ecosystem health and environmental quality. Rapport (1986) described a stress-response framework and used it as the basis for Canada's early SOE reports. The Marine Environmental Quality (MEQ) Working Group of Environment Canada built on Rapport's stress-response model and presented a framework with four components – characteristics and uses, stress factors, ecosystem responses (using indicators), and health or condition of the environment (Wells and Rolston 1991). Harding (1992) presented the MEQ model as including stressors, characteristics of exposure, measurement of effects, and indicators of quality. Most recently, Smiley et al. (1998) presented a modified MEQ framework, with the components being condition, stress, effects and response (indicators). Finally, Fisheries and Oceans Canada (2000) succinctly described MEQ in the new Oceans Act as involving guidelines and objectives, indicators and assessment. Westhead elaborates on this framework in these Proceedings (see pages 262-266).

The various approaches show some common needs in coastal and ocean assessments. These are: (1) understanding of the habitats and ecosystem(s) under consideration, and recognition of what we do not know well or at all, given ecosystem complexity; (2) indicators of 'health' and 'quality' that can be developed by research and used in monitoring; and (3) a feedback loop via assessments, monitoring, and management and societal action (through a range of mechanisms, including regulations). Mechanisms are required to complete the loop, such as this workshop, and periodic reports and report-cards on progress.

By necessity, various terms are used in this field, but not always in the same way. After all, the field is interdisciplinary and evolving. However, this causes confusion both in conceptualizing the issue of 'ecological or ecosystem health' and in its application, i.e. conducting assessments and prioritizing issues. One solution, a major part of this paper, is to discuss the key terms and concepts; they include health, ecosystem health, ecological health, coastal health, ecological condition, ecological integrity, ecological change, and (marine) environmental quality.

One view of the relationship between the various health concepts, time and space, and level of biological organization is shown in Table 1. Health and integrity are a description of the current state, condition or status, a view over the short term (one to a few generations, varying with organism, lasting from hours to decades). Quality and change are a description of trends from the 'baseline' or original, undisturbed conditions, a view over the longer term (many generations and life spans, covering decades to centuries). In practice, as shown below, ecological or ecosystem integrity are used to describe both short- and long-term conditions. Importantly, the terms are used precisely in relation to level of biological organization, i.e. an individual organism is healthy or unhealthy, whereas a community has or lacks ecological integrity. These distinctions are not trivial as they reflect the need for quite different indicators of condition across the structural and functional components of ecosystems.

Table 1. How the terms and concepts on health and ecosystem health relate, across time, space and levels of biological organization

	Levels of Biological Organization		
Time/space scale	Individuals	Populations	Communities/Ecosystems
Short term, local, current state	Health	Health	EH*, Integrity**
Long term, regional, changes/trends	–	Quality, Change	Change, EQ*** Integrity**

* Ecosystem health
** Ecological or ecosystem integrity
*** Environmental quality

2.1 Current Health and State of the Ecosystem

2.1.1 Health

Health, as in ocean health or health of the oceans, is a commonly used and publicly accepted term referring to the condition or state of the seas (note Goldberg 1976; Kullenberg 1982; Wells and Rolston 1991; McGinn 1999; Knap et al. 2002). But, curiously, its users usually avoid exact definitions of the word or phrase! Health is defined in the Oxford dictionary as "soundness or condition of body (good, poor, bad, ill, health)" (Sykes 1976). Health means freedom from or coping with disease on the one hand (the medical view), and the promotion of well-being and productivity on the other (the public health view); "in essence, there are two dimensions of health – the capacity for maintaining organization or renewal, and the capacity for achieving reasonable human goals or meeting needs" (Nielsen 1999). Importantly, Nielsen states that "health is not a science per se; it is a social construct and its defining characteristics will evolve with time and circumstance". Earlier, Rapport et al. (1980) considered the concept of health and the need to recognize vital signs, a topic explored below under "indicators". Finally, health is usually defined by what is NOT, such as "the occurrence of disease, trauma or dysfunction" (Gove 1993). Therefore, a healthy marine environment requires individuals (ecologically, individual organisms) with signs of wellness and productivity, based on vital signs, and the absence of obvious disease or lack of function. Health as a concept is readily understood, has social capital, is transferable to ecosystems (as shown in Table 1 and below), and is measurable.

2.1.2 Ecosystem health

Ecosystem health, as a concept and practice, has been discussed at length for two decades. Papers include Costanza et al. (1992); Fairweather 1999; IJC (International Joint Commission) 1991; Kutchenberg 1985; Rapport (1989, 1992, 1998); Rapport et al. (1980, 1998, 1999); Schaeffer (1996); B. H. Sherman (2000); Tait et al. (2000); Vandermeulen (1998); and Wood and Lavery (2000).

Rapport and his colleagues are leaders in exploring the field of ecosystem health. Rapport et al. (1980) discussed early warning indicators of disease, hypersensitivity, epidemiological models, the crucial role(s) of certain parts of a living system, Selye's concept of stress without distress (Selye 1974), and immune antibody responses. These topics have advanced further due to research in medicine, toxicology, and environmental toxicology since the 1980s. Rapport et al. (1980) stated that "the corresponding ecological concept to health might be ecosystem persistence, or ecological resilience. Presumably this property can be assessed using a range of indicators ...; candidate vital signs include primary productivity, nutrient turnover rates, species diversity, indicator organisms, and the ratio of community production to community respiration." A very important observation was that "once ecosystems are adequately characterized in terms of vital signs, the development of more comprehensive diagnostic protocols might be the next logical step". Developing and standardizing such protocols have been at the heart of applied ecotoxicology for years now. In addition, this step has been taken by groups such as HEED (Center for Health and the Global Environment at Harvard University) (Sherman, B. H. 2000) and Kenneth Sherman of NOAA with his internationally recognized work on large marine ecosystems or LMEs (Sherman, K. 2000). Much work is continuing with molecular biomarkers (M. Depledge, pers. comm.), and the connections across levels of biological organization to populations and communities (e.g., Downs and Ambrose 2001).

A review of the core studies of ecological health and ecosystem health reveals some key observations:

On indicators and indices, "ecosystem health is a characteristic of complex natural systems ... defining it is a process involving a) the identification of important indicators of health; b) the identification of important endpoints of health; and c) the identification of a healthy state incorporating our values. Historically, the health of an ecosystem has been measured using indices of a particular species or component" (Haskell et al. 1992). It is clear that we need to choose indicators and monitor ecosystems with them, and then to summarize and interpret the responses using indices. This in fact is being done, for example, in EPA's estuarine programs, in larger comprehensive coastal programs such as in Chesapeake Bay, and in a multitude of community-led monitoring programs around the Gulf of Maine (Chandler 2001).

On the components of ecosystem health, Schaeffer et al. (1988) gave ten guidelines for assessing ecosystem health (Haskell et al. 1992). At two 1991 workshops, participants developed a working definition of ecosystem health, defining health in terms of four characteristics applicable to any complex system – sustainability, which is a function of activity, organization, and resilience. Sustainability implies that the ecosystem can maintain its structure and function over time. The conclusion was that "an ecological system is healthy and free of 'distress syndrome' if it is stable and sustainable – that is, if it is active and maintains its organization and autonomy over time, and is resilient to stress". This, of course, implies that activity, organization and resilience can be measured for at least each major component of each ecosystem, a daunting task indeed.

One problem of defining ecosystem health is choosing the appropriate scale, i.e. which ecosystem are we managing and what level are we focusing on? For example, for Chesapeake Bay, is the Bay and its many estuaries being considered, or is it the whole Chesapeake watershed? The same question applies to the Bay of Fundy – do we focus on the whole Bay (there are already 38+ issues), the extensive watersheds (the proposed approaches of the GOMCME, and the Minas Basin Working Group of BoFEP), or just one part (e.g., Passamaquoddy Bay)? Choosing the appropriate spatial scale has implications for a wide range of activities associated with managing and maintaining ecosystem health; issues of policy, governance, research, assessment, management tools, monitoring, communication and stakeholder involvement ultimately have to be considered.

The human health assessment model was described by Haskell et al. (1992). It has six parts: a) identify symptoms; b) identify and measure vital signs; c) make a provisional diagnosis; d) conduct tests to verify the diagnosis; e) make a prognosis; and f) prescribe a treatment. For a large marine ecosystem, in this case the Bay of Fundy, this model of health assessment could work as below. A compendium for a) and b) is as yet incomplete, so examples come from previous Fundy Science Workshops, ongoing projects, and an aging memory!

a) **Identify symptoms**: What are the first signals that the system is 'unhealthy'? From the physical to the biotic environment, some are: physical changes to shorelines (e.g., barriers, such as causeways and dykes; increased coastal development, especially homes along the shorelines); changed sediment patterns in estuaries; contaminants in sediments and tissues; increased numbers of aquaculture sites in bays; abundant debris on shorelines; reduced fisheries catches or failing fisheries; the requirement to open new fisheries on new or previously 'under-utilized' species; reduced numbers of seabirds (Phalaropes), and marine mammals (Right Whales); and increased small boat traffic in bays and inlets (noise, water and air pollution).
b) **Identify and measure vital signs**: There are a number of critical changes in key attributes of the ecosystem that collectively show the system is under stress or change, e.g., loss of/reduced fisheries (herring); loss or reduction of species (wild Atlantic salmon, *Salmo salar)*; changed distributions of seabirds such as the Red-necked Phalarope, *Phalaropus lobatus*; high levels of some chemicals in biota (e.g., Cu in crustaceans, and PCBs in birds and mammals); changed water flows or hydrologies in estuaries; and overall reduced salt marsh acreage in the upper Bay.
c) **Provisional diagnosis:** At the 1996 Fundy Science Workshop (Percy et al. 1997), the participants concluded that the Bay of Fundy was showing a number of signs of poor health and lowered quality, and a listing of 38 key issues was made. Many of these have been discussed

at subsequent Fundy Science Workshops, and many other recent meetings around the Gulf of Maine (e.g., Regional Association for Research on the Gulf of Maine (RARGOM) Conference, Wallace and Braasch 1997; Rim of the Gulf Conference 1997; habitat conferences; further RARGOM meetings, e.g., Pesch 2000). The Conservation Council of New Brunswick has recently expressed concerns for coastal habitats throughout the Bay, with a careful record of habitat loss or modification (Harvey et al. 1998), and there are marked changes in fisheries over 200 years and the presence of chemical burdens in Passamaquoddy Bay species (Lotze and Milewski 2002).

d) **Tests to verify diagnosis:** Diagnostic tests include: monitoring for trace contaminants in mussels and in the food chain (levels, responses of biomarkers, effects); monitoring for algal toxins; monitoring for bacterial pathogens; monitoring for effects of salmon aquaculture wastes on benthic species and communities; assessment of condition of remaining salt marsh habitat; and assessment of effects of tidal barriers (e.g., the 2000–02 tidal restriction audits being completed in New Brunswick and Nova Scotia). This important verification step ensures that the ecological health issue is real and important (economically and ecologically). It is also more tractable to address single issues than the whole system at once. With multiple issues, the potential for cumulative effects and the potential for confounding with natural variables in ways difficult to predict, diagnosing the whole system is the goal but can be achieved most successfully with 'bite-sized' efforts.

e) **Make a prognosis for the Bay:** This is the 'ecosystem health report' and a statement of the future for the Bay's habitats, inhabitants, and natural and living resources (also see Section 2.1.4). Is there a good chance of 'recovery', or 'maintaining the status quo' if we continue to act through protection, conservation and remediation efforts? This prognosis is probably most effective if looked at by sector – fisheries, marine mammals, wildlife, sediments, coastlines, estuaries, etc. – and by regions within the Bay – from Passamaquoddy Bay around to Annapolis Basin, St. Mary's Bay and the coast to Yarmouth. The prognosis is best captured in periodic State of the Bay of Fundy and State of the Gulf of Maine reports.

f) **Treatment:** This step describes the actions required to restore ecosystem health to the Bay of Fundy. For example, recent positive actions include working with the International Maritime Organization (United Nations) to relocate sea lanes away from the Northern Right Whale feeding areas (a real success!); remediation of unused salt marsh in Shepody Bay; better management plans for specific fisheries species such as bait worms (polychaetes) and green sea urchins (*Strongylocentrotus droebachiensis*); gradually improved sewage treatment, such as at Saint John; efforts to remediate a tidal river e.g., Petitcodiac River; improved aquaculture practices in south-western NB; and identifying the potential for opening selected causeways and restoring tidal flows in estuaries, e.g., Windsor, NS. Actions are small and large, most are opportunistic, but all contribute to the momentum of addressing issues confronting the Bay.

What is our capacity to conduct ecosystem health assessments? Many traditional state of the environment reports have been prepared, some very thoroughly (e.g., AMAP 1997, 2002; see Section 2.1.4). But we may only be in the early stages of being able to do actual 'ecosystem health assessments' well because we lack the medical encyclopedia for ecosystems (Haskell et al. 1992). As Norton et al.

(1991) and Haskell et al. (1992) point out (everyone knows this, but it is worth recalling), medicine deals with the individual, whereas "ecosystems exist on many levels, can be described on many scales, and require a consensus of public goals on the road to having diagnostic tests for ecosystem stress". A framework for starting to evaluate an ecosystem could consist of a) types of stress; b) response variables or symptoms of ecosystem distress; and c) monitoring, fiscal resource, management and other needs. The table in Percy et al. (1997), pages 140–141, is an excellent tool but requires an update! We have to move from the traditional environmental report, a valued but often uninspired tally of characteristics of the system, to an actual health assessment, which is an analysis of how the whole system is functioning or not. The Gulf of Maine and Bay of Fundy offer an opportunity few if any other places have to prepare such an ecosystem health assessment.

There are obviously limitations to the concept of ecosystem health, and especially to putting the concept into practice. The concept has a history in Western-based science, medicine and conservation. It first formally "emerged in the mature thought of Aldo Leopold as a bridge between technical management and formulation of management goals" (Leopold 1949; Haskell et al. 1992), hence it is not only a scientifically-based concept. This is very important because there is great value, indeed crucial value, in the link to environmental management goals (see Section 3.4), and metaphorically, the concept and term have the strength of communicating the problem to a wide audience. The term 'ecosystem health' was used in the 1960s and 1970s in the context of the Great Lakes, especially Lake Erie, once considered 'dead', rather than having impaired 'ecosystem health'! Lake Erie survives, with impaired but improving health (it is alive and productive) and a lower quality (its current condition compared to the original state of the lake). Likewise, in the United States, the ecosystem health concept has been applied to the important estuaries and coastal bays, such as Chesapeake and San Francisco (see numerous EPA reports, such as EPA 1998, 1999, 2000a,b).

However, several important limitations with the ecosystem health concept should be kept in mind, as we consider the Bay of Fundy. First, "no longer are communities (natural) considered normative. Disturbance is common; communities and ecosystems are in constant flux. Knowing what is natural is difficult" (Ehrenfeld 1992). That is, the normal range for a variable may be quite wide (particularly note Schindler 1987), and in this age of marked climate change, even more so, e.g., air temperature, storm events and levels of precipitation. The baseline for 'normal ecosystem health' fluctuates! Secondly, "a determination of ecosystem health can be a function of which process you are looking at, which in turn is determined by your own values" (Ehrenfeld 1992). Ecosystem health has a social context, as does the science behind it. Thirdly, the word 'health' should not be defined or applied too rigorously because communities of plants, animals and micro-organisms comprising ecosystems vary greatly in their state of equilibrium. Hence, the term is best used as a bridging concept between the science and non-scientists (Ehrenfeld 1992), a starting place for dialogue on issues, priorities and indicators.

Systems ecologists also have views as to what is meant by ecosystem health. These views shed light on the selection of suitable indicators for the Bay of Fundy. For example, Ulanowicz (1992) states that "a healthy ecosystem is one whose trajectory towards a climax (referring to ecological succession) is relatively unimpeded and whose configuration is homeostatic to influences that would displace it back to early successional stages. Assessing the health of ecosystems requires a pluralistic approach and a number of indicators of system status" (also see Karr 1991; Schaeffer et al. 1988). Ulanowicz uses the approach of network ascendancy, an index that captures four key properties of quantified networks of trophic interactions in healthy systems: greater species richness, more niche specialization, more developed cycling and feedback, and greater overall activity. This approach could be usefully applied to the Bay of Fundy and its various ecosystems and regions; one could hypothesize that in some places, e.g., near aquaculture sites, in urbanized harbours, near industrial effluent locations, these properties have been diminished, and then investigate them accordingly (as in the aquaculture studies of G. Pohle, Huntsman Marine Science Centre).

Karr, a fisheries biologist, stated that "a biological system can be considered healthy when its inherent potential, whether individual or ecological, is realized, its condition is stable (meta-stable), its capacity for self-repair when perturbed is preserved, and minimal external support for management is needed" (Karr et al. 1986). One can analyze the Bay of Fundy using this approach (Table 2). Hence, when evaluated as a system, the Bay of Fundy's condition could be considered as deteriorating and in need of enlightened integrated management.

Table 2. A hypothetical health status of the Bay of Fundy (based on approach in Karr 1992 and earlier papers)

System Criterion	Health Status		
	Good	Fair	Poor
Inherent potential	+ >		
Condition		+ >	
Self-repair	+ >		
Management support		<+	

Finally, and following from above, consider which components of ecosystem health are required. Costanza (1992) discusses ecosystem health in the context of a system's overall performance. "To understand and manage complex systems, we need some way of assessing the system's overall performance (its relative health)". He summarizes the components of ecosystem health as:

- homeostasis
- the absence of disease
- diversity or complexity
- stability or resilience
- vigour or scope for growth
- balance between system components

"Systems are healthy if they can absorb stress and use it creatively, rather than simply resisting it and maintaining their former configurations". "An ecological system is healthy and free from distress syndrome if it is stable and sustainable – that is, if it is active and maintains its organization and autonomy over time, and is resilient to stress". To be healthy and sustainable, the system must maintain its metabolic activity level, maintain its internal structure and organization, and be resilient to outside stresses.

Costanza (1992) has attempted to quantify ecosystem health:

HI=overall health index
HI=V*O*R

where V=system vigour; O=system organization index (0-1); and R=system resilience (to stress) (0-1). (See Box 1, Rapport et al. 1998.) This approach, producing an Overall Health Index, could be tried for the various regions, habitats and trophic levels of the Bay of Fundy. In fact, Rapport et al. (1998) have taken this approach and advanced upon it. They stated that "many ecosystems are unhealthy – their functions have become impaired". They looked at the literature and presented several case studies. Using their choice of indicators of ecosystem health, a hypothetical assessment of the Bay of Fundy might appear as Table 3.

Table 3. Hypothetical assessment of ecosystem health of the Bay of Fundy using Rapport's indicators of stress (Rapport et al. 1998)

Stress results in	Location			
	Bay of Fundy	Passamaquoddy Bay	Minas Basin	Saint John Harbour
Biotic impoverishment	Yes	Yes	?	Yes
Impaired productivity	?	?	Yes	Yes
Altered biotic composition	Yes	Yes	Yes	Yes
Reduced resilience	?	?	?	Yes
Increased disease prevalence	Yes	Yes	?	Yes
Reduced economics	Yes	Yes	Yes	Yes
Risks to human/organism health	Yes	Yes	?	Yes

2.1.3 Marine ecosystem health

In an early paper on ecological terms for large lakes, Pamela Stokes' description (Stokes 1981:86) of 'healthy', in the context of aquatic ecosystem health, was that "it includes: 1) stability – gross structure unchanged over many years; 2) balance; and 3) functioning. In the context of lakes, an example of 'unhealthy' would be a condition caused by the addition of toxins; if algae are killed and bacteria increase out of balance, the lake is not healthy".

For coastal and open ocean systems, the term 'marine ecosystem health'or MEH is often used (amongst others, Wells and Rolston 1991; Wells 1996, 1999a; Smiley et al. 1998; Vandermeulen 1998; Sherman, B. H. 2000; Sherman, K. 1994, 2000). Paul Epstein's definition of marine ecosystem health is: "to be healthy and sustainable, an ecosystem must maintain its metabolic activity level, its internal structure and organization, and must be resistant to stress over a wide range of temporal and spatial scales" (Epstein 1999).

B. H. Sherman (2000) states that "ecosystem health is a concept of wide interest for which a single precise scientific definition is problematical". He describes the HEED approach of Harvard University – "a marine health assessment that is a rapid global survey of possible connections and costs associated with marine disturbance types". This program was initiated in 1995; it published its first survey in 1998 (Epstein and Rapport 1996; HEED 1998). Eight disturbance types are described, shown below (Table 4) in the context of Bay of Fundy. "The 8 general types of disturbance may provide a first approximation of the comparative health of coastal marine ecosystems." Mortality, disease and chronic disturbances are the three major variables or changes "reported across a wide spectrum of taxonomic groups" (Sherman, B. H. 2000). Assessments using a marine epidemiological approach can track these changes in ecosystem health (Epstein and Rapport 1996).

Table 4. Disturbances in the Bay of Fundy. A preliminary list, following from Epstein and Rapport (1996), HEED (1998) and B. H. Sherman (2000)

Type of Disturbance*	Bay of Fundy Occurrence	
	Y/N	Comments
Biotoxin and exposure	Y	Toxic algal blooms Beach closures
Anoxic/hypoxic	N	Unlikely due to tidal exchange
Trophic-magnification	Y	Toxic algal blooms Contaminants
Mass lethal mortality	N?	—
Physically-forced (climate/ocean)	Y	Severe storms
Disease	Y/N?	Imposex in snails; none in birds
New, novel occurrences and invasives	Y?	Crabs (Green, Japanese Shore)
Keystone endangered and chronic cyclical	Y	Algal blooms; beach closures; fisheries closures; invertebrate declines; bivalve contamination

Kenneth Sherman's large marine ecosystem (LME) approach (Sherman et al. 1996; Sherman and Skjoldal 2002; other LME publications), is applicable to the Gulf of Maine and Bay of Fundy. Indeed, the Gulf of Maine is part of an LME and is identified as the Northeast Shelf Ecosystem (unfortunately, the boundaries of which may be jurisdictional rather than ecological!). Methods to assess the health of LMEs are being developed from modifications to a series of indicators and indices described by several investigators (see Costanza and Mageau 1999); the methods form part of the pollution and ecosystem health module of the LME approach. Recent workshops sponsored by NOAA (USA) and the Nordic Council of Environment Ministers (Europe) considered the concepts of ecosystem health and marine ecosystem health (Sherman, K. 2000). The Pollution and Ecosystem Health module consists of eutrophication, biotoxins, pathology, emerging disease and health indices. Five health indices (biodiversity, productivity, yield, resilience, stability) are included as experimental measures of changing ecosystem states and health. Hence, the module emphasizes stresses and indices (based on numerous indicators), consistent with current thought on how to approach marine ecosystem health.

In practice, the pollution and ecosystem health module of the LME uses benthic invertebrates, fish and other biological indicator species, and accepts the following set of measures (Sherman et al. 1996; Sherman, K. 2000):

- bivalves (Musselwatch) (similar to Gulfwatch employed in Fundy, Chase et al. 2001)
- patho-biological examination of fish
- estuarine and nearshore monitoring of contaminants and contaminant effects in water, sediments and organisms (note NOAA's programs, Wade et al. 1998)
- routes of bioaccumulation and trophic transfer of contaminants
- examination of critical life stages and food chain organisms to demonstrate exposure
- impaired reproductive capacity
- organ disease
- impaired growth
- impacts on individuals and populations

Sherman et al. (1996) adopted a holistic approach inherent in the LME concept, as it encourages agencies and other stakeholders to address issues of over-fishing, habitat loss, pollution, and recreation needs from a multi-disciplinary ecosystems perspective.

Vandermeulen (1998), in a Canadian summary, stated that MEH indicators are being identified in five categories: contaminants; biotoxins, pathogens and disease; species diversity and size spectrum; primary productivity and nutrients; and instability or "regime shifts". These were adopted from the literature, and hence are similar to MEH indicators chosen by the many expert groups involved in the LME approach (Sherman, K. 2000).

The terms marine ecosystem health (MEH) and marine environmental quality (MEQ – see below) are often used inter-changeably in the literature and in common practice when communicating about the health of coastal seas and the oceans (Wells 1991). The case made in this paper, however, is that the terms health and quality are not the same (Section 2, Introduction), and that there are benefits from using them more precisely in an assessment of the health of coastal waters, in this case the Bay of Fundy, i.e. we want to maintain and sustain a healthy bay of high quality!

2.1.4 Ecological condition and state of the environment

Ecological condition and state of the environment are terms used in statements or reports on the current condition of specific ecosystems, terrestrial to marine. Encouragingly, there are many recent examples of such marine reports (AMAP 1997, 2002; Birkett and Rapport 1996; Crawford et al. 1994; EPA 1998, 1999; GESAMP 1990; Kay 1989; Konrad et al. 1990; Marine Institute 1999; Sheppard 2000; Waldichuk 1989; Wallace and Braasch 1997; Wells and Rolston 1991; White and Johns 1997; Zaitsev and Mamaev 1997). Some reports are popular accounts for the general reader and the decision maker (e.g., Atkinson et al. 2000; Earle 1995; GESAMP 2001a; GOMCME 1989; Johnston et al. 1998; Marx 1999; McGinn 1999; Milewski et al. 2001). The 'state of the environment' literature reflects the popular and accessible (not necessarily current) concepts of ecosystem health, and the suite of most useful indicators deployed by scientists and community volunteers to monitor the state of the marine environment (i.e. ocean health).

For example, Birkett and Rapport (1996), Crawford et al. (1994) and others have evaluated the ecological health of specific coastal areas. Birkett and Rapport (1996) presented a summary table identifying some of the common signs of ecosystem stress. This has been adapted below to assess the Bay of Fundy (Table 5):

Table 5. Common signs of ecosystem stress, and preliminary subjective assessment of their occurrence in the Bay of Fundy

Sign of Stress*	Bay of Fundy	Level of Severity#
Habitat changes	Yes	++
Elevated nutrient levels	Yes (in places)	+
Biological productivity changes	Yes	++
Biotic composition and characteristics	Yes	++
Bioaccumulation of contaminants	Yes	+
Disease prevalence	? (perhaps localized)	++
Effects of exotic species	?	?

* From Birkett and Rapport (1996)   # ++ high; + moderate; ? no information

The above discussion shows that there is considerable commonality of the key components of any assessment of ecosystem health. What are needed are the monitoring programs providing systematically collected data over long time periods so that such assessments can be made reliably (see GESAMP 1994b).

2.1.5 Ecological integrity

Ecological integrity (also called ecosystem integrity) is "the dimension of health that reflects the capacity to maintain organization; it is akin to the term 'integrity', especially when used at the scale of ecosystems" (Karr, many refs.). It incorporates the ideas of resilience, vigour and homeostasis. "Many regard integrity, when used in a purely ecological sense, to refer to the evolution of the ecosystem without human disturbance" (Nielsen 1999). Key papers include Karr (1981, 1992), Woodley et al. (1993), Noss (1995), Nielsen (1999), and Campbell (2000). Karr (1992) and Campbell (2000) discussed the concept in detail. Integrity "implies an un-impaired condition, or the quality or state of being complete or undivided" (Karr 1992). It also means "un-impaired when compared with the original condition" (Campbell 2000).

Systematic assessments of the status of ecological resources (i.e. ecological integrity) have three requirements: they must be based on biology and biological processes; there must be a selection of measures of health or integrity appropriate for the place and biological attributes of concern; and there must be biological benchmarks or reference conditions (Karr 1992). On the second requirement, an array of attributes of biological/ecological integrity is used. Collectively, they must be very diagnostic of local conditions. For example, five attributes (individual health, species richness, relative abundance of species, population age structure, genetic diversity) measured together can describe local conditions. Efforts to assess ecological integrity are more likely to detect degradation if those efforts are conceptually diverse – from the use of individuals to populations to assemblages to landscapes, for the measurement of attributes (Karr 1992).

Karr uses the terms 'conditions', 'ecological health' and 'integrity' interchangeably, not surprising given the similarity of their components but unhelpful to using the concepts in practice with precision! Campbell (2000) agrees with previous writers (Suter 1993) that we need operational definitions of concepts such as ecosystem health, and by analogy, ecological integrity. Campbell concludes that "ecological integrity is an ecosystem property that is greatest when all the structural components of a system that should be there, are there (i.e. structure is complete), and all the processes operating within the system are functioning optimally (i.e. the ecosystem is 'healthy')". Perhaps what is important is that condition, ecological health and integrity refer to the current state of a system, how well it is composed and functioning now. Semantic arguments fall prey to practical needs!

Can we assess the Bay of Fundy with the more operationally useful definition of Campbell (2000) – Are all the structures/parts and functions of the Bay of Fundy's ecosystems present and operating optimally? Are we monitoring enough to be able to describe the integrity of natural communities and ecosystems in the Bay of Fundy as a whole, or will we do this only for selected sites e.g., salmon aquaculture sites, tidal barriers, harbours, points of industrial discharge?

Finally, which of the terms, ecosystem health or ecological/ecosystem integrity, has more social capital associated with it? It is noteworthy and very encouraging that the GOMCME, in Goal 2 of its third five-year action plan (GOMCME 2002), addresses "… human health and ecosystem integrity", with three social, management oriented objectives: increasing awareness and improving management of priority contaminants, identifying reduction strategies for priority contaminants, and enhancing citizen stewardship. Protecting and assessing the ecological or ecosystem integrity of the Gulf of Maine and the Bay of Fundy has been identified as a long-term social goal of institutions around the Gulf.

2.1.6 Coastal health

Coastal health is a broad term signifying the interconnections and overlap between three areas – human health (as above); environmental health (as above, MEH and ecological integrity); and community health. Community health involves all of the public(s) – all of the communities that are present along the shores of a water body, and within the watersheds. It covers many functions of each coastal community. Community health includes consideration of economic sustainability and opportunities, and appropriate civic planning and conduct to enhance the quality of life in the community, e.g., parks, green spaces, public health and health care, education, opportunities for the young. Community health and the ecological/environmental health of the surrounding watersheds and marine ecosystems of the Bay of Fundy and Gulf of Maine are closely linked. There are many examples in the fishing communities, as the economies of the fisheries are affected by issues such as contaminants (mercury, hydrocarbons), natural toxins (PSP), and tourism and recreation.

Coastal health should be considered in the design and practice of integrated coastal management plans/programs. It also should be included in any assessment of the Bay of Fundy's health, as it is a holistic representation of people, their activities and their impacts integrated with the ecology and living resources of the coast.

2.2 Longer-Term Ecosystem Change

Change is constant, i.e. continual, in Earth's ecosystems. Marine ecosystems are no exception to this rule. What is important is to distinguish between natural ecological change, important anthropogenically driven change, and the two combined (Schindler 1987; Spellerberg 1991; Ollerhead et al. 1999; Wells 1999b; Jackson 2001; amongst others), and to identify the important adverse change(s) that can be ameliorated (e.g., ozone depletion due to CFCs; contamination of food supplies and ecosystems by other synthetic chemicals; climate change if we control carbon dioxide emissions). Changes should be observed or measured over the long term and compared to measurements of or approximations of the original conditions (set at some arbitrary time). The choice of appropriate indicators (see section 3.3.2), the monitoring design, and modeling (Jakeman et al. 1993) are critical to success. "The question is how to better identify, monitor, anticipate, and respond to the network of changes in the ecosystem" (Zelazny 2001), and how best to report periodically on and interpret such change for the Bay of Fundy-Gulf of Maine.

2.2.1 Change and ecological change

Change and ecological change have been studied and/or discussed by Baird and Burton (2001); Clark and Frid (2001); Duarte et al. (1992); Epstein and Rapport (1996); Earle (1995); Harvell et al. (1999); HEED (1998); Jackson (2001); Jickells 1998; Lotze and Milewski (2002); Mann 2000; McGowan et al. (1998); McMichael (1993); Myers (1995); Rapport (1990); Rapport and Whitford. (1999); Rose et al. (2000); Schindler (1987); Spellerberg (1991); Wells (1999b); and others. Ecological change has been taking place over the geological epochs, and in 'recent time' in the Bay of Fundy region. Since the last ice cover 12,500-15,000 years ago (Atlantic Geoscience Society 2001), sea levels have risen and the land has been re-occupied by plants and animals. Both gradual change and occasional abrupt occurrences (disturbances, including extinction events) are normal to ecosystems. Organisms, populations and communities adapt in a variety of ways, from physiological to reproductive to shifted distributional patterns. What must be understood is how ecosystems accommodate to the natural change and the changes imposed by human activity at the same time, particularly when the latter includes large perturbations such as biomass removal, habitat destruction or modification, chemical effects (toxicity), and competition from bio-invaders or exotics in coastal waters (Wells 1999a).

Ecological change can be subtle. A change in the health of the system may lead to a change in the system's overall quality, without being noticed or measured. Examples are numerous – the ecological effects of new fisheries for so-called under-utilized species (e.g., sea urchins, sea cucumbers, rockweed, gastropods, polychaetes), the impacts of barriers on tidal rivers on mudflats and other intertidal zones, the progressive loss of freshwater reproductive habitat (e.g., salmon), and the potential impact of tourism on migratory shorebirds (e.g., disturbance at critical feeding and roosting areas in the intertidal zones and on islands).

Ecological systems are complex and chaotic. Many interactions are non-linear (Myers 1995), and some species play pivotal roles in the transfer of energy between trophic layers (e.g., keystone species such as *Corophium volutator,* D. Hamilton, pers. comm.). Once disturbed by an anthropogenic stress(or), the ecosystem may not recover or offer the possibility for remediation (e.g., over-fished areas, water bodies with introduced species, areas of coastal development, highly contaminated sites), the system entering a new and different ecological state.

Ecological change(s) occurs at different spatial and temporal scales. For example, compare the impact of a single fishery for a keystone benthic species such as the sea urchin, the change caused by removal occurring rapidly over many hectares, to the predicted impacts of global climate change on sea temperatures and sea surface levels, the change occurring gradually, by years and decades, over tens of thousands of square kilometers. This range of change is probably very common in ecosystems, though most of it goes undetected and unaccounted for. The challenge is to examine the Bay of Fundy as a system and ecosystem, and to determine the type of change(s) occurring, the causes, the interactions, and the pragmatic actions society should take.

2.2.2 Marine environmental quality (MEQ)

Papers covering the concepts and practice of marine environmental quality (MEQ) include DFO (2000), Harding (1992), IOC (1996), Lane (1998), NOAA's many programs re the long-standing USA MEQ Status and Trends Program (T. O'Connor and D. Wolfe, pers. comm.), Percy and Wells (2002), Rapport's many papers, Wells and Côté (1988), and Wells and Rolston (1991).

In Canada, MEQ was defined during the 1980s and early 1990s by the Environment Canada MEQ Working Group (Wells and Côté 1988; Wells and Gratwick 1988; Wells 1991, 1996), and accepted by the federal Interdepartmental Committee on Oceans in 1989.

> MEQ is the condition of a particular marine environment measured in relation to each of its intended uses and functions. It can be described subjectively, especially if stresses impinging on the system are large and if the ecosystem or habitat are obviously degraded. However, MEQ is usually assessed quantitatively for each environmental compartment, on temporal and spatial scales. It is measured using sensitive indicators of natural condition and change. Such measures are interpreted using objectives and limits set by environmental, health and resource agencies (Wells 1991).

MEQ differs from MEH; quality denotes historical recorded change in the condition, whereas health is the present condition and the direction of change (as discussed above; A. Gaston, pers. comm.). However, the terms MEQ and MEH are often used synonomously in the literature, especially the non-technical literature, and importantly in day-to-day practice by conservation and protection groups, to mean 'ocean health' (e.g., IOC 1996; Frith 1999; McGinn 1999). The social and political currency of the term 'health' captured in the context of 'oceans' and 'coastal' was the compelling reason for calling the 1991 report on Canadian MEQ, *Health of Our Oceans*, and likely the reason for the earlier report *Health of the Northwest Atlantic* (Wilson and Addison 1984).

Harding (1992) further explored the MEQ concept and measures, developing a framework focused on chemical contaminants and incorporating the ecological risk assessment components of sources, exposure, effects (indicators), and risk estimation; this was an important conceptual advance to understanding the breadth of MEQ and the importance of linking stresses and effects to management action through risk analysis and management. Chang (1999) and Chang and Wells (2001) developed an MEQ framework for the Bay of Fundy. It shows the linkages between research, monitoring (indicators), objectives/guidelines, assessments, and management response. This framework was very useful at evaluating selected stresses on the ecosystem, e.g., PCBs, mercury and algal toxins.

As with assessments of health and ecological health, MEQ requires indicators and marine environmental guidelines, objectives and standards. The objective is to take measurements of key ecosystem variables and compare values to original baseline conditions. Quantitative guidelines, objectives or standards for air, water, sediments, tissues, and habitats are essential. Underpinning both the choice of indicators and guidelines is research. For example, the Gulf of Maine mussel watch program (Gulfwatch) is an MEQ program, using an indicator species approach (the mussel), guidelines (largely from human health), and supportive research. Contaminant levels in mussel tissues are measured annually at various stations around the Gulf of Maine; values are compared to earlier ones, and all measurements over time, as part of a status and trends analysis, and the values are compared with environmental and health advisory guidelines (Chase et al. 2001; Jones et al. 2001). The program has given a picture of trace chemical contamination around and across the Gulf in the 1990s; tissue levels of trace contaminants are elevated, stable or often declining, and largely below health guideline values (Chase et al. 2001).

Within the new Canadian Oceans Act (1997), MEQ focuses on the requirement for objectives and guidelines for protecting ocean health, the latter not being defined. However, MEQ activity under the Oceans Act plans to cover research on and testing of indicators of ocean health, the development and use of objectives and guidelines, and the production of assessments of ocean health (DFO 2000). It has also taken on a broader context than just chemical contaminants, although that appears to be the emphasis in an excellent review of contaminants on the Scotian Shelf and the adjacent coastal waters (e.g., Stewart and White 2001). Most recently, the Oceans Strategy of DFO (DFO 2002a,b) considers MEQ under the umbrella of "Understanding and Protecting the Marine Environment", with an emphasis on science support for oceans management (which includes "assessing the state of ecosystem health"), marine protected areas (MPAs) and MEQ guidelines. Canada now has a mandated operational concept of MEQ that should stimulate co-operative multi-agency and multi-partner research, monitoring, MPAs, ecosystem-based guideline development, and ecosystem assessments for its oceans, including the Bay of Fundy and its adjacent waters.

2.3 Connections Between Human Health and Ecosystem Health and Integrity

There are obvious connections between human and ecosystem health through air, water, and sediments and soils that have been discussed by many previous authors (e.g., McMichael 1993; di Guilio and Monosson 1996; Knap et al. 2002). These connections are well recognized by environmental scientists, resource managers and policy makers in the context of the Bay of Fundy and greater Gulf of Maine, and they are the imperative for much action in its coastal waters (GOMCME 2002). The second goal of the GOMCME 2001–2006 action plan is to "protect human health and ecosystem integrity" from contaminant exposures – to ensure that " contaminants in the Gulf of Maine are at sufficiently low levels to ensure human health and ecosystem integrity". The plan is currently addressing sewage, mercury and nitrogen. Sewage is the one priority pollutant in the Gulf and Bay of Fundy emphasizing the human-ecosystem health connections without doubt (Hinch et al. 2002, in prep; GESAMP 2001a,b), justifying the large expenditures to reduce the inputs.

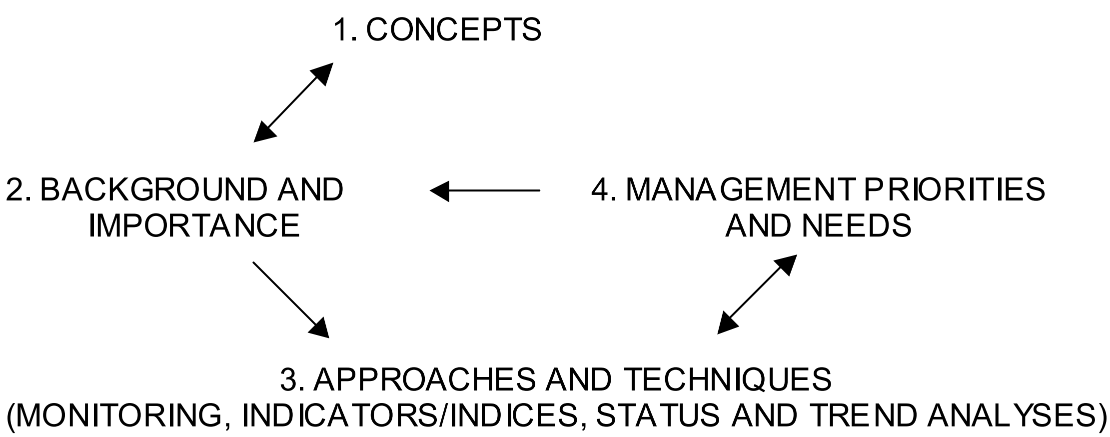
3. A Framework for Assessing Health of the Bay of Fundy

The previous section reviewed the concepts of 'ocean health'. This understanding is central to a rigorous technical assessment of the various environments and ecosystems of the Bay of Fundy and

Gulf of Maine, including their watersheds. What follows is a brief discussion of some considerations in conducting such an assessment. These include: how (i.e. the contents and approach), how often (i.e. the number and frequency of reports) and with what resources should we be tackling the task of reporting on the State of the Bay of Fundy report(s), and ultimately, preparing the State of the Gulf of Maine report(s)? Such assessment reports will likely appear as a State of the Gulf report or reports as planned for the next few years by the GOMCME (GOMCME 2002), GPAC (GPAC 2001) through its Coastal Forum and Summit process, and BoFEP through its Minas Basin Working Group.

Assessing health of the Bay of Fundy includes: a) understanding the concepts, b) background considerations and importance, c) approaches and techniques, d) indicators and early warning signals, e) status and trends analysis, f) identifying mechanisms for action, and g) identifying new directions for scientific, management and community-led activities. This framework (Figure 1) is meant as a starting point to preparing a comprehensive ecosystem health assessment on the Bay.

Figure 1. Components of a framework for an ecosystem health assessment for the Bay of Fundy/Gulf of Maine



3.1 Dimensions of the Marine Ecosystem Health Concept – A Synopsis

Understanding the concepts of ecosystem health and environmental quality is a cornerstone of any successful report on the health of the Bay and the Gulf. The concepts have been reviewed in the above sections. Marine ecosystems are complex, partially understood (even after >100 years of research), likely to change in unpredicted ways, and perceived differently by the various stakeholders. Having some consensus on the elements of 'healthy ecosystems' to measure and monitor in the habitats around the Bay, i.e. the indicators, and the integration of the data and information into statements of 'health' would allow comparable assessments over the long term, and real knowledge of 'how the Bay and Gulf are doing'. Whereas the 1989 GOMCME report (GOMCME 1989) and the Bay of Fundy report (Percy et al. 1997) were primarily descriptive of the current state or condition, new reports should benefit from the current science of ecosystem health, and advances in many related areas, such as environmental monitoring, data retrieval, analysis and synthesis, and information management and display.

3.2 Background Considerations and Importance of 'Healthy Marine Ecosystems'

The Bay of Fundy and the greater Gulf of Maine are data and information rich areas, historically one of the most studied marine areas on the globe. The region has a number of large, well-established research institutions, many smaller ones, and many active community groups (e.g., GPAC, Coastal Communities Network) and university groups (e.g., RARGOM) (see Schroeder et al. 2001). This puts the region in the unique position of basing new 'health assessments' on the most current and state of the art ecological and resource information, and a background of enormous knowledge and understanding (see the references cited, but note the holdings of libraries such as at the Marine Biological Laboratory (MBL) at Woods Hole, MA and the Bedford Institute of Oceanography (BIO), Dartmouth, NS). The challenge will be in the approach, selection of indicators, analysis, synthesis and interpretation.

There are now well-recognized linkages between ecosystem health and human health (McMichael 1993; di Guilo and Monosson 1996) or ocean health and human health in its widest context (Knap et al. 2002; many refs.). For the marine environment, examples abound, e.g., algal toxin effects, sewage impacts, trace chemical effects, quality of seafood, reduced use, aesthetics, quality of life. Internationally, the linkage between ocean and human health is being pursued actively through the IOC/UNESCO (Knap et al. 2002; A. Knap, pers. comm.), especially in the context of native subsistence users, and the inhabitants of small island states. For the Bay of Fundy, closed or restricted shellfish beds are the most obvious sign of the social and health impacts of a degraded system (also see Section 2.3).

The other major imperative is an ethical one – that the Fundy and Gulf of Maine ecosystem and their inhabitants equally deserve protection and conservation, and that this should be done as a matter of good ethics and citizen and corporate responsibility. Arguments for the protection and conservation of the natural living resources come before the economic ones. The use of the non-living resources, e.g., minerals or aggregate rocks, which is a growing interest, solely for economic reasons should be pursued with great caution.

3.3 Approaches and Techniques for Assessing the Bay's Health

This section describes some of the essential approaches and techniques for acquiring the data and information, and the analyses essential for an assessment of the Bay of Fundy's health. It refers back to how we study, measure and analyze ecosystem health, and in that context, ecological and ecosystem change (Section 1). There is a large literature and many active programs pertaining to approaches and techniques, not only relating to the Bay of Fundy and the Gulf of Maine. This section is simply meant to be a checklist of components to consider while organizing an assessment.

3.3.1 Monitoring approaches

In Canada, the importance of monitoring and the data that it produces has been reiterated recently with the passage of the Oceans Act (1997). The MEQ component of the Oceans Act includes indicators, guidelines, assessments, but not research and monitoring, explicitly. However, the key role of ocean monitoring is assumed and is slowly being strengthened in the context of programs such as GOOS or Global Ocean Observing System (P. Strain, pers. comm.) and harbour monitoring (e.g., Halifax, J. Hellou, pers. comm.). MEQ has been discussed at the CZC 2000 session on ocean health in Saint John, NB (S. Courtney, pers. comm.) and a Department of Fisheries and Oceans (DFO) winter 2001 meeting on objectives and indicators for ecosystem-based management in Victoria (Jamieson et al. 2001). There is continued monitoring, such as with the Gulf of Maine GOMCME EQ Monitoring committee, with Gulfwatch (Chase et al. 2001; Jones et al. 2001; Jones and Wells 2002). There are the offshore EEM programs, using sophisticated methods of monitoring ocean change and contaminant sources, fate and effects (Gordon et al. 2000). There are also the environmental effects monitoring (EEM) programs applied to and by the pulp and paper industry that use current field ecotoxicology techniques for monitoring.

It is important to mention monitoring activity sponsored by the United Nations. The Gulf of Maine GOOS program is part of the larger global GOOS of UNESCO/IOC. Some of it goes on under the auspices of Global Inland Waters Assessment (GIWA) and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). There is also Global Environmental Facility/Large Marine Ecosystem (GEF/LME) activity (IUCN 1998), with LME assessments taking place globally. There is one for the US Northeast Shelf and one for the Scotian Shelf, both of which overlap the Bay of Fundy (Sherman and Skjoldal 2002). As described above (Section 2.1.3), the pollution and ecosystem health module of each LME covers eutrophication, biotoxins, pathology, emerging disease, and health indices.

> Systematic monitoring data of bio-indicator species including bottom fish and mollusks (Musselwatch) are examined for endocrine disrupters and organ pathology. Water quality and plankton examinations are made for phytoplankton toxicity, eutrophication, persistent organic pollutants, and evidence of emerging disease. Examinations of changing states of health of LMEs are based on indices of ecosystem biodiversity, productivity, yield, resilience, and stability (K. Sherman, pers. comm.).

These examples reiterate the role that systematic monitoring plays in providing the data, short and long-term, essential for any ecosystem health assessment. The initial challenge is two-fold: agreeing on the indicators and finding support for the programs. It should also be recognized that effective marine monitoring programs would benefit from having components of data analysis and interpretation, sample and data management, research on new techniques, and communication, in addition to the basic, routine sampling programs (Jones and Wells 2002).

3.3.2 Indicators and indices

There has been fair agreement in the area of MEH and MEQ indicators over the past few years. Useful papers and reports include: Bilyard 1987; Burger and Gochfeld 2001; EPA 2000a,b; GESAMP 1994a; IJC 1991; Long and Buchman 1989; Nettleship 1997; NOAA 1999; O'Connor and Dewling 1986; Rapport 1991b, 1999; Salánki 1986; Schwaiger 1997; Soule and Kleppel 1998; Thompson and Hamer 2000; Vandermeulen 1998; Van Dolah 2000; and Wichert and Rapport 1998. A synthesis of indicators currently used in USA NOAA coastal programs was assembled for the GOMCME (W. O'Bearne, pers. comm.). The reader should also refer to Section 4, the Coastal Forum, as one of the challenges of this workshop was to discuss, identify and reach consensus on the suite (assemblages) of suitable indicators of health and quality for the Bay of Fundy (Question 3, Coastal Forum).

When one views and considers the size, dynamics and various ecologies and species in the Bay, it is very hard to imagine the Bay's ecosystems being significantly impaired through human activity (with the obvious exception of fisheries; Jackson et al. 2001). The Bay simply appears too large, dynamic, biologically diverse, and ever renewed by the tides. However, scientific programs of research and monitoring tell a different story (e.g., see Proceedings of the first four Fundy Science Workshops – Percy et al. 1997; Burt and Wells 1998; Ollerhead et al. 1999; Chopin and Wells 2001). Parts of the system can become impacted or impaired, in both the short and long-term. So the question becomes: which indicators and indices, used in combination, give the 'best' measure of the state of the Fundy system and/or its component places and parts?

Schaeffer et al. (1988) described four major measures of ecosystem health, which can be tested here – sustainability, activity, organization, and resilience. As stated above, "sustainability implies that the system can maintain its structure and function over time". Basically, the authors are saying that the best indicators are structure, function and resilience of each ecosystem, and that there are readily measured endpoints of these indicators to incorporate into a monitoring program. Karr (1992) states: "the development of indicators is, arguably, the most important step needed to mobilize social support for reversal of the trend towards biotic impoverishment". Many ecological concepts, such as resilience, resistance, connectivity, and ascendancy, may suggest important indicators of a systems condition, but they have practical difficulties – what do you measure operationally in the real world?

It is crucial to use practical, measurable, interpretable and current indicators. There may be a disconnect between the people discussing the concepts of ecosystem health and indicators (Rapport et al. many refs.; Constanza et al. 1992), basic ecologists, and those in the aquatic science field who have been deploying techniques in the field and assessing areas as to health and quality, i.e. condition, for several decades (Soule and Kleppel 1998; Simon 2002). Immense advances have been made in marine environmental monitoring approaches and techniques over the past 3–4 decades. We are not starting at the beginning (e.g., B. H. Sherman's work HEED and Ken Sherman's work LME, above; the existing Gulfwatch program, and similar programs worldwide; many others, especially in selected specialized fields such as the fate and effects of oils spills)! Dr. John Pearce, who has worked in this area for several decades (note McIntyre and Pearce 1980; Pearce 2000; Pearce and Wells 2002; Pearce, this volume, pages 309-319) has offered valuable insights as to the appropriate set(s) of indicators to use for measuring ecosystem health in the Gulf of Maine. As shown by Butler (1997), even single well-known species act as easily monitored ‘sentinel species’.

Finally, Smiley et al. (1998), in an internal Canadian review of indicators on MEH (not differentiated from MEQ), reached two conclusions useful to the discussion of appropriate indicators for the Bay of Fundy: (1) The development of indicators to measure MEH generally involves the following key steps: a) scope the issues, b) evaluate the knowledge base, c) select indicators, and d) conduct targeted research and monitoring of the indicators; and (2) The ABC’s of selecting indicators are: a) some indicators should be related to ecosystem structure and function, b) some indicators should be selected (and deployed!) in combination, and c) indicators should be selected using the guidance of criteria acceptable to all involved parties.

3.3.3 Status and trends analysis

Indicators should be deployed so as to answer the question: Is the quality of the Fundy marine ecosystem (or parts of it) getting better or worse in the short and longer term? This requires substantial data bases for status and trends analysis. A number of monitoring programs for coastal waters have selected measures of health and quality that allow for such analysis. That is, measurements of selected variables in water, sediments and biota are conducted over space and time to provide a longer term picture of the magnitude of the response and the direction of change.

Examples include: Gulfwatch for trace chemical contaminants (Chase et al. 2001; Jones et al. 2001); algal toxins (as per the Harmful Algal Blooms program); input of aerial contaminants (Clair et al. 2002, acid rain; R. Cox, pers comm., toxic chemicals in fog; E. Sunderland, pers. comm., mercury in air and marine sediments); bacterial levels along the coasts, especially at shellfish beds; condition, i.e. catch statistics, of specific fisheries; state of the water and benthic environments around aquaculture operations; numbers and locations of tidal barriers or obstructions; location of dykes, maintained and un-maintained; sediment quality at selected sites (K. Tay, pers. comm.); nutrients, especially nitrogen; and sewage treatment and effects. Ultimately, the current status and trends programs will provide data for a major chapter on this question of ‘better or worse’ or no change in the State of the Bay of Fundy/ Gulf of Maine Report(s).

3.4 Connecting with Management Priorities and Needs

A section of the planned State of Fundy/State of the Gulf Reports should address management priorities and needs (at various levels, in various sectors), and present recommendations as to how to proceed with future reports. The whole process is started with and finished with management support and involvement. No single report or report card on the Bay will be perfectly completed. How can such reports be improved? What do we need? Is a series of reports on different issues, treated in depth separately, more useful than periodic tomes covering all issues? These questions were addressed more fully in the Coastal Forum (see separate report, in prep., 2004). This is simply an introduction to stimulate discussion between the practitioners of monitoring and assessments, and the clients, the managers and the coastal communities.

3.4.1 Mechanisms for action

Do we have the information, human capacity and resources to produce periodic State of the Bay of Fundy Reports? Importantly, do we have the resources to continue to monitor selected variables, i.e. indicators in the Bay, so that the data and information bases remain current and relevant? What else do we need to have? Who do we direct these to?

3.4.2 New directions

There are a number of needs and new directions to consider (also see discussion from the Coastal Forum), given the role of research, monitoring, assessment and information management in reports on the ecosystem health of the Bay of Fundy. They include:

1. More of a collective vision of the stakeholders as to what they envisage the Bay of Fundy and its watershed(s) to be like in 20, 50, 100 years time, and the mechanisms to protect and conserve their natural features and living resources.
2. More research on practical monitoring tools (e.g., Rapid Assessment of Marine Pollution (RAMP), Wells et al. 2001; the expanded Gulfwatch program).
3. More resources into MEQ and MEH monitoring and data analysis (such as HEED effort).
4. More attention to the networking of existing programs involved in monitoring and assessment and guidelines – linked together.
5. More practitioners in monitoring and assessments are needed.

4. The Coastal Forum: “Taking the Pulse of the Bay of Fundy”

4.1 Guiding Questions for Discussion

There are five important questions – simply stated but not necessarily simply answered. This was a starting point to the open workshop discussions. It assumed and hoped that other pertinent questions pertaining to the overall goal would likely appear! The five questions are:

1. What is the present health or condition of the Bay of Fundy?
2. Are conditions improving or deteriorating?
3. What kinds of indicators do we consider most useful in trying to answer these questions?
4. Are there adequate resources (institutional, financial, scientific, etc.) to protect or restore the health of the Bay?
5. What kinds of new information and approaches do we need to protect the health of the Bay?

As shown in these Proceedings (see separate report, in prep., 2004), the workshop participants addressed the questions from their own perspectives, using their own knowledge, and making use of the new information presented at the meeting (as well as at the previous meetings).

4.2 Developing the Synthesis

To assess the health of the Bay of Fundy, it is necessary to summarize and evaluate the data from the chosen suite of ecological health/environmental quality indicators. For example, and following from previous examples (various US Environmental Protection Agency (EPA) reports; Wells and Rolston 1991; Costanza et al. 1992), one could take ten indicators, reached by consensus, and summarize the data for them in a number of locations around the edges of the Bay (Note: stresses often occur at edges or interfaces, a topic in itself!). The process is: rank the results of each of the ten indicators, each indicator being marked out of 10 (e.g., 1 – very clean/undisturbed, 10 – very dirty/very disturbed). Then add the scores, 100 being the top score (1–25: very good; 26–50: good to marginal; 51–75: compromised and disturbed; 76–100: very affected/extreme disturbance).

For some indicators, the values assigned could and should be determined by comparison with existing guidelines, objectives or standards, e.g., contaminant levels in sediments, using the Canadian Environmental Protection Act values; tissue concentrations of contaminants, US Food and Drug Adminstration (FDA). The scores (1 to 100) could be portrayed as circles (open to filled in) or circles with colors (green, yellow, orange, red – an EPA technique), and be placed on a map of the Bay of Fundy to give a visual portrayal of the health and quality, in general, of the Bay. (See EPA reports that have used this technique (EPA 1998), as well as Chapter 6, Wells and Rolston 1991.) Arrows can also be included to show direction of change. The summary across the table, in a row, gives the extent of the problem across the Bay using each indicator. The summary down the table, in a column, gives an impression of the number of stresses affecting one ecosystem or area of the water body (i.e. the Bay of Fundy), hence an impression of the potential for cumulative change in one area of the Bay.

It is important to recognize the problems with the above approach. The big problem with this approach is its linearity – all indicators and indexes are given the same weight in the analysis, whereas in reality, some stresses, e.g., habitat loss, may exceed in total impact another stressor, e.g., periodic low DO (dissolved oxygen). However, this could be accommodated at a local level, with different indicators being given different percentages of the total scores (up to 100). A second problem is that the relative impacts of stresses will change across seasons, e.g., bacterial levels in shellfish growing areas; tourism-wildlife interactions; harmful algal blooms. Finally, a number of the stresses cannot be easily or accurately quantified, i.e. measured, so judgement has to be used, e.g., impact of whale watching boats on the behaviour of whales. Certainly, the reader can think of more limitations and resolve them! The limitations notwithstanding, the approach is a beginning of a comprehensive discussion, ranking and synthesis of the issues and stresses on the Bay. As shown in these Proceedings, it was used successfully in the Coastal Forum.

5. Summary and Conclusions

The paper discusses the concepts of health and ecosystem health, and introduces components of a framework for assessing the Bay of Fundy. Several challenges faced the participants of this 5th Bay of Fundy Science Workshop and Coastal Forum, as they met and discussed issues, approaches and indicators for two and one half days. Some conclusions were reached by this author. We collectively have to address and understand the concepts and dimensions of the topic of 'marine ecosystem health' and 'marine environmental quality (MEQ)' in the context of the Bay of Fundy and Gulf of Maine, if the goal remains to produce a 'health assessment'. We will have to organize, assimilate and summarize a large amount of historical and recent data and information in order to evaluate the 'health' of the Bay. We should strive to be constructively critical when interacting between disciplines and between sectors, in this activity of ecosystem health assessment. Finally, we have to consider how often and with what venue we should continue to meet and discuss the benchmark measures or indicators, to organize a synthesis, and finally to assess whether we are or are not achieving the task of protection, conservation and restoration of the Bay, its vital watersheds, and their natural resources.

6. Acknowledgments

Many scholars have contributed to this field; they are thanked for their obvious dedication to an understanding of ecosystem health and to the ecology of the Bay of Fundy. Discussions with colleagues, especially those with BoFEP, GESAMP, GOMCME and GPAC, encouraged continued thought about this topic. Questions for the Fundy Coastal Forum were developed in discussion with Graham Daborn, Barry Jones, Jon Percy and Maxine Westhead, all members of BoFEP. The paper is dedicated to the memories of three outstanding Bay of Fundy scientists at the Bedford Institute of Oceanography, Dartmouth, NS – Dr. Kathy Ellis, Mr. Nicholas (Nick) Prouse, and Dr. Peter Schwinghamer.

7. Literature Cited

Arctic Monitoring and Assessment Programme (AMAP). 1997. *Arctic Pollution Issues. A State of the Arctic Environment Report*. AMAP, Oslo, Norway. 188 pp.

AMAP. 2002. *Arctic Pollution 2002*. AMAP, Oslo, Norway. At: <http://www.amap.no>. Accessed: 22 October 2002.

Atlantic Geoscience Society. 2001. *The Last Billion Years. A Geological History of the Maritime Provinces of Canada*. Nimbus Publ. Ltd., Halifax, NS. 212 pp.

Atkinson, J., P. M. Brooks, A. C. Chatwin, and P. Shelley. 2000. *The Wild Sea. Saving Our Marine Heritage*. Conservation Law Foundation, Boston, MA. 120 pp.

Backus, R. H. and D. W. Bourne (Eds.). 1987. *Georges Bank*. The MIT Press, Cambridge, MA and London, UK. 593 pp.

Baird, D. J. and G. A. Burton (Eds.). 2001. *Ecological Variability: Separating Natural from Anthropogenic Causes of Ecosystem Impairment*. SETAC Press, Pensacola, FL. 307 pp.

Bilyard, G. R. 1987. The value of benthic infauna in marine pollution monitoring studies. Marine Pollution Bulletin 18(11): 581–585.

Birkett, S. H. and D. J. Rapport. 1996. Comparing the health of two large marine ecosystems: the Gulf of Mexico and the Baltic Sea. Ecosystem Health 2(2): 127–144.

Burger, J. and M. Gochfeld. 2001. On developing bioindicators for human and ecological health. Environmental Monitoring and Assessment 66: 23–46.

Burt, M. D. B. and P.G. Wells (Eds.). 1998. *Coastal Monitoring and the Bay of Fundy.* Proceedings of the Maritime Atlantic Ecozone Science Workshop, November 1997. Huntsman Marine Science Centre, St. Andrews, NB and Environment Canada, Dartmouth, NS. 196 pp.

Butler, R.W. 1997. *The Great Blue Heron. A Natural History and Ecology of a Seashore Sentinel*. University of British Columbia Press, Vancouver, BC. 167 pp.

Campbell, D. E. 2000. Using energy systems theory to define, measure, and interpret ecological integrity and ecological health. Ecosystem Health 6(3): 181–204.

Chandler, H. 2001. Marine Monitoring Programs in the Gulf of Maine. An Inventory. Internal Report, prepared for the Gulf of Maine Council on the Marine Environment. Maine State Planning Office and the Gulf of Maine Council, Augusta, ME. 115 pp.

Chang, C. P. 1999. A Marine Environmental Quality Framework: Managing the Marine Ecosystem by Choosing Appropriate Guidelines, Objectives and Standards. Thesis, Master of Marine Management, Dalhousie University, Halifax, NS. 88 pp.

Chang, C. P. and P. G. Wells. 2001. A marine environmental quality (MEQ) framework and the Bay of Fundy. Abstract, Page 127. In: *Opportunities and Challenges for Protecting, Restoring and Enhancing Coastal Habitats in the Bay of Fundy*. *Proceedings of the 4th Bay of Fundy Science Workshop, Saint John, NB, September 19-21st, 2000*. T. Chopin and P.G. Wells, Eds. Environment Canada – Atlantic Region, Occasional Report No. 17, Sackville, NB and Dartmouth, NS.

Chase, M. et al. 2001. Gulfwatch: Monitoring spatial and temporal trends of trace metal and organic contaminants in the Gulf of Maine (1991-1997) with the blue mussel, *Mytilus edulis* L. Marine Pollution Bulletin 42 (6): 491–505.

Chopin, T. and P. G. Wells (Eds.). 2001. *Opportunities and Challenges for Protecting, Restoring and Enhancing Coastal Habitats in the Bay of Fundy*. *Proceedings of the 4th Bay of Fundy Science Workshop, Saint John, NB, September 19-21, 2000*. Environment Canada – Atlantic Region, Occasional Report No. 17. Environment Canada, Sackville, NB and Dartmouth, NS. 237 pp.

Clair, T. A. et al. 2002. Changes in freshwater acidification trends in Canada's Atlantic provinces: 1983–1997. Water, Air, and Soil Pollution 135: 335–354.

Clark, R. A. and C. L. J. Frid. 2001. Long-term changes in the North Sea ecosystem. Environmental Review 9: 131–187.

Costanza, R. 1992. Chapter 14. Toward an operational definition of ecosystem health. Pages 239-256. In: *Ecosystem Health. New Goals for Environmental Management*. R. Costanza, B. G. Norton and B. D. Haskell. Island Press, Washington, DC.

Costanza, R. and M. Mageau. 1999. What is a healthy ecosystem? In: *The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management*. H. Kumpf, K. Steidinger, and K. Sherman, Eds. Blackwell Science, Malden, MA.

Costanza, R., B. G. Norton and B. D. Haskell. 1992. *Ecosystem Health. New Goals for Environmental Management*. Island Press, Washington, DC. 269 pp.

Crawford, D. W., N. L. Bonnevie, C. A. Gillis and R. J. Wenning. 1994. Historical changes in the ecological health of the Newark Bay estuary, New Jersey. Ecotoxicology and Environmental Safety 29: 276–303.

Di Giulio, R. T. and E. Monosson (Eds.). 1996. *Interconnections Between Human and Ecosystem Health*. Ecotoxicology Series 3. Chapman and Hall, London, UK. 275 pp.

Downs, T. J. and R. F. Ambrose. 2001. Syntropic ecotoxicology: A heuristic model for understanding the vulnerability of ecological systems to stress. Ecosystem Health 7(4): 266–283.

Duarte, C. M., J. Cebrian and N. Marba. 1992. Uncertainty of detecting sea change. Nature 356 (March 19): 190.

Ehrenfeld, D. 1992. Ecosystem health and ecological theories. Pages 135-143. In: *Ecosystem Health. New Goals for Environmental Management*. R. Costanza, B. G. Norton and B. D. Haskell. Island Press, Washington, DC.

Environmental Protection Agency (EPA). 1998. *Condition of the Mid-Atlantic Estuaries*. USEPA Office of Research and Development, Washington, DC. EPA 600-R-98-147. 50 pp.

EPA. 1999. *The Ecological Condition of Estuaries in the Gulf of Mexico*. USEPA Office of Research and Development, Washington, DC. EPA 620-R-98-004. July 1999. 71 pp.

EPA. 2000a. *Stressor Identification Guidance Document*. USEPA, Office of Research and Development, Washington, DC. EPA/822/B-00/025. December.

EPA. 2000b. *Evaluation Guidelines for Ecological Indicators*. EMAP, USEPA, Office of Research and Development, Washington, DC. EPA/620/R-99/005. 97 pp.

Epstein, P. R. 1999. Large marine ecosystem health and human health. Pages 417–438. In: *The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management*. H. Kumpf, K. Steidinger, and K. Sherman, Eds. Blackwell Science, MA.

Epstein, P. R. and D. J. Rapport. 1996. Changing coastal marine environments and human health. Ecosystem Health 2(3): 166–176.

Earle, S. A. 1995. *Sea Change. A Message of the Oceans*. G. P. Putnam's Sons, New York. 361 pp.

Fairweather, P. G. 1999. Determining the "health" of estuaries: Priorities for ecological research. Australian Journal of Ecology 24: 441–451.

Fisheries and Oceans Canada (DFO). 2000. *Working Together to Protect and Promote Canada's Oceans.* Booklet, Department of Fisheries and Oceans, Ottawa. 9 pp.

DFO. 2002a. *Canada's Oceans Strategy. Our Oceans, Our Future*. Oceans Directorate, Department of Fisheries and Oceans, Ottawa. 30 pp.

DFO. 2002b. *Canada's Oceans Strategy. Our Oceans, Our Future*. *Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments in Canada*. Oceans Directorate, Department of Fisheries and Oceans, Ottawa. 36 pp.

Frith, K. 1999. Ocean and Human Health: How the health of the oceans affects our well-being. Currents, Bermuda Biological Station for Research, Inc. Spring. Pages 7–8.

GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). 1990. *The State of the Marine Environment*. Blackwell Scientific Publications, Oxford, UK. 146 pp.

GESAMP. 1994a. *Biological Indicators and Their Use in the Measurement of the Condition of the Marine Environment*. GESAMP Reports and Studies No. 55. United Nations Environment Programme, Nairobi. 56 pp.

GESAMP. 1994b. *Guidelines for Marine Environmental Assessments*. GESAMP Reports and Studies No. 54. International Maritime Organization, London. 31 pp.

GESAMP. 2001a. *A Sea of Troubles*. GESAMP Reports and Studies No. 70. GESAMP, London. 35 pp.

GESAMP. 2001b. *Protecting the Oceans from Land-based Activities*. GESAMP Reports and Studies No. 71. United Nations Environment Programme, Nairobi.

Goldberg, E. D. 1976. *The Health of the Oceans*. The Unesco Press, Paris. 172 pp.

GOMCME (Gulf of Maine Council on the Marine Environment). 1989. *The Gulf of Maine: Sustaining Our Common Heritage*. Maine State Planning Office, Augusta, ME, November. 63 pp.

GOMCME. 2002. *Gulf of Maine Council on the Marine Environment Action Plan 2001-2006.* At: <http://www.gulfofmaine.org/action_plan2001_06.html>. Accessed: 5 October 2002.

Gordon, D. C., Jr., L. D. Griffiths, G. V. Hurley, A. L. Muecke, D. K. Muschenheim and P. G.Wells (Eds.). 2000. Understanding the Environmental Effects of Offshore Hydrocarbon Development. Canadian Technical Report of Fisheries and Aquatic Sciences 2311. Department of Fisheries and Oceans, Dartmouth, NS. 82 pp. + appendices.

Global Program of Action Coalition (GPAC). 2001. *The Gulf of Maine Summit: State of the Environment Reporting from the Bottom-Up. A Handbook for Forum Conveners*. GPAC, Blue Hill, ME. 18 pp.

Gove, P. B. (Ed.). 1993. *Webster's Third New International Dictionary, Unabridged*. Merriam-Webster, Springfield, MA.

Harding, G. C. H. 1992. A Review of Major Marine Environmental Concerns Off the East Coast in the 1980's. Canadian Technical Report of Fisheries and Aquatic Sciences 1885. Department of Fisheries and Oceans, Dartmouth, NS. 38 pp.

Harding, L. E. 1992. Measures of marine environmental quality. Marine Pollution Bulletin 25(1–4): 23–27.

Harvard Health, Ecological and Economic Dimensions of Global Change Program (HEED). 1998. *Marine Ecosystems: Emerging Diseases as Indicators of Change. Health of the Oceans from Labrador to Venezuela*. Center for Health and the Global Environment, Harvard Medical School, Boston, MA. 85 pp.

Harvell, C. D. et al. 1999. Emerging marine diseases – climate links and anthropogenic factors. Science 285: 1505–1510.

Harvey, J., D. Coon, and J. Abouchar. 1998. *Habitat Lost: Taking the Pulse of Estuaries in the Canadian Gulf of Maine*. Conservation Council of New Brunswick, Fredericton, NB. 79 pp.

Haskell, B. D. , B. G. Norton and R. Costanza. 1992. Introduction. What is ecosystem health and why should we worry about it? Pages 3-20. In: *Ecosystem Health. New Goals for Environmental Management*. R. Constanza, et al. Island Press, Washington, DC.

Hinch, P., S. Bryan and P. G. Wells (Eds.). 2002. *Sewage Management in the Gulf of Maine. Workshop Report*. In preparation, July.

Intergovernmental Oceanographic Commission (IOC). 1996. *A Strategic Plan for the Assessment and Prediction of the Health of the Ocean: A Module of the Global Ocean Observing System*. IOC/UNESCO, IOC/INF-1044, May. IOC, Paris. 39 pp.

International Joint Commission (IJC). 1991. *A Proposed Framework for Developing Indicators of Ecosystem Health for the Great Lakes Region*. Council of Great Lakes Research Managers, IJC, USA and Canada. July. 47 pp.

IUCN - The World Conservation Union. 1998. An Ecosystem Strategy for the Assessment and Management of International Coastal Ocean Waters. Brochure. IUCN, NOAA and IOC/UNESCO. 8 pp.

Jackson, J. B. C. 2001. What was natural in the coastal oceans? Proceedings of the National Academy of Science 98(10): 5411–5418.

Jackson, J. B. C. et al. 2001. Historical over-fishing and the recent collapse of coastal ecosystems. Science 293: 629–638.

Jakeman, A. J., M. B. Beck and M. J. McAleer (Eds.). 1993. *Modelling Change in Ecological Systems*. John Wiley and Sons, Chichester, NY. 584 pp.

Jamieson, G. et al. 2001. *Proceedings of the National Workshop on Objectives and Indicators for Ecosystem-based Management. Sidney, BC, 27 February – 2 March, 2001*. Canadian Science Advisory Secretariat Proceedings Series 2001/09. Department of Fisheries and Oceans, Ottawa.

Jickells, T. D. 1998. Nutrient bio-geochemistry of the coastal zone. Science 281: 217–222.

Johnston, P. et al. 1998. *Report on the World's Oceans*. Greenpeace Research Laboratories Report, University of Exeter, UK, May. 154 pp.

Jones, S. H. and P. G. Wells (Eds). 2002. *Gulf of Maine Environmental Quality Monitoring Workshop, 3 April – 1 May, 2001. Summary Report*. In press, September. Gulf of Maine Council on the Marine Environment, Durham, NH and Dartmouth, NS.

Jones, S. H. et al. 2001. Monitoring for toxic contaminants in *Mytilus edulis* from New Hampshire and the Gulf of Maine. Journal of Shellfish Research 20(3): 1203–1214.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6: 21–27.

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1: 66–84.

Karr, J. R. 1992. Chapter 13. Ecological integrity. Protecting Earth's life support systems. Pages 223–238. In: *Ecosystem Health. New Goals for Environmental Management*. R. Constanza, et al. Island Press, Washington, DC.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. *Assessing Biological Integrity in Running Water: A Method and its Rationale*. Special Publication 5. Illinois Natural History Survey, Champaign, IL. 28 pp.

Kay, B. H. 1989. *Pollutants in British Columbia's Marine Environment. A Status Report.* SOE Report No 89-1, April 1989. Environment Canada, Ottawa. 59 pp.

Knap, A. H., et al. 2002. Indicators of ocean health and human health: Developing a research and monitoring framework. Environmental Health Perspectives 110(9): 839–845.

Konrad, V., S. Ballard, R. Erb and A. Mortin. 1990. *The Gulf of Maine: Sustaining Our Common Heritage*. Maine State Planning Office and the Canadian-American Center of the University of Maine, Augusta, ME. 270 pp.

Kullenberg, G. 1982. *The Review of the Health of the Oceans*. GESAMP Reports and Studies No. 15. UNESCO, Paris. 108 pp.

Kutchenberg, T. C. 1985. Measuring the health of the ecosystem. Environment 27: 32–37.

Lane, P. A. 1998. Chapter 9. Assessing cumulative health effects in ecosystems. Pages 129–153. In: *Ecosystem Health*. D. Rapport et al., Eds. Blackwell Science, Oxford, UK.

Leopold, A. 1949. *A Sand County Almanac, and Sketches Here and There*. Oxford University Press, London. 226 pp.

Lomborg, B. 2001. *The Skeptical Environmentalist. Measuring the Real State of the World*. Cambridge University Press, Cambridge, UK. 515 pp.

Long, E. R. and M. F. Buchman. 1989. An Evaluation of Candidate Measures of Biological Effects for the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 45. April, Seattle, WA (Executive Summary).

Lotze, H. and I. Milewski. 2002. *Two Hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy*. Conservation Council of New Brunswick, Fredericton, NB. 188 pp.

Mann, K. H. 2000. *Ecology of Coastal Waters, with Implications for Management*. Blackwell Science Publications, Cambridge, UK. 406 pp.

Marine Institute. 1999. *Ireland's Marine and Coastal Areas and Adjacent Seas. An Environmental Assessment*. Marine Institute, Dublin, Ireland. 388 pp.

Marx, W. 1999. *The Frail Ocean. A Blueprint for Change in the New Millennium*. Hartley and Marks, Vancouver, BC. 272 pp.

McGinn, A. P. 1999. *Safeguarding the Health of Oceans*. Worldwatch Paper 145, March. Worldwatch Institute, Washington, DC. 87 pp.

McGowan, J. A., D. R.Cayan and L. M. Dorman. 1998. Climate-ocean variability and ecosystem response in the Northeast Pacific. Science 281: 210–217.

McIntyre, A. D. and J. Pearce (Eds.) 1980. *Biological Effects of Marine Pollution and the Problems of Monitoring.* Rapports Procès-Verbaux des Réunions Conseil International pour l'Exploration de la Mer 179, 1-346. ICES, Copenhagen, Denmark.

McMichael, A. J. 1993. *Planetary Overload. Global Environmental Change and the Health of the Human Species*. Cambridge University Press, Cambridge, UK. 352 pp.

Milewski, I., J. Harvey and S. Calhoun. 2001. *Shifting Sands. State of the Coast in Northern and Eastern New Brunswick.* Conservation Council of New Brunswick, Fredericton, NB. 144 pp.

Myers, N. 1995. Environmental unknowns. Science 269: 358–360.

National Oceanic and Atmospheric Administration (NOAA). 1999. *National Status and Trends Program for Marine Environmental Quality. South Florida*. NOAA, CCMA, Regional Report Series 2. US Department of Commerce, NOAA. 40 pp.

Nettleship, D. N. 1997. Long-term monitoring of Canada's seabird populations. Pages 16-23. In: *Monitoring Bird Populations: The Canadian Experience*. E. H. Dunn, M. D. Cadman and J. B. Falls, Eds. Occasional Paper Number 95. Canadian Wildlife Service, Environment Canada, Ottawa.

Nielsen, N. O. 1999. The meaning of health. Ecosystem Health 5(2): 65–66.

Norton, B. G., R. E. Ulanawicz, and B. D. Haskell. 1991. Scale and Environmental Policy Goals. Report to the EPA, Office of Policy, Planning and Evaluation. Environmental Protection Agency, Washington, DC.

Noss, R. 1995. *Maintaining Ecological Integrity in Representative Reserve Networks*. World Wildlife Fund Canada, WWF USA, Toronto and Washington, DC. 77 pp.

O'Connor, J. S. and R. T. Dewling. 1986. Indices of marine degradation: Their utility. Environmental Management 10(3): 335–343.

Ollerhead, J., P. W. Hicklin, P. G. Wells and K. Ramsey (Eds.). 1999. *Understanding Change in the Bay of Fundy Ecosystem*. Environment Canada - Atlantic Region, Occasional Report No. 12. Environment Canada, Sackville, NB and Dartmouth, NS. 143 pp.

Pearce, J. B. 2000. The New York Bight. Marine Pollution Bulletin 41(1-6): 44–55.

Pearce, J. B. and P. G.Wells. 2002. Editorial. Key(s) to marine ecology and understanding pollution impacts. Marine Pollution Bulletin 44: 179–180.

Percy, J. A. and P. G. Wells. 2002. Taking Fundy's Pulse: Monitoring the Health of the Bay of Fundy. BoFEP Fundy Issues #22, Autumn. Environment Canada, Dartmouth, NS. 8 pp.

Percy, J. A., P. G. Wells and A. J. Evans (Eds.). 1997. *Bay of Fundy Issues: A Scientific Overview.* Environment Canada - Atlantic Region, Occasional Report No. 8. Environment Canada, Sackville, NB and Dartmouth, NS (Reprinted April 2002).

Pesch, G. 2000. Establishing a Framework for Effective Monitoring of the Gulf of Maine. RARGOM Report 00-1. September 29, 2000. Regional Association for Research on the Gulf of Maine. 9 pp.

Plant, S. 1985. Bay of Fundy Environmental and Tidal Power Bibliography. Canadian Technical Report of Fisheries and Aquatic Sciences 1339. Department of Fisheries and Oceans, Dartmouth, NS.

Rapport, D. J. (Ed.). 1986. *State of Canada's Environment*. Environment Canada, Ottawa.

Rapport, D. J. 1989. What constitutes ecosystem health? Perspectives in Biology and Medicine 33(1): 120–132.

Rapport, D. J. 1990. Challenges in the detection and diagnosis of pathological change in aquatic ecosystems. Journal of Great Lakes Research 16(4): 609–618.

Rapport, D. J. 1992. Evaluating ecosystem health. Pages 15-24. In: *Assessing Ecosystem Health: Rationale, Challenges and Strategies*. M. Munawar (Ed.). Kluwer, Amsterdam.

Rapport, D. J. 1998. Dimensions of ecosystem health. Pages 34-40. In: *Ecosystem Health*. D. J. Rapport, et al., Eds. Blackwell Science, Oxford, UK.

Rapport, D. J. 1999. Epidemiology and ecosystem health: Natural bridges. Ecosystem Health 5(3): 174–180.

Rapport, D. J., R. Costanza and A. J. McMichael. 1998. Assessing ecosystem health. TREE (Trends in Ecology and Evolution) 13(10) (October 10): 397–401.

Rapport, D. J. and W. G. Whitford. 1999. How ecosystems respond to stress. Common properties to arid and aquatic systems. Bioscience 49(3): 193–203.

Rapport, D. J. et al. 1980. Commentary. Ecosystem medicine. Pages 180-189. In: *Perspectives on Adaptation, Environment and Population*. J. C. Calhoun, Ed. Praeger, New York.

Rapport, D. J. et al. 1998. *Ecosystem Health*. Blackwell Science, Oxford, UK. 372 pp.

Rapport, D. J. et al. 1999. Ecosystem health: the concept, the ISEH, and the important tasks ahead. Ecosystem Health 5(2): 82–90.

Rose, G. A. et al. 2000. Perspective. Distribution shifts and overfishing the northern cod (*Gadus morhua*): A view from the ocean. Canadian Journal of Fisheries and Aquatic Sciences 57: 644–663.

Salánki, J. (Ed.). 1986. *Biological Monitoring of the State of the Environment: Bioindicators*. *An Overview of the IUBS Programme on Bioindicators 1985*. International Union of Biological Sciences, Paris.

Schaeffer, D. J. 1996. Diagnosing ecosystem health. Ecotoxicology and Environmental Safety 34: 18–34.

Schaeffer, D. J., E. E. Herricks and H. W. Kerster. 1988. Ecosystem health: 1. Measuring ecosystem health. Environmental Management 12: 445–455.

Schindler, D. W. 1987. Detecting ecosystem responses to anthropogenic stress. Canadian Journal of Fisheries and Aquatic Sciences 44 (Suppl. 1): 6–25.

Schroeder, P. C. et al. 2001. The Gulf of Maine Environmental Information Exchange: Participation, observation, conversation. Environment and Planning B: Planning and Design 28: 865–887.

Schwaiger, J. et al. 1997. The use of histopathological indicators to evaluate contaminant-related stress in fish. Journal of Aquatic Ecosystem Stress and Recovery 6: 75–86.

Selye, H. 1974. *Stress Without Distress*. Lippincott, Philadelphia, PA. 171 pp.

Sheppard, C. 2000. *Seas at the Millennium*. 3 vols. Pergamon Press, Oxford, UK.

Sherman, B. H. 2000. Marine ecosystem health as an expression of morbidity, mortality and disease events. Marine Pollution Bulletin 41(1–6): 232–254.

Sherman, K. 1994. Sustainability, biomass yields, and health of coastal ecosystems: An ecological perspective. Marine Ecology – Progress Series 112: 277–301.

Sherman, K. 2000. Why regional coastal monitoring for assessment of ecosystem health? Ecosystem Health 6(3): 205–216.

Sherman, K., N. A. Jaworski, and T. J. Smayda. 1996. *The North-East Shelf Ecosystem. Assessment, Sustainability and Management*. Blackwell Science, Cambridge, MA. 564p.

Sherman, K. and H. R. Skjoldal (Eds.). 2002. *Large Marine Ecosystems of the North Atlantic. Changing States and Sustainability*. In press.

Simon, T. P. (Ed.). 2002. *Biological Response Signatures. Indicator Patterns Using Aquatic Communities*. CRC Press, Boca Raton, FL. 576p.

Smiley, B., D. Thomas, W. Duvall and A. Eade. 1998. *State of the Environment Reporting. Selecting Indicators of Marine Ecosystem Health: A Conceptual Framework and an Operational Procedure*. Environment Canada, Occasional Report Series No. 9, Environment Canada, Ottawa. 33 pp.

Soule, D. F. and G. S. Kleppel (Eds.). 1998. *Marine Organisms as Indicators*. Springer-Verlag, New York.

Spellerberg, I. F. 1991. *Monitoring Ecological Change*. Cambridge University Press, Cambridge, UK. 334 pp.

Stewart, P. and L. White. 2001. A Review of Contaminants on the Scotian Shelf and in Adjacent Waters: 1970–1995. Canadian Technical Report of Fisheries and Aquatic Sciences 2351. Department of Fisheries and Oceans, Dartmouth, NS. 158p.

Stokes, P. 1981. Discussion. Pages 85–89. In: *Ecotoxicology and the Aquatic Environment*. P. M. Stokes, Ed. Pergamon Press, Oxford.

Suter, G. W. 1993. A critique of ecosystem health concepts and indexes. Environmental Toxicology and Chemistry 12(9): 1533–1539.

Sykes, J. B. 1976. *The Concise Oxford Dictionary of Current English*. 6th Edition. Oxford University Press, Oxford, UK.

Tait, J. T. P., I. D. Cresswell, R. Lawson and C. Creighton. 2000. Auditing the health of Australia's ecosystems. Ecosystem Health 6(2): 149–163.

Thompson, D. R. and K. C. Hamer. 2000. Stress in seabirds: Causes, consequences and diagnostic value. Journal of Aquatic Ecosystem Stress Recovery 7: 91–110.

Ulanowicz, R. E. 1992. Chapter 11. Ecosystem health and trophic flow networks. In: *Ecosystem Health. New Goals for Environmental Management*. R. Costanza et al. Island Press, Washington, DC.

Vandermeulen, H. 1998. The development of marine indicators for coastal zone management. Ocean & Coastal Management 39: 63–71.

Van Dolah, F. M. 2000. Marine algal toxins: origins, health effects, and their increased occurrence. Environmental Health Perspectives 108(Suppl. 1): 133–141.

Wade, T. L. et al. 1998. NOAA's mussel watch project: current use of organic compounds in bivalves. Marine Pollution Bulletin 37: 20–26.

Waldichuk, M. 1989. The state of pollution in the marine environment. Marine Pollution Bulletin 20(12): 598–602.

Wallace, G. T. and E. F. Braasch (Eds.). 1997. *Proceedings of the Gulf of Maine Ecosystem Dynamics, Scientific Symposium and Workshop. September 1996, St. Andrews, NB*. RARGOM Report 97-1. Regional Association for Research on the Gulf of Maine. 352p.

Wells, P. G. 1991. Chapter 6. Assessment. Pages 115–122. In: *Health of the Oceans. A Status Report on Canadian Marine Environmental Quality*. P. G. Wells and S. Rolston, Eds. Environment Canada, Ottawa and Dartmouth, NS.

Wells, P. G. 1996. Measuring ocean health: resetting a cornerstone of Canadian marine policy, science and management. Pages 241–249. In: *Annexes of the Canadian Ocean Assessment. A Review of Canadian Ocean Policy and Practice*. International Ocean Institute, Halifax, NS.

Wells, P. G. 1999a. Biomonitoring the health of coastal marine ecosystems – the roles and challenges of microscale toxicity tests. Marine Pollution Bulletin 39(1–12): 39–47.

Wells, P. G. 1999b. Understanding change in the Bay of Fundy ecosystem. Pages 4–11. In: *Understanding Change in the Bay of Fundy Ecosystem*. J. Ollerhead, P. W. Hicklin, P. G. Wells and K. Ramsey, Eds. Environment Canada - Atlantic Region, Occasional Report No. 12. Environment Canada, Sackville, NB and Dartmouth, NS.

Wells, P. G. and R. P. Côté. 1988. Protecting marine environmental quality from land-based pollutants. Marine Policy 12: 9–21.

Wells, P. G., M. H. Depledge, J. N. Butler, J. J. Manock and A. H. Knap. 2001. Rapid toxicity assessment and biomonitoring of marine contaminants – exploiting the potential of rapid biomarker assays and microscale toxicity tests. Marine Pollution Bulletin 42(10): 799–804.

Wells, P. G. and J. Gratwick (Eds.). 1988. *Canadian Conference on Marine Environmental Quality: Proceedings*. International Institute for Transportation and Ocean Policy Studies, Dalhousie University, Halifax, NS.

Wells, P. G. and S. J. Rolston (Eds.). 1991. *Health of the Oceans. A Status Report on Canadian Marine Environmental Quality*. Environment Canada, Ottawa and Dartmouth, NS. 187 pp. (Reprinted with index, Fall 1991.)

White, L. and F. Johns. 1997. *Marine Environmental Assessment of the Estuary and Gulf of St. Lawrence*. Department of Fisheries and Oceans, Ottawa. 128 pp.

Wichert, G. A. and D. J. Rapport. 1998. Fish community structure as a measure of degradation and rehabilitation of riparian systems in an agricultural drainage basin. Environmental Management 22(3): 425–443.

Wilson, R. C. H. and R. F. Addison (Eds.). 1984. *Health of the Northwest Atlantic*. A Report to the Interdepartmental Committee on Environmental Issues. Environment Canada, Department of Fisheries and Oceans, Department of Energy, Mines and Resources, Ottawa. 174 pp.

Wood, N. and P. Lavery. 2000. Monitoring seagrass ecosystem health – the role of perception in defining health and indicators. Ecosystem Health 6(2): 134–148.

Woodley, S., J. Kay and G. Francis. 1993. *Ecological Integrity and the Management of Ecosystems.* St. Lucie Press, Delray Beach, FL. 220 pp.

Zaitsev, Y. and V. Mamaev. 1997. *Marine Biological Diversity in the Black Sea. A Study of Change and Decline.* GEF Black Sea Environmental Programme. United Nations Publications, New York. 208 pp.

Zelazny, D. E. 2001. Introduction. Great Lakes Research Review 5(2): i–ii.

Personal Communications

Simon Courtney, Department of Fisheries and Oceans, Moncton, NB
Michael Depledge, University of Plymouth, UK
Anthony Gaston, Canadian Wildlife Service, Ottawa, ON
Diana Hamilton, University of New Brunswick, Fredericton, NB

Jocelyne Hellou, Department of Fisheries and Oceans, Dartmouth, NS
Anthony Knap, Bermuda Biological Station for Research, Bermuda
William O'Bearne, National Oceanic and Atmospheric Administration, Washington, DC
Thomas O'Connor, National Oceanic and Atmospheric Administration, Washington, DC
Kenneth Sherman, National Oceanic and Atmospheric Administration, Narragansett, RI
Peter Strain, Department of Fisheries and Oceans, Dartmouth, NS
Elsie Sunderland, Simon Fraser University, Burnaby, BC
Kok-leng Tay, Environment Canada, Dartmouth, NS
Daniel Wolfe, National Oceanic and Atmospheric Administration, Washington, DC

Session One

COASTAL ZONE AND INFORMATION MANAGEMENT

Chair: Michael Butler, Atlantic Coastal Zone Information Steering Committee, Halifax, Nova Scotia

COASTAL ZONE MANAGEMENT AND INTEGRATED OCEAN MANAGEMENT: WHERE DO THE CONCEPTS MEET?

Marianne Janowicz[1] and Robert Rutherford[2]

[1] New Brunswick Department of the Environment and Local Government, Fredericton, NB.
marianne.janowicz@gnb.ca

[2] Oceans and Coastal Management Division, Fisheries and Oceans Canada, Dartmouth, NS.
rutherfordb@mar.dfo-mpo.gc.ca

Background: Why are both the federal and provincial government now looking at ways to manage the coastal zone?

The coastal zone can be defined as the zone where land, sea and air interact to yield an area of some of the highest biological productivity on earth. Coastal zone management is a tool for developing the larger and longer term vision of how the coastal zone can be utilized today and in the future so that it maintains its ecological integrity and provides the foundation for the continuing existence of coastal communities.

Over the years there have been many calls for improved coastal zone management in Canada from a broad range of groups. One such call was as early as 1977. A report by Marine Research Associates Ltd. identifying the effects of a proposed liquified natural gas terminal on the fisheries around Lorneville, New Brunswick stated the following:

> We must recommend that government should establish a coastal zone management system which identifies areas of vital resource value as well as suitable sites for industrial development; sites where stringent controls insure the co-existence of new industry and the fishery.

These requests for coastal zone management have resulted in several initial attempts to develop coastal zone management policies and programs by various federal or provincial departments. To date there has not been a clear lead at either level of government, and the vision developed by these initiatives has not always been reflective of the broader community interest. Community groups and networks of organizations have also tried to take a lead but have been limited by a lack of funds, capacity and decision-making powers.

The result is that we have not yet been successful in developing and delivering a comprehensive and integrated approach to coastal zone management. The reasons for this are as numerous as the past attempts and the number of people you ask. However, they can be summed up by saying that a lack of a defined goal on the part of all players has been a significant obstacle to progress.

In the absence of an integrated approach to coastal zone management, development in the coastal zone is increasing at a rapid rate. Pollution from land-based activities is affecting the health of the coastal ecosystems, often hurting traditional uses. Urban centers are growing in size and the development is spreading along the coast, there is more interest in tourism and coastal recreation, and new industries are developing and taking space in an already heavily used coastal area.

Over the past few years there have been several positive changes that have moved both the government policy and community involvement forward on coastal zone management. We intend to pursue this positive direction to achieve a new way of doing business in the coastal zone.

The Federal Perspective

In 1997 the federal government recognized the need for one of their ministers to take the lead on oceans policy issues and to develop and deliver a program of oceans and coastal management in collaboration with the other federal departments, the provincial governments, affected Aboriginal communities, users and coastal communities and the broader public. The Minister of Fisheries and Oceans was given this role through the Oceans Act.

The first part of the Oceans Act formally extends Canada's sovereignty and jurisdiction to the full extent allowed under international law. The coastal baselines and 200 nautical mile (nm) exclusive economic zone (EEZ) lines from the repealed Territorial Seas and Fishing Zones Act became regulations under the Oceans Act. It also made an extended continental shelf claim and set out a 12 nm territorial sea and 24 nm contiguous zone. Along with claiming this huge territory and the management of the resources came some responsibilities. The first is to manage the EEZ's living resources in a sustainable manner on behalf of the world community, and the second is to set up an effective and comprehensive management process. Canada has decided to do this for all of its ocean areas, including the coastal waters in the territorial sea and marine waters inside of the baselines.

The Oceans Act sets out an oceans management strategy framework based on sustainable development, integrated management, and the precautionary, collaborative and ecosystem principles and approaches. The meaning of these principles was not defined in operational terms but, when taken together, they do provide guidance on direction and intent. In a word, the vision is to achieve sustainability. This means addressing the four aspects of sustainability: social or community, economic, environmental, and the way we manage ourselves (institutional). The Department of Fisheries and Oceans (DFO) has recently released its strategy for tackling this task and an action plan (DFO 2002a and 2002b). The oceans strategy will also outline a stewardship program. This will integrate similar programs within the Department and other federal departments in a way which ensures they work well together to support community stewardship of marine living resources and their habitats.

The Minister was also directed by Parliament to achieve this vision by leading and facilitating the development and implementation of integrated management plans, in collaboration with all interests, for all activities in or affecting the marine ecosystem. This initiative has two focusses: a planning process which will develop oceans and coastal management plans, and working collaboratively to develop social capital and capacity for the effective development and implementation of the plans. DFO intends to do this by involving the broad community of interests in defining the vision of where we want to be, balancing between the four elements of sustainability, and developing the indicators relevant in the planning area with measurable target levels. This will be an open plan requiring updates and regular review periods. An integrated management (IM) framework will be released for discussion in the near future.

The Oceans Act also includes authority and powers to implement marine environmental guidelines, standards and regulations in support of the management plan. This is required in order to set a common basis for all activities and to fill gaps between the current sector-based ecosystem protection activities. The framework for this aspect of the plans will be released soon.

The New Brunswick Perspective

In 1990, the Premier's Roundtable on the Environment and the Economy issued a report, *Sustainable Development in New Brunswick: Because We Want To Stay/Developpement durable au Nouveau-Brunswick: Nous tenons a y rester*. It included a recommendation stating that the maintenance and sustainable use of the natural wealth of the oceans and the coastal zone will require integrated approaches to coastal zone management.

In New Brunswick, 1993 was the pivotal year for initiation of a broader discussion within government of coastal zone management. That year, the Commission on Land Use and the Rural Environment (CLURE) recommended that the province develop a coastal zone management plan. Government responded, saying that such a plan was in the development stages. The decision was made to develop the coastal lands policy as the initial component while recognizing the marine portion would be integrated at a later date.

In April 2000, the Government of New Brunswick created the Department of the Environment and Local Government (DELG), with a mandate of integrating activities to develop a comprehensive air, land and water management approach. This reinforced the opportunity to take planning into the coastal zone.

The first stage of the New Brunswick coastal zone management policy is the *Coastal Areas Protection Policy* which was released earlier in 2002 for consultation (DELG 2002). The policy identifies two zones where activities are either restricted or go through a review process in order to protect the integrity of the coastal zone. The three factors identified as influencing the attention to coastal protection are: increased knowledge of how ecosystems in coastal areas function, greater pressure for development in coastal areas, and climate change and its associated risks to human health and safety. The next stage is the marine planning and management framework that is currently under development. Together, the two components will form the basis for the New Brunswick coastal zone management framework.

The legislative support for provincial activity in the marine environment comes from the Water Quality Regulations of the Clean Environment Act, the Clean Water Act, the Crown Lands Act and the Community Planning Act. The Water Quality Regulation 82-126 identifies actions in or upon the "waters of New Brunswick" that are in contravention of the Regulation and the Act. The Clean Water Act further defines waters of New Brunswick as "all waters in the Province of New Brunswick and, — includes coastal water within the jurisdiction of the Province". Regulations under the Community Planning Act state that the Lieutenant-Governor in Council may, on the recommendation of the Minister, make regulations respecting "land use and development policies including planning for coastal zones". The Crown Lands Act governs submerged lands in the province. Which of these mechanisms will ultimately be used to support coastal zone management is yet to be decided.

Provincially, the overriding intent in developing a marine planning and management framework to complement the coastal areas protection policy is to create a mechanism to manage human use and impacts in the marine environment in order to ensure a sustainable future for the marine ecosystem and the coastal communities dependent upon it. The principles to be used in the development of the marine component and the local visions are:

- Ensure ecological, social and economic sustainability
- Protect biodiversity
- Protect cultural and aesthetic values
- Develop a mechanism for increased local management and decision making

It should be noted that the province is using the same general approach as the federal government and the policy will be reflective of the community vision.

Institutional Arrangements

What measures or arrangements will be developed for the federal (DFO) and provincial (DELG) governments to co-operate in their approach? The current priorities for the two departments are to further develop their respective lead roles. This involves "writing the rules" for working together as well as with the broader community. Formal arrangements may be put in place as required to effectively implement the coastal zone programs.

Some of these areas of jurisdiction between the two governments are quite clear, while others are shared. Others overlap, where either could have the jurisdiction or where neither has an appropriate legislative base, due to the complexity of governance in the coastal area. This has been key to government inaction on many issues in the past, but has also allowed some interests to move forward without proper input from all interests. Both governments recognize the need to commit to an active program to work this out and to bring in other departments. In support of this priority, DELG has formed an intergovernmental committee of the relevant departments to act as a sounding board in the policy development process.

Coastal zone planning creates the need for the governments to clearly identify their role in community development in order to ensure balanced input into the plan. The coastal zone planning initiative provides the opportunity to work with the various community interests to develop a way of working together to create a vision and decision-making framework. There is a need to find a balance between community interests rather than just dealing with self-identified groups.

Methodology

The vision of the two levels of government is not really that different nor are either well enough defined to prevent co-development of the concepts and approaches. The differences that do exist are most likely due to the different frameworks under which the departments work and the expertise within the departments. These differences in focus can be used to advantage to identify respective areas of concentration.

For the federal government, the emphasis is on identifying ecotypes and associated objectives with target levels to be met for the health of that ecosystem. This is based on the EEZ requirement to preserve ecological sustainability as a condition of sovereignty and to better our understanding of this aspect of management over the social and economic or even the institutional aspects. DFO is working to develop a balanced approach in pilot areas, but it is a learning experience for all of us. In the offshore pilot areas, DFO has engaged the community, developed a common vision, completed use audits, and compiled legislative, regulatory and existing management documents, as well as ecosystem overviews. Inshore, DFO has engaged the community at several sites and completed many elements of a coastal management plan. However, more effort is still required toward inter-government collaboration to effectively develop and implement coastal plans.

The July 2001 DELG strategic plan embraces many of the activities that development of a marine component of coastal management will require. These include:

- Bringing government closer to the grassroots of communities to identify local needs and issues
- Promoting responsible stewardship of our air, water and land resources
- Enhancing local autonomy within a provincial framework
- Improving co-ordination and co-operation among agencies
- Strengthening the focus on integrated ecosystem management

The envisioned first step is to engage coastal communities to articulate their relationship to their marine area and to identify present usages of the marine environment and desirable and feasible future usages. The province has experience in engaging local communities and may take the lead in this area.

Along with engaging communities comes developing local capacity for dialogue and leadership. One of the primary tools for this activity is to increase stewardship of the marine environment, in other words, to increase coastal people's knowledge and curiosity about how the marine environment works. Much of this knowledge is already in these communities. Sometimes it is an intuitive knowledge that does not find expression in words. Stewardship, to a large extent, is a way of taking this intuitive knowledge and putting it into words. Both the provincial and federal governments have programs that can support stewardship initiatives in coastal communities.

There is also a need for very specific information and data that will help in the formulation of plans for marine areas. Here, federal departments may assume the lead where they are more experienced in working with communities to compile information about the marine ecosystem and setting sustainability objectives.

As knowledge increases, so does discussion. Once communities and stakeholders are engaged, local capacity has increased and there is a better understanding of the marine ecosystem, then the framework for planning and management can be utilized to develop a management plan. The plan would be based on the overriding principles of ensuring ecological sustainability, protecting biodiversity, protecting cultural and aesthetic values, and developing effective local management and decision making.

Design of Community Involvement

Several activities could happen simultaneously to start the process of coastal zone planning. Focus groups may be established in the three coastal regions of the province to bring together a selected group of coastal residents to help forward the ideas of how to proceed. This would include discussion about possible pilot areas, boundaries of planning pilot areas, and methods of engaging coastal residents and stakeholders. Presentations would also be made to community groups and to other agencies to receive their input. The intent is to develop the vision with the whole community and to take the decisions back to them with an explanation of why they were made.

In some instances, simultaneous with the focus groups, pilot projects may be initiated. The purpose of the pilot projects would be to try out some methods for community visioning. There are a number of approaches that can be taken to engage communities. One approach could be to find willing local partners to take a lead in organizing the coastal peoples. They could engage the population on a one-on-one basis or in small kitchen table discussions to identify the present and future priorities in an area. Once these priorities are known, the framework for a discussion document emerges.

The suggestion is often made that there has to be an issue-oriented exercise to capture the interest of the residents. However, while we can use specific local coastal issues as a means to start the larger debate on marine management, coastal zone management is not merely solving problems that are affecting the quality of life along our shoreline, disrupting regular ways of doing business or cleaning up pollution sites. Coastal zone management is developing the larger and longer term vision for present and future coastal zone usage that is compatible with maintaining ecological integrity and coastal communities. Resolving coastal environmental issues may be an outcome of the exercise, but it is not the goal. In effect, the vision identifies the blueprint for future community action. Many Maritime communities are starting to work on coastal planning for social or economic reasons, or just to help ensure the ecosystem stays the way it is now, without having been motivated by an environmental crisis.

Identification of the marine boundaries of the area that we want to develop a vision for is an important part of the process. There are three potential ways to define the boundaries: community legal boundaries such as village or county lines, the area where a community utilizes the marine environment, or ecological boundaries as defined by water circulation or habitats.

If the pure planning approach is taken, based on the existing provincial planning structure, existing legal boundaries would be utilized. However, in New Brunswick, simultaneous with the marine planning exercise is an exercise to look at watersheds from an integrated planning perspective. Watershed boundaries do not coincide with existing legal boundaries. This multi-fronted integrated planning exercise in the provincial arena fits well into using ecological boundaries for the marine planning exercise. On the other hand, setting boundaries based on identified existing community usage patterns in the marine environment may have considerable appeal in some areas. Obviously, this is an area where discussion must occur on the federal/provincial/community front.

Tools: Planning Versus the Pure Ecosystem Approach

Once a vision has been articulated, objectives, goals and indicators can then be established. These may include water quality standards, zoning for various uses, etc., as well as indicators showing how the process works in relation to ecological and economic health and social/cultural values. The lists below are sample indicators for each aspect of sustainability.

Social/community sustainability includes:

1. Common vision
2. Access to knowledge
3. Traditions and cultural values
4. Access for people
5. Way of life
6. Healthy community
7. Balance between economic, environmental and social interests

Ecological/environmental sustainability includes:

1. Preserving natural biodiversity
2. Resilience
3. Living resource sustainability
4. No net loss of productivity
5. Habitat restoration

Economic/social sustainability includes:

1. Income
2. Health and safety
3. Employment
4. Profitability
5. Indebtedness
6. Diversity
7. Resilience

Institutional sustainability includes:

1. Adequacy of management resources
2. Integrated approach to management
3. Participation and transparency
4. Locally appropriate
5. Inclusive decision-making process

Finding an acceptable balance between the four groupings of indicators will ensure a sustainable coastal zone.

Conclusions

Coastal zone planning and management is about developing sustainability. Sustainability has social, economic, environmental, and institutional components. It is not just about protecting the environment or finding out how to economically develop without impacting the environment. Coastal zone planning and management is an effort that will provide security to our coastal communities and the marine environment that they are dependent upon.

References

Department of Fisheries and Oceans (DFO). 2002a. *Oceans Strategy*. Oceans Directorate, Fisheries and Oceans Canada, Ottawa. 30 pp. URL: <http://www.dfo-mpo.gc.ca/oceanscanada/newenglish/htmdocs/cos/publications_e.htm>. Date accessed: 12 August 2002.

Department of Fisheries and Oceans. (DFO). 2002b. *Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments in Canada*. Oceans Directorate, Fisheries and Oceans Canada, Ottawa. 30 pp. URL: <http://www.dfo-mpo.gc.ca/oceanscanada/newenglish/htmdocs/cos/publications_e.htm>. Date accessed: 12 August 2002.

Department of the Environment and Local Government (DELG). 2002. *A Coastal Areas Protection Policy for New Brunswick*. Sustainable Planning Branch, New Brunswick Department of the Environment and Local Government, Fredericton, NB. 15 pp. URL: <http://www.gnb.ca/elg-egl/0371/0002>. Accessed 12 August 2002.

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

Brian Craig and Hague Vaughan

Ecological Monitoring and Assessment Network Coordinating Office, Environment Canada, Burlington, ON. brian.craig@ec.gc.ca and hague.vaughan@ec.gc.ca

Abstract

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

EMAN is developing a set of standardized measurements which can be carried out by interested sites, networks and communities to establish whether and how local ecosystems are changing while at the same time contributing to timely status and trends reporting. These can serve as a basis for developing partnerships with a variety of protected areas. EMAN proposes co-operative development and implementation of a standard approach to ecosystem monitoring within such areas which includes cost-effective strategies, protocols, data management, interpretation and communication and which fills the information needs of local managers, associated communities, relevant supporting agencies, and Environment Canada.

Introduction

In 1994, Environment Canada created the Ecological Monitoring and Assessment Network Coordinating Office (EMAN CO) to augment Canada's ability to describe ecosystem changes, to provide timely information to decision makers, and to help inform the Canadian public. The EMAN CO facilitated the establishment of the Ecological Monitoring and Assessment Network (EMAN) which links the many groups and individuals involved in ecological monitoring in Canada in order to better detect, describe and report ecosystem changes. Essential elements of EMAN include numerous national and regional monitoring programs, over 80 long-term integrated ecosystem monitoring sites and a diversity of ecological monitoring initiatives conducted by numerous partners at all levels of government, by non-government organizations, and by volunteers (Vaughan et al. 2001). EMAN:

- engages in co-operative projects to collect, collate, manage, and interpret long-term ecological science;

- promotes collaborative multidisciplinary research and assessment of long-term ecological monitoring data to detect ecosystem changes;
- identifies information gaps and priorities, and facilitates development of monitoring initiatives to address them;
- promotes standardized electronic information catalogue systems (metadata);
- provides a central access point for long-term integrated monitoring and assessment information;
- develops and promotes needed ecological monitoring protocols, methods and standards in co-operation with appropriate research institutes and agencies;
- promotes and facilitates community and volunteer involvement;
- delivers information and knowledge, including traditional knowledge; and
- provides information for improved understanding about ecological changes to decision makers and the public.

The EMAN web site (URL: <www.eman-rese.ca>) provides examples and describes current initiatives pertaining to these activities.

Many parks and protected areas in Canada are EMAN partners. They include many relatively undisturbed ecosystems that provide an opportunity to collect information on large-scale stressors, such as global climate change, increased UV-B radiation and long-range transport of atmospheric pollutants. The information can then be compared with that from working landscapes subject to these and other more localized anthropogenic stressors such as land conversion, habitat fragmentation, transportation corridors, eutrophication and industrial effluents. Such comparisons can allow a better understanding of the potential ecological impacts of large-scale stressors, local stressors, and the synergistic effects of both on an ecosystem. Long-term monitoring in protected areas and in the working landscape will also facilitate the early detection and description of emerging environmental issues at national, ecozone and local scales, providing timely information to facilitate adaptive management of science, development and policy.

The EMAN CO has been focussing on developing a set of standardized ecosystem monitoring protocols (EMPs) that will work together as a suite to detect and track ecosystem changes over time, and which can be monitored in protected areas and working landscapes. A suite of about twenty EMPs has been selected that:

1. Will identify significant changes in ecosystems beyond normal ranges of fluctuations so as to trigger and guide the design of future more rigorous investigations;
2. Are suitable for measurement and comparison among a variety of sites;
3. Are characterized by cost effective sampling methods; and,
4. Will easily fit into existing monitoring programs (Environment Canada 2000a).

The EMPs were distilled from 1,770 monitoring variables assembled from a variety of sources including major environmental monitoring programs around the globe. The variables were subjected to efficacy testing to ascertain their response to a variety of issues including:

- Endocrine disrupters
- Invasive species
- Global carbon cycle changes/global climate warming
- Increased ultra violet "B" (UV-B) radiation
- Habitat fragmentation
- Transportation corridors
- Acid rain
- DDT
- Eutrophication
- Ground-level ozone
- Pulp and paper mill effluent; and
- Groundwater contamination (Environment Canada 2000b)

The majority of the selected variables are quite responsive to most of the stressors but redundancies and gaps were identified through this process and the suite was altered appropriately (Table 1).

Several EMPs can provide multiple measures of ecosystem change. For instance, measuring species diversity of frogs also provides measures of morphological symmetry, species richness, and exotic species. The total number of field measures can therefore be reduced while retaining the capacity to measure different aspects of ecosystem change. There is general consensus among the EMAN partners that this suite is a suitable starting point for the tracking and early detection of ecosystem change. The suite will no doubt evolve as pertinent new information on ecosystem changes becomes available.

An impediment to making comparisons at varying scales has been the lack of availability of comparable data: this can be addressed through development and implementation of standardized ecosystem monitoring protocols. EMAN is making a concerted effort to use, adapt and develop standardized monitoring methods for each of the EMPs and for other aspects of ecosystem monitoring as opportunities arise. National standardized monitoring methods are currently in use for several of the EMPs, particularly stream flow (Water Survey of Canada) and ice phenology (Meteorological Service of Canada). Anuran (frogs and toads) and earthworm distribution and abundance monitoring methods are currently being tested in all provinces and territories. However, for the majority of the EMPs, the monitoring methods have been developed at local, regional and national levels, and although often similar, do not allow for direct comparisons at larger scales.

For example, aquatic invertebrate monitoring programs have been implemented in the Province of Ontario by the Ministry of Environment, the Ministry of Natural Resources, individual conservation authorities, universities, and citizens groups, among others. The sampling frame, sample design, field methods, and data analysis, although similar, preclude regional and provincial comparisons. A workshop hosted by the National Water Research Institute and EMAN CO was held in the spring of 2001 and was attended by representatives from the aforementioned agencies. The representatives readily reached a consensus to develop a standardized monitoring method that will contribute to local, provincial and national information needs. This attitude is proving typical for ecosystem monitoring practitioners, as there is a growing trend among the majority of agencies and non-governmental organizations to maximize monitoring efforts by sharing information and adopting common field collection methods, lab protocols, taxonomies and data management systems. Workshops are being planned to engage other agencies and organizations in developing pan-Canadian aquatic invertebrate monitoring methods. Similarly, initiatives are under way to develop pan-Canadian monitoring methods for lichen diversity, plant phenology, small-scale monitoring of bird diversity, and salamander diversity. A working draft, EMAN Monitoring Protocols (Environment Canada 2001), has been published and EMAN CO is continuing to work with Network partners to define, describe and refine appropriate standardized monitoring protocols.

The proliferation of environmental non-governmental organizations (ENGOs) during the past several decades points to a growing concern by Canadians towards maintaining healthy ecosystems. Many of these groups have established local ecosystem monitoring programs and are using the results to influence policy and decision making at local, regional and national scales. Progressive ENGOs are seeking assistance to develop and implement comprehensive community-based and volunteer monitoring programs.

EMAN, in partnership with the Canadian Nature Federation, has established a series of NatureWatch programs that are designed to collect reliable information that can contribute to local, regional and national monitoring programs. Sound scientific protocols are established with relevant agencies and scientists. From these, succinct instructions are provided, informing volunteer observers how to collect reliable information. The NatureWatch programs are Internet based but allow for hardcopy observation submissions. FrogWatch (URL: <www.frogwatch.ca>) was launched in the spring of 2000 and collects information on the distribution and abundance of anurans across Canada. This program is supported by partnerships with anuran experts in each province and territory who check the submissions for accuracy and investigate outliers. WormWatch (URL: <www.wormwatch.ca>), developed in partnership with Agriculture and AgriFood Canada, collects information on the distribution and abundance of earthworms in Canada and was launched in the fall of 2001. Developed in partnership with the Meteorological Service of Canada and Laval University, IceWatch (URL: <www.icewatch.ca>) collects information on lake and river ice phenology and was also launched in the fall of 2001. PlantWatch (URL: <www.plantwatch.ca>), developed in partnership with plant phenology experts in each province and territory, collects information on a suite of fifteen appropriate plants and was launched in the spring of 2002. NatureWatch programs are also under development for lichen and aquatic invertebrate abundance and diversity, and tree health.

Community-based and volunteer monitoring benefits government agencies by increasing geographical coverage of observations and generating community support for ecosystem monitoring programs. Other benefits include the potential of reduced monitoring costs by engaging citizens in collecting complementary data and the potential to use citizens' data to locate suspected problem sites and assess the success of habitat restoration. Benefits are also accrued to the volunteers, such as: improving their environmental awareness, the opportunity to interact with government professionals, the opportunity to play an active role in safeguarding the environment, and, perhaps the most important, providing information for better decision making by the local community.

Volunteer monitoring programs have been criticized as being incapable of providing data of sufficient quality as they do not often address the quality assurance/quality control issues of sensitivity (recognition of species and individuals); reliability (reproducible results); and accuracy (lack of systematic bias). The NatureWatch programs provide training and reference materials which exceed requirements to address the issue of sensitivity; provide scientifically sound, tested and easily understood protocols to address the issue of reliability; and offer a multitude of independent observers and observations to address the issue of accuracy.

EMAN NatureWatch programs further define important but limited goals for the resulting data: goals that directly complement and augment professionally collected measurements and observations. NatureWatch programs are focussed on providing co-ordinated and timely information on ecosystem changes so as to provide suitable input to policy development and priority setting. This is needed to augment the peer review process that often requires 10–15 years of routine data gathering to establish statistical certainty. Adaptive management of policy, science or sustainability requires timely feedback which must as a result be openly based on risk or best judgement rather than certainty. Volunteer programs therefore achieve their maximum utility when their information is used to provide initial indications of a probable change in conditions that merits further scientific study or assessment. Well-designed volunteer programs are unique in their ability to extend line agencies' capacity to detect and respond to changes.

The establishment of the Ecological Monitoring and Assessment Network is a giant step towards implementing effective national, regional and local integrated monitoring programs that will meet the needs of decision makers and the public, and contribute to effective adaptive management programs at all scales. Protected area mangers across Canada are implementing standardized ecosystem monitoring methods, developed with their colleagues in EMAN, that will meet their local management needs as well as contribute to ecozone and national management needs. Network resource constraints have been partially overcome by forming efficient and practical partnerships that meet the needs of the partners and of the Network, but much remains to be accomplished. However, the strength of EMAN is people—people who are working collaboratively and tirelessly to provide timely information on ecosystem change to the Canadian public, protected area managers, and decision makers. The future is bright!

References

Environment Canada. 2000a. Selecting core variables for tracking ecosystem change at EMAN sites. Final consultants report prepared by Geomatics International Inc., Guelph, Ontario, for EMAN Coordinating Office, Environment Canada, Burlington, Ontario. URL: <http://www.eman-rese.ca/eman/reports/publications/2000_eman_core_variables/>.

Environment Canada. 2000b. Case studies to test the efficacy of EMAN core monitoring variables. Final consultants report prepared by North-South Environmental Inc., Campbellville, Ontario, for EMAN Coordinating Office, Environment Canada, Burlington, Ontario. URL: <http://www.eman-rese.ca/eman/reports/publications/2000_eman_core_efficacy/>.

Environment Canada. 2001. EMAN core monitoring variables draft field methods manual: A first approximation. Final consultants report prepared by North-South Environmental Inc. Campbellville, Ontario, for EMAN Coordinating Office, Environment Canada, Burlington, Ontario.

Vaughan, H., T. Brydges, A. Fenech, and A. Lumb. 2001. Monitoring long-term ecological changes through the Ecological Monitoring and Assessment Network: Science-based and policy relevant. Environmental Monitoring and Assessment 67(1–2): 3–28.

Table 1. EMAN suite of ecosystem monitoring protocols

	Core Monitoring Variable	**Derived Measures**
1	Water quality – dissolved oxygen	
2	Water quality – water clarity	
3	Stream flow – stream flow rate	
4	Lake level – lake level fluctuation	
5	Air quality – lichen indicators	
6	Temperature mean – soil temperature/permafrost depth	
7	Snow/Ice phenology – lake ice-out / ice-in timing	
8	Lake sediment – sediment core analysis	
9	Species richness – amphibians	MS,RS,ES
10	Species richness – mammals	RS,ES
11	Species diversity – birds	RS,ES,SR
12	Species diversity – plants	RS,ES,SR
13	Species diversity – frogs and salamanders	MS,RS,ES
14	Species diversity – aquatic invertebrates / benthos	RS, ES, SR
15	Community biomass – benthos	
16	Indicator species group – fish Index of Biotic Integrity	MS, RS, ES, CB, CP, GP
17	Land cover change	
18	Plant phenology	
19	Community productivity – phytoplankton	
20	Community productivity – plants	CB
21	Soil health – earthworm species richness and soil decomposition	
22	Tree health – crown and bole condition	

Abbreviations used: MS – morphological symmetry, RS – rare species, ES – exotic species, SR – species richness, SD – species diversity, CB – community biomass, CP – community productivity, GP – gross pathology

GULF OF MAINE BIOGEOGRAPHICAL INFORMATION SYSTEM PILOT STUDY: CONSOLIDATION OF MARINE DATA SETS

Angela J. Martin, Lou Van Guelpen, and Gerhard Pohle

Huntsman Marine Science Centre, St. Andrews, NB. arc@mar.dfo-mpo.gc.ca

We present the status of collaborative efforts under way by the Atlantic Reference Centre (ARC) in the development of large-scale marine biodiversity and biogeographic information systems. Aside from scientific literature, museum specimens and associated geographical information represent a key source of largely untapped data for the determination, understanding and interpretation of patterns of marine diversity. Work on integrating available marine databases has begun to be addressed by organizations such as the Census of Marine Life (CoML) with the objective of assessing species diversity, distribution and abundance. The Ocean Biogeographic Information System (OBIS), the information component of CoML, was created to address the difficulty of data retrieval and integration of distributed data. From this underlying problem came the creation of a pilot study focussing on the Gulf of Maine. The goal of the Gulf of Maine Biogeographical Information System (GMBIS) is to provide a framework for the integration, visualization, analysis and dissemination of diverse types of biogeographical and oceanographic information that can also be used as a fisheries management tool. The pilot study consists of a compilation of databases that includes ARC. ARC represents the specimen-based species database used for the GMBIS objective. Information on taxonomy, distribution and ecology of species will be available through the ARC server to the GMBIS server, linking accessible data to the public. This framework of public access projected by GMBIS is intended to create a global model for the development of biogeographic systems in other regions.

DEVELOPMENT OF A CANADIAN ATLANTIC BIODIVERSITY INFORMATION SYSTEM BY THE ATLANTIC REFERENCE CENTRE

Amanda McGuire, Lou Van Guelpen and Gerhard Pohle

Atlantic Reference Centre, Huntsman Marine Science Centre, St. Andrews, NB.
arc@mar.dfo-mpo.gc.ca

Species are the basic measure of biodiversity within an ecosystem. Changes in species or their abundance indicate environmental disturbance, which can only be quantified if there is baseline information. The long-term objective of the Atlantic Reference Centre (ARC) is to develop a detailed biodiversity information system for Canadian Atlantic organisms. A project listing fishes found within the Canadian Atlantic waters, which developed into an on-line photographic compendium describing the biological and ecological characteristics of each fish, served as a template to incorporate annelids, echinoderms and crustaceans of the Bay of Fundy. Each species is listed by its common and scientific names and synonyms. Brief descriptions of reproduction, predators, maximum size and diet are also given, though habitat, abundance and importance to the environment and man are the focus. An application is pending to add remaining organisms. The final product of this database will be an up-to-date resource of biodiversity information encompassing all major taxonomic groups from phytoplankton to mammals for the Bay of Fundy. In the future, this database will be transformed into an on-line version and will be expanded to include all Canadian Atlantic organisms. Ultimately, ARC will be linked to complementary biodiversity initiatives, both nationally and internationally, as well as to environmental data and tools to analyze these records. This will provide a comprehensive and easily accessible biodiversity information system, allowing researchers and managers to better protect the natural environment and to promote sustainable use of natural resources.

GEOMATICS RESEARCH ALONG THE BAY OF FUNDY COASTAL ZONE

Tim Webster, David Colville, Bob Maher and Dan Deneau

Applied Geomatics Research Group, Centre of Geographic Sciences (COGS), Middleton, NS.
tim@cogs.ns.ca

The Applied Geomatics Research Group (AGRG) has been involved in a study of the Bay of Fundy coastal zone, from Annapolis Basin to Minas Basin since 1999, when it received an infrastructure grant to facilitate applied research. In the fall of 1999 the area was imaged by the airborne polarimetric synthetic aperture radar (SAR) system operated by Environment Canada. The system operates in the C-band region of the spectrum in a quad-pole configuration similar to the sensor planned for Radarsat-2. The inter-tidal mudflats of the Minas Basin were exposed at low tide during the SAR acquisition. The data will be used to interpret the type of shoreline (cliff, sand, salt marsh, etc.), land cover and the coastal geology. In the summer of 2000, high-resolution airborne laser altimetry (LIDAR) and airborne multi-spectral imagery (CASI) were collected. During the image acquisition, a simultaneous field sampling campaign was undertaken, including the deployment of two tide gauges. The imagery collected in 2000 will be used for the development of shoreline extraction routines. The land/water boundary represents a snapshot in time of a given tidal level. By relating the image acquisition time with the tide gauge data, an orthometric height can be assigned to the extracted inter-tidal shoreline. Several areas in the Annapolis Basin were imaged at different tidal levels and multiple inter-tidal contours can be derived. These data can be used to extract information about the coastal zone, such as slope. The LIDAR data have been used to construct a 2-metre resolution digital elevation model (DEM) for the area and, in combination with global positioning system (GPS) points collected in the field, have been used to validate the shoreline heights. Classification of the exposed inter-tidal zone has also been completed using Ikonos satellite imagery. Related areas of AGRG research include using DEMs for watershed modelling and flood-risk mapping associated with storm surges.

Session Two

CLIMATE AND SEA LEVEL CHANGE

Chair: Michael Brylinsky, Acadia Centre for Estuarine Research, Acadia University, Wolfville, Nova Scotia

EVIDENCE OF LATE HOLOCENE SEA LEVEL AND TIDAL CHANGES IN THE BAY OF FUNDY: HOW RISING SEA LEVEL HAS LOWERED THE FLOOD RISK

John Shaw[1], Carl L. Amos[2], Charles T. O'Reilly[3], and George S. Parkes[4]

[1] Natural Resources Canada, Dartmouth, NS. johnshaw@nrcan.gc.ca
[2] Southampton Oceanography Centre, Southampton, UK
[3] Canadian Hydrographic Service, Dartmouth, NS
[4] Meterorological Service of Canada (Atlantic), Dartmouth, NS

We discuss sea level change on several times scales. The configuration of the Bay of Fundy/western Gulf of St. Lawrence from 13000 (radiocarbon years) BP onwards is demonstrated by a series of high-resolution paleogeographic reconstructions. We use data from the Amherst Point area to demonstrate that during the last 3,000 years, sea level rise has been stepwise due to eustatic cycles imposed on regional crustal subsidence. As a result, marshes at the head of the Bay repeatedly alternated between marine and brackish conditions. The modern rapid increase of sea level is merely the latest of the cycles and began c. 1600 AD. Data from Amherst Point, combined with data from elsewhere, reveal that tidal range c. 4000 BP was small. Tidal range expanded rapidly beginning 3400 BP and has continued to increase, albeit at a lesser rate, since 2700 BP. We speculate on the mechanisms that caused tidal expansion, and argue that the lessened risk of inundation due to storm surges in this region of extreme tidal range is attributable to sea level rise and related factors.

CHANGING SEA LEVEL—
CHANGING TIDES IN THE BAY OF FUNDY

David Greenberg

Ocean Sciences Division, Fisheries and Oceans Canada, Dartmouth, NS
greenbergd@mar.dfo-mpo.gc.ca

This work addresses questions relating to flood risk from increasing high water levels in the Bay of Fundy induced by climate change. High water levels can vary in time from both changing mean sea level and from changing tides. We show here that the two are related. An analysis of long-term sea level records has been done by Smith and Blanchard (Dalhousie University) as part of this study and will be briefly reported here. That study showed that independent of climate change, sea level and tide range are increasing in the Bay of Fundy/Gulf of Maine system. The modelling work shows that local tectonic changes in sea level are presently giving rise to increasing tides. The combined effects of present day sea level rise, climate induced sea level rise, and the increasing tidal range they induce will give rise to a flood risk significantly higher than that from considering the climate-induced sea level in isolation. If the model predictions are accurate, the risk of flooding at higher high water will increase dramatically over the coming century.

MITIGATION OF NATURAL HAZARDS: STORM SURGES, RISING SEA LEVELS AND COASTAL EROSION

Charles T. O'Reilly[1], Glen King[1], John Shaw[2], Russ Parrott[2], Robert Taylor[2] and George S. Parkes[3]

[1] Canadian Hydrographic Service (Atlantic), Dartmouth, NS. oreillyc@mar.dfo-mpo.gc.ca
[2] Geological Survey of Canada (Atlantic), Dartmouth, NS
[3] Meteorological Services Canada (Atlantic), Dartmouth, NS

Advances in remote sensing and global positioning system (GPS) technology have made it possible to develop very high resolution digital elevation models of topographic landforms. Recent projects utilizing airborne laser technology (LIDAR) have created three-dimensional (3-D) maps of coastal shore and inter-tidal areas with horizontal footprints of less than one meter square, containing decimeter vertical precision. These data were reviewed by several partners, including hydrographers, geomorphologists, coastal engineers, academic researchers, emergency measures organizations, and the Transportation Safety Board. The coastline can no longer be considered as two-dimensional lines on paper, but as a 3-D landform which is undergoing very dynamic physical change. It has been proposed to utilize remote sensing to initiate high resolution 3-D baseline mapping in low-lying areas under threat of coastal flooding, rising sea level and tsunami run-up. This presentation discusses several applications of merging land and sea data sets for coastal zone management and natural disaster mitigation. Stakeholders include all levels of governments, the insurance industry, the Department of National Defence, as well as numerous environmental and marine interests affected by climate change.

REGIONAL CLIMATE CHANGE SCENARIOS IN ATLANTIC CANADA UTILIZING STATISTICAL DOWNSCALING TECHNIQUES: PRELIMINARY RESULTS

Gary S. Lines[1] and Elaine Barrow[2]

[1] Climate Change Division, Meteorological Service of Canada (Atlantic), Dartmouth, NS.
gary.lines@ec.gc.ca
[2] Canadian Climate Impacts Scenarios (CCIS) Project, Environment Canada - Prairie and Northern Region, Regina, SK

Introduction

On a global scale, mean surface air temperature has been increasing over the past century by 0.6°C (Houghton et al. 2001) due, directly or indirectly, to increasing greenhouse gas emissions. Global climate models (GCMs) provide projections of such climate changes into the next 100 years, but do it on a global, coarse-grid scale. Temperature trends differ on a regional scale, resulting in varying impacts at that scale. In order to best describe the expected climate change impacts for a region, climate change scenarios and climate variables must be developed on a regional, or even site-specific, scale. To best provide those values, projections of climate variables must be "downscaled" from the GCM results, utilizing a variety of techniques, both dynamic and statistical.

Two of the more popular methods are output from a regional climate model (RCM) and statistical techniques to "downscale" climate variables from global climate models. Since the RCM capability for Canadian territory is being developed and output for Atlantic Canada is not readily available, a statistical technique is explored in this study to generate the downscaled climate variables in this region. Statistical techniques have the added advantage of being computationally efficient and affordable. Most statistical models can be run on Pentium PCs in short time spans, at times allowing for multiple runs.

This study utilizes the statistical downscaling model (SDSM), developed by Wilby and Dawson, to construct a suite of climate change scenarios for Atlantic Canada. Observed data sets of daily temperature are used to initialize and validate the model. Values for climate variables such as minimum and maximum temperature are calculated at a specific location for various future times and different GCM output experiments.

Background

Atlantic Canada includes Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland and Labrador. It is situated along the east coast of Canada covering nearly 20 degrees of latitude and 20 degrees of longitude. The climate of the region is varied, including Atlantic, Boreal, and Sub-Arctic climates and influenced by the warm Gulf Stream and the cold Labrador Current.

Utilizing GCM output over this region limits the researcher to six grid-boxes, spanning 300 x 400 km each, to cover sites of interest. Also some of those boxes are defined as "ocean" boxes where the climate variables respond as if the surface boundary is North Atlantic ocean water.

Researchers require specific values for various climate variables at those sites of interest in the region, based on the sensitivities of the species or ecosystem that they happen to be studying. If the species lives on the boundary of a grid box or two species with different sensitivities live in the same grid box, no substantial conclusions can be made about the impact of climate change simply using the grid box output.

Methodology

The statistical downscaling model (SDSM) is a hybrid of regression and stochastic downscaling methods. It utilizes a predictor-predictand process to determine a set of parameters. The objective is to choose a climate variable predictor, such as mean temperature, that can be projected into the future with some reliability by the GCMs and calculate the statistical relationship between it and a climate variable that may be physically related to it, such as minimum temperature. This statistical relationship now constitutes a set of parameters that can be used to reconstruct future sets of these climate variables and hence future climate scenarios.

In order to develop these parameters, the SDSM model is initiated with high quality observational data from the site of interest and a specific climate variable chosen as the predictand; in this case, the minimum temperature. For a predictor, a set of variables that have been recalculated to the same grid as the GCM, and based on an observational data set, are constructed. This study used the National Centers for Environmental Protection (NCEP) Reanalysis over Atlantic Canada as the comparative observational data set. These variables are then "screened" by the SDSM to determine what amount of explained variance exists when the predictand and predictor are statistically compared. The user then chooses the predictor that has the best explained variance and some reasonable physical connection to the predictand. In this study, the mean temperature was the most consistent variable that met those criteria.

The SDSM is then "calibrated" using the predictor-predictand relationship and a parameter file is created. Once the parameter file has been created, an entire set of synthesized data for that site of interest can be developed over the normalized period 1961-1990. Since our observational data cover the same period, a comparison can then be made between the original values and the synthesized ones. How they compare is a measure of how well the now-calibrated model behaves, and whether or not it can effectively downscale that particular climate variable.

The next steps involve running the SDSM using GCM output, for both the current period (1961-2000) and any future time. At each step the data results can be analyzed statistically to see if the values are within sensible ranges for significance.

Although the procedure sounds simple, early decisions can alter the final results in a dramatic way. The selection of predictors is crucial to meaningful downscaled values. The choice of GCM output and model experiment is instrumental in providing values that are neither too divergent from the model solution nor not divergent enough. The SDSM model aids you in making these choices and, due to its short computation times, allows you to experiment with various combinations of predictors and GCM output.

Data

The daily minimum, maximum and mean temperatures for 14 stations across Atlantic Canada used in this analysis (see Figure 1) were extracted from the Historical Canadian Climate Database (HCCD). The HCCD consists of daily minimum, maximum and mean temperatures for 210 stations across Canada (Vincent 1998). The data have been adjusted for inhomogeneities caused by non-climatic factors, such as station relocation and changes in observing practices, using a regression model technique. Monthly adjustment factors from previous work were interpolated to generate daily factors. These factors were used to obtain the adjusted daily temperatures resulting in the reliable long-term daily temperature data set used in this analysis.

The global climate model output over Atlantic Canada was taken from the Canadian Climate Centre for Modeling and Analysis (CCCma), the First Version of the Coupled General Circulation Model (CGCM1) and prepared by the Canadian Climate Impacts Scenario (CCIS) Project (conducted by Elaine Barrow) to provide a list of predictors ranging from basic variables such as mean temperature and mean sea level pressure to calculated values such as specific humidity at 850 Pa. The output is available in two sets: the current period (1961-2000) and future periods in three 30-year slices, 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099). They are in the form of daily data from the CGCM1 GHG+A1* experiment normalized with respect to 1961-1990.

To provide a gridded observational data set, the NCEP Reanalysis data were interpolated to the CGCM1 grid over the Atlantic region. Both the GCM variables and the NCEP data set were made available in the grid boxes illustrated in Figure 2 and contain the same list of variables as noted above.

* "GHG+A1" is a typical designation describing the type of "experiment" parameters that were used during a specific climate model run. Most climate models are "forced" with a percentage of greenhouse gases (GHG), typically an increase of 1% a year for 100 years, to give projections of their impacts out to 2100. Some models also add sulphate aerosols (A) as a controlling parameter, since aersols have the effect of "cooling" the atmosphere. A designation of GHG+A1 on a particular set of climate model output refers to the fact that the results of the model run were done using greenhouse gases and aerosols as controlling parameters. The 1 (one) refers to the fact that there may be more than one GHG+A experiment and this one happens to be number one.

Results

Utilizing 30 years of data from the 14 observing sites across Atlantic Canada, a statistical downscaling model was used to produce new climate variable values for each of the sites. This report displays results, focussing on the minimum temperature at those sites for the month of January (Table 1). On the left hand-side the 14 sites are listed. Under "Obs" are the values available from the observational data set. The synthesized data for each site are next under "Synth", utilizing the NCEP data for each of the grid boxes. The GCM model output values were extracted from the CCIS Project web-site. And finally, the last column has the downscaled values, those derived from using the GCM output for a future time, the 2080s (2070-2099).

For most sites, there is a strong correlation between the observed data and the synthesized data, supporting the correct choice of predictor parameter. Most of the sites show more warming than is evident in the GCM grid box model output. Most of that warming is related to the capability of the model to properly identify regional climate forcing coupled with the large-scale forcing that is provided by the GCM grid box output.

Of interest is the much less significant warming at the last four sites. These locales are in the easternmost portion of the region. This suggests that the GCM is overdoing the warming at these sites and that the downscaling process has allowed the regional forcing to dominate.

Summary

This study examined downscaled values for the minimum temperature at 14 sites across Atlantic Canada utilizing a statistical downscaling model. These values were compared, internally to synthesized data as well as to non-downscaled values taken directly from the GCM model output.

This study highlights the ability of the SDM to deliver reasonable downscaled climate values utilizing economical computational methods. These techniques can allow regional climate forcings to be taken into account in a much more meaningful way.

The next steps will be to expand the work into other sites in Atlantic Canada, other climate variables, such as precipitation, and for other GCM models and experiments, such as the Hadley General Circulation Model (HADGCM) and scenarios based only on greenhouse gases (GHGs) or on GHG and aerosol combinations.

Acknowledgments

I would like to acknowledge the vital role played by Rob Wilby, C. Dawson and Elaine Barrow in facilitating this paper. They were directly responsible for the existence of SDSM and the crucial data sets required to complete the downscaling process (Wilby et al. 2000 and 2001; Wilby and Dettinger 2000).

References

Houghton, J. T., Y. Ding, D. J. Griggs, M. Nogur, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson (Eds). 2001. *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Vincent, L. A., 1998. A technique for the identification of inhomogeneities in Canadian temperature series. Journal of Climate 11: 1094–1104.

Wilby, R. L., C. W. Dawson, and E. M. Barrow. 2001. SDSM a decision support tool for the assessment of regional climate change impacts. Environmental and Modelling Software, in press.

Wilby, R. L., L. E. Hay, W. J. Gutowski, R. W. Arritt, E. S. Tackle, G. H. Leavesley, and M. Clark. 2000. Hydrological responses to dynamically and statistically downscaled general circulation model output. Geophysical Research Letters 27: 1199–1202.

Wilby, R. L. and M. D. Dettinger. 2000. Streamflow changes in the Sierra Nevada, CA simulated using a statistically downscaled General Circulation Model scenario of climate change. Pages 99–121. In: *Linking Climate Change to Land Surface Change*. S. J. McLaren and D. R. Kniveton (Eds.). Kluwer Academic Publishers, Dordrecht.

Canadian Climate Impacts Scenarios (CCIS) Project. URL: <http://www.cics.uvic.ca/scenarios>.

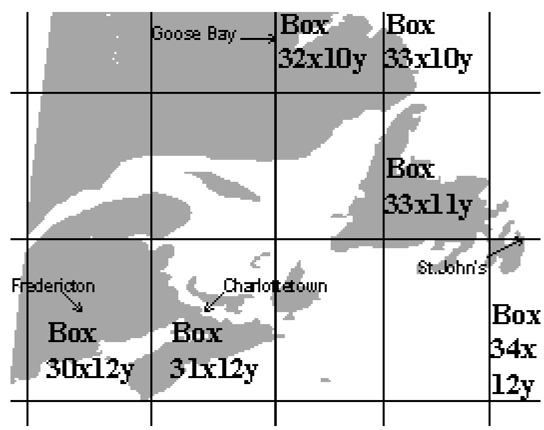
Statistical Downscaling Model Download Site. URL: <https://co-public.lboro.ac.uk/cocwd/SDSM/>.

Table 1. Mean monthly minimum temperature values – January observed versus 2080s

Site	Obs	Synth.	GCM model	GCM2080s downscaled
Fredericton	-14.4	-14.4	-9.1	-7.6
Charlo	-16.5	-16.5	-11.2	-10.8
Saint John	-12.9	-12.9	-7.6	-6.4
Chatham	-15.3	-15.3	-10.0	-8.9
Shearwater	-8.1	-8.8	-4.8	-2.7
Charlottetown	-11.3	-12.1	-8.0	-6.0
Kentville	-9.5	-10.1	-6.2	-4.3
Greenwood	-10.2	-10.8	-6.9	-5.2
Moncton	-12.8	-13.6	-9.5	-6.6
Nappan	-12.1	-12.9	-8.8	-6.3
Goose Bay	-21.8	-22.2	-13.2	-17.6
Cartwright	-18.1	-18.5	-9.5	-12.9
Gander	-10.7	-11.4	-5.1	-6.7
St. John’s	-8.1	-10.1	-2.5	-5.6

Figure 1. Data sites in Atlantic Canada

Figure 2. GCM grid boxes – Atlantic Canada



Session Three

FISH AND FISHERIES

Chair: Rod Bradford, Fisheries and Oceans Canada, Halifax, Nova Scotia

POPULATION DESCRIPTION, STATUS, LISTING UNDER COSEWIC AND RECOVERY ACTIONS FOR INNER BAY OF FUNDY ATLANTIC SALMON (*SALMO SALAR*)

Peter G. Amiro

Science Branch, Fisheries and Oceans Canada, Dartmouth, NS. amirop@mar.dfo-mpo.gc.ca

Abstract

Wild anadromous Atlantic salmon (*Salmo salar*) of the inner Bay of Fundy (iBoF) have declined 90% or more in abundance since 1989. Although the stock has historically varied in abundance, the current decline is more severe and the population is at a lower abundance than previously documented. Annual recruitment to spawning of iBoF salmon stocks was not correlated with other Atlantic coast salmon populations. Recognition of the distinct phenotypic features of these stocks dates to the 19th century. Early maturity, successive annual spawning, local migration and distinct genetic profiles characterize two distinct stocks within the iBoF. The population was estimated to have been as many as 40,000 adult salmon in some years, likely less than 500 adult salmon in 1998, less than 250 in 1999, and showing signs of further reductions in 2000 and 2001. A reduction in repeat spawning survival and survival to first spawning placed the stock in a steep decline. Monitoring of juvenile salmon in the two largest rivers, Stewiacke River and Big Salmon River, as well as in six other rivers of the iBoF, confirmed that the decline is extensive within iBoF rivers and that the loss was marine based. River-specific population extinction has been noted. Since 1990, no fisheries have been permitted to harvest iBoF salmon. Based on numeric and genetic assessments of salmon populations within 32 rivers of the iBoF, the entire stock complex of iBoF salmon was listed as *endangered* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in May, 2001. A recovery team comprised of advisory, planning and four technical committees (monitoring, fish culture, genetics, and research) prepared a formal recovery strategy following the listing by COSEWIC.

Biology

Adult salmon return to rivers to spawn in the late fall. Eggs are deposited in gravel redds and fertilized by mature male salmon or mature male parr. Young salmon actively feeding in freshwater are termed parr. After two to three years in freshwater, parr undergo physiologic change and become smolts. Smolts attain the silvery colour of the adult and migrate to sea. Seaward migration may begin in autumn, but actual movement into saltwater normally occurs in late May or June. The majority of individuals mature and spawn after one winter at sea. Prior to the recent decline, significant numbers returned to spawn after a second and third winter at sea. Repeat spawners contributed to as much as 60% of the annual egg deposition. Although post-smolts (immature salmon at sea) occur in areas rich in amphipods (small crustaceans) and juvenile herring, there is no published data on the diet or for aging behaviour for these populations.

Population and Distribution

Historically, inner Bay populations may have numbered 40,000 adults in some years. Their numbers declined to less than 500 by 1998, and to less than 250 in 1999. At least 32 of approximately 42 rivers (Figure 1) that drain into the Minas Basin and Chignecto Bay, from Cornwallis River at the head of the Annapolis Valley in Nova Scotia to the Black River in New Brunswick, were known to have supported populations of salmon.

Habitat

In freshwater, salmon prefer natural stream channels with rapids and pools, a mixed substrate bottom, and water temperatures between 15 and 25°C in summer. In the marine environment, the infusion of cold oceanic water into the Bay of Fundy and Gulf of Maine provides temperature and biotic conditions necessary to support Atlantic salmon on a year round basis. Salmon from these populations have been documented within the Bay of Fundy as late as October as post-smolts and as early as March as pre-spawning adult salmon. However, it is not known where inner Bay of Fundy salmon winter.

Threats

Population growth appears to be limited by marine survival rather than freshwater production capacity. The cause of the collapse in marine survival is unknown, but may be due to ecological changes in the Bay of Fundy. Changes may originate from tidal barriers placed at the mouths of rivers and streams, biological regime shifts caused by over-harvesting of commercially important species, and from increases in populations of higher trophic level animals. Commercial salmon farms may also be a factor in the decline since they may attract and modify predator behaviour, alter habitat, obstruct migration, and/or harbour disease.

Protection

In Canada, the Atlantic salmon is protected under the Fisheries Act. The international North Atlantic Salmon Conservation Organization, established under the Convention for the Conservation of Salmon in the North Atlantic, can propose regulatory measures for fishing in the area of fisheries jurisdiction of a member country whose catches originate in rivers of other member countries.

Recovery Efforts

All commercial fishing for Atlantic salmon in the Bay of Fundy was stopped in 1985. The recreational fishery in rivers of the inner Bay of Fundy has been closed since 1990. Supplementation through traditional parr and smolt stocking, grown from river-of-origin adult broodstock, began in 1984 and stopped in 1994 when insufficient numbers of adult broodstock could be obtained to minimize genetic risks.

Under the direction of an ad hoc Science Steering Sub-Committee of the inner Bay of Fundy Salmon Fishing Areas 22 and 23 Advisory Committee, a collection of wild salmon parr in Stewiacke and Big Salmon rivers was initiated in 1998. These fish have been reared to mature adults at fish biodiversity facilities located at Coldbrook and Caledonia in Nova Scotia and at Mactaquac in New Brunswick. An additional sub-population of Big Salmon origin is being held separately at Minto, New Brunswick. Collections have been made annually and the first progeny from the genetically controlled pedigree-breeding program began in 2001. To maximize diversity re-selection of future broodstock from parr, smolts or adult collections will be controlled through genetic screening.

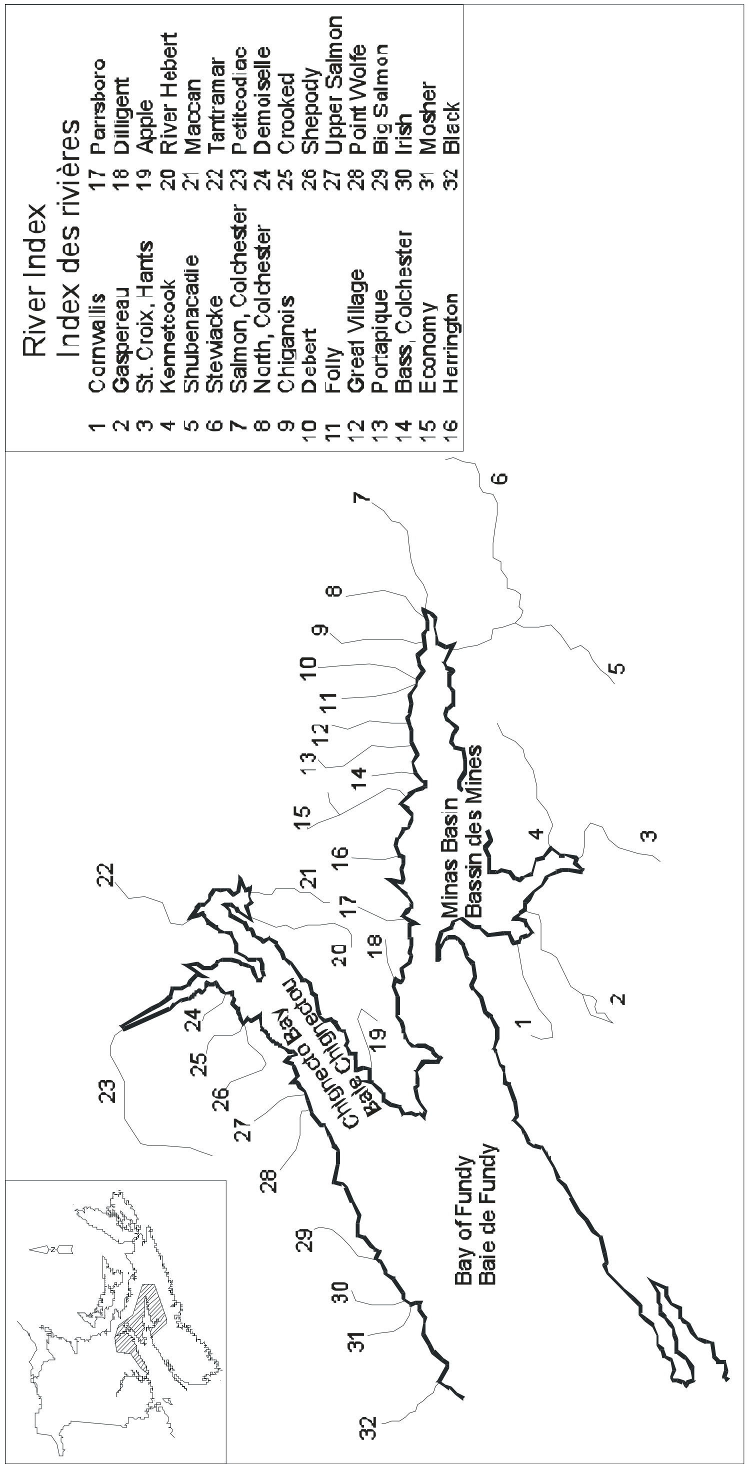
A recovery team comprised of advisory, planning and four technical committees (monitoring, fish culture, genetics and research) prepared a formal recovery strategy following the listing by COSEWIC.

Summary of Progress to Date

Currently a total of 633 adult salmon broodstock from the Big Salmon River and 926 adult salmon from the Stewiacke and Gaspereau Rivers are being held for spawning or release. The majority of the broodstock were grown from parr collections made since 1998. Biodiversity facilities are holding over 500,000 fry and parr of Minas Basin origin and over 750,000 fry and parr of Cobequid Basin origin and released over 250,000 fry to three inner iBoF rivers in 2001.

In 2000, 42 rivers of the inner Bay were sampled by electrofishing, and remnant populations were found in 19 rivers. Tissue samples are being analyzed to further describe the genetic phylogeny of inner Bay of Fundy salmon.

Figure 1. Rivers draining into the Minas Basin and Chignecto Bay



A HYPOTHESIS CONCERNING THE DECLINE OF ADULT RETURNS TO WILD AND CULTIVATED POPULATIONS OF ATLANTIC SALMON IN THE NORTH ATLANTIC AND THE RELATIONSHIP TO THEIR OCEAN MIGRATION

Michael Dadswell[1], Michael Stokesbury[2], Joseph Rassmussen[3] and Roger A. Rulifson[4]

[1] Department of Biology, Acadia University, Wolfville, NS. mike.dadswell@acadiau.ca
[2] Department of Biology, Dalhousie University, Halifax, NS
[3] Department of Biology, McGill University, Montreal, PQ
[4] Department of Biology, East Carolina University, Greenville, NC

Adult returns to wild and cultivated populations of Atlantic salmon in the North Atlantic have declined severely since the mid-1930s. The decline has shown a south to north pattern, with Maine and Bay of Fundy populations declining first, followed by more northern and European populations. Continuous stock enhancement, commercial fishery closures, and angling restrictions, have not arrested the decline and many wild salmon populations in Maine, the Canadian Atlantic and Europe are nearing extinction. Acid precipitation, hydroelectric projects, aquaculture and other human impacts have been suggested for some population declines, but adult returns to many rivers and cultivated populations with no obvious human impacts exhibit a similar pattern of decline. In addition, large numbers of adult or near adult aquaculture escapees, which were raised near to their freshwater origin, have failed to return to their natal watersheds.

Numerous studies have suggested that low adult returns have been caused by changes in ocean climate or marine predator abundance but these hypotheses are unsubstantiated by the continued absence of the former, annual cyclic behaviour in abundance of adult returns after ocean conditions returned to a favourable state and when possible predators are themselves exploited. Also, the continued success of the hatchery-supported Baltic Sea salmon fishery, which has annual landings in excess of 3,000 t, and the fact that 43% of salmon captured by experimental long-line fishery off the Faeroe Islands during the 1990s were of aquaculture origin, indicate that hatchery production is effective and oceanic feeding grounds are healthy.

Recent and past research has demonstrated that salmon from Northwest Atlantic populations migrate for extended periods much further into the eastern Atlantic than was previously thought, placing them in international and far territorial waters that lack surveillance and allow for exploitation by illegal and undirected fisheries. We propose that the loss of cyclic behaviour in adult return rates and their decline to low levels regardless of management, the probable migration pattern of ocean feeding salmon, and the occurrence of legal and illegal fisheries all suggest marine exploitation, primarily illegal, is the cause of low adult returns. Our study to date suggests salmon are being taken illegally on the high seas by Danish, Spanish, Faeroes and possibly Japanese interests. The major site of exploitation appears to be in the region outside of EEZs south of the Faeroes and in the Norwegian Sea. During the period 1985-93, a considerable amount of this illegal catch was landed as supposed Baltic Sea caught salmon. As recently as March 30, 2002 it was reported in *The Economist* that Norwegian salmon were being landed at Vigo, Spain.

Study Methods

We propose to examine marine migration patterns and ocean exploitation of Atlantic salmon in a two-part study.

First, we will examine the levels of the radioactive isotope Cesium 137 in the flesh and bones and the pattern of microelement distribution in the otoliths of Atlantic salmon from a series of selected salmon populations including wild and cultivated stocks. A sample of post-smolts and returning adults (primarily grilse) from each population will be examined using excised heads and tails. Sample size will be 15-30 salmon/population and life stage. We propose to obtain samples from wild populations in the Bay of Fundy, the Atlantic coast of Nova Scotia, the Gulf of St. Lawrence, Ireland, and aquaculture stocks in the Bay of Fundy and Ireland. The aquaculture stocks will include both pen-cultured fish and escaped adults returning to rivers in salmon farming regions.

Cesium 137 is a radioactive isotope from nuclear reactors that bioaccumulates in marine food chains. Because of nuclear accidents around the Irish Sea and at Chernobyl, the eastern Atlantic has much higher Cesium 137 levels than the western Atlantic and fish inhabiting or migrating through these regions bioaccumulate Cesium 137 considerably in excess of fish which remain in the western Atlantic (Tucker et al. 1999). Otolith microelement analysis is a powerful research tool for determining the source and life history stanza movement patterns of fish.

The second part of the study will involve the technical development of a satellite tag capable of being placed in a grilse-size or smaller salmon. These tags will be placed in either cultivated post-smolts or grilse-size salmon and released to migrate in the open ocean. Tags will be time-release so that the pattern of migration can be studied. Tags which report back before their specified time release may suggest sites of illegal marine exploitation. We hypothesize that these sites will be largely in the eastern Atlantic.

Reference

Tucker, S., I. Pazzia, D. Rowan and J. B. Rasmussen. 1999. Detecting Pan-Atlantic Migration in Salmon (*Salmo salar*) Using 137Cs. Canadian Journal of Fisheries and Aquatic Sciences 56: 2235–2239.

LOCAL KNOWLEDGE AND LOCAL STOCKS: EVIDENCE FOR GROUNDFISH SPAWNING ACTIVITY IN THE BAY OF FUNDY

Jennifer Graham

Centre for Community-Based Management, St. Andrews, NB. grahamja@nb.sympatico.ca

Abstract

This project provides information on current and historic groundfish spawning in the Bay of Fundy, its timing and relationship to fish migrations, and overwintering stocks. It also presents some hypotheses for the decline of Fundy spawning grounds and local stocks. Active and retired groundfishermen were interviewed about the location and timing of groundfish spawning activity in the Bay of Fundy. The project built on the work of Benham and Trippel (2002). The results are digitized maps that provide evidence for contemporary and historic groundfish spawning activity in the Bay of Fundy and the existence of local groundfish stocks in the Bay.

Bay of Fundy spawning grounds and associated local stocks have dramatically declined over the last 50 years. Of the 19 distinct cod spawning areas identified by fishermen as active in the 1950s, only three are now considered to be active. Haddock spawning areas declined from 39 to two in the same time period. Pollock spawning areas declined from 28 to four.

Introduction

This project documents fishermen's knowledge of local groundfish stocks and spawning grounds in the Bay of Fundy. Such expertise can contribute to improved fisheries management but, to date, local knowledge has been underutilized in protecting and managing fish stocks. The report consolidates the knowledge of individual fishermen to assemble collective wisdom about Bay of Fundy groundfish.

Many traditional Bay of Fundy fisheries have already disappeared, and fishermen fear the remaining groundfisheries will also be lost if current trends are not reversed. Many fishermen are convinced that the disappearance of inshore fisheries is related to the loss of local groundfish stocks that spawn (spawned) in the Bay of Fundy.

At the heart of this report are maps showing where and when fishermen have caught spawning pollock, haddock and cod and the decline of these areas over time. This information was collected through interviews with fishermen from New Brunswick and Nova Scotia. The text accompanying the maps explains the context in which spawning areas and local stocks were identified.

Local knowledge and scientific knowledge are *both* important to improved fisheries management. Fishermen have information that is very detailed and area specific. This information should shape the management of local stocks.

Summary of the Report

Background and Previous Research. This project evolved out of an urgent need to better understand Bay of Fundy groundfish. The Bay of Fundy was once an extremely productive system that supported a number of year-round inshore fisheries. The decline and collapse of many of these fisheries has lead to demands for a management system designed by fishermen and based on their knowledge and values. In many places, this frustration is driving a movement towards community-based management.

Methodology and Research Process. To address fishermen's interests, this project evolved from a simple mapping of groundfish spawning areas to a more holistic discussion of local stocks, inshore fisheries, habitat, and spawning activity. The information collected from fishermen was mapped on a geographic information system (GIS) so that seasonal changes over time could be illustrated.

Evidence for Local Stocks. Presently most groundfish stocks are managed under the assumption that they spawn on offshore banks such as Georges or Browns. Based on when and where fishermen have caught spawning fish, there is strong evidence that cod, haddock and pollock also spawn within the Bay of Fundy. The loss of local inshore fisheries is associated with the disappearance of local spawning.

Inactive Spawning Areas. There has been a progressive loss of groundfish spawning areas in the Bay of Fundy over the last 30 years. Fishermen attribute the loss to the effects of overfishing, habitat loss, diminished food availability, pollution, and ecosystem change.

Active Spawning Areas. There are a small number of fishing grounds that fishermen consider to be active spawning areas. These are mostly places where spawning groundfish have been protected from overexploitation by weather conditions or bottom topography.

Conclusions and Recommendations for Further Research. Some of the spawning areas identified in this report remain active and continue to support fisheries, but others have declined or disappeared completely. There is an urgent need to learn more about groundfish stock structure in the Bay of Fundy so we can protect and rehabilitate local stocks. Fishermen's knowledge can contribute greatly to this endeavor and should play a significant role in driving research and management initiatives.

To obtain a copy of this report please contact: Centre for Community-Based Management, Bay of Fundy Program. Telephone: (506) 755-2893 or E-mail: mariar@nb.sympatico.ca

Reference

Benham, A. A., and E. A. Trippel. 2002. Mapping Fishermen's Knowledge of Groundfish and Herring Spawning and Nursery Areas in the Bay of Fundy, Gulf of Maine and Eastern Nova Scotian Shelf. Canadian Technical Report of Fisheries and Aquatic Sciences (in press).

DISTRIBUTION OF RARE, ENDANGERED AND KEYSTONE MARINE VERTEBRATE SPECIES IN BAY OF FUNDY SEASCAPES

Kate A. Bredin[1], Stefan H. Gerriets[1] and Lou Van Guelpen[2]

[1] Atlantic Canada Conservation Data Centre and Atlantic Reference Centre, St. Andrews, NB.
kbredin@mta.ca
[2] Atlantic Reference Centre, Huntsman Marine Science Centre, St. Andrews, NB.
arc@huntsman.ca

As part of a framework for marine protected areas planning, the World Wildlife Fund (WWF) has developed an oceanographically-based marine habitat classification system that uses abiotic factors to identify a set of *seascapes* for the Scotian Shelf, including the Bay of Fundy. The WWF framework "uses an ecologically-based hierarchical classification of marine environments to determine the diversity of physical habitat types and ... reflects the range of conditions that influence species distribution ... The classification ... uses physical attributes alone and essentially predicts the expected species assemblages on the basis of documented enduring or recurring geophysical characteristics" (Day and Roff 2000: vii). The physical attributes used to define the set of seascapes include water-mass temperature, depth, bottom temperature, stratification, exposure, slope, and sediment type.

To test the classification framework, WWF Canada undertook a case study in 1998 on the Scotian Shelf of Canada, including the Bay of Fundy. The study resulted in the preliminary identification of nine marine natural regions[1] and 62 specific seascapes[2]. Two of the regions and 32 seascapes were found within the Bay of Fundy with some of these extending outside the Bay (Figure 1).

In continuing to advance this case study and to build a practical case for marine protected areas (MPAs) in the Scotian Shelf/Bay of Fundy area, WWF Canada desired to incorporate biological and ecological data to determine whether there are affinities by species and by communities to marine natural regions and seascapes. Among the desirable biological data are locational information on any rare, endangered and/or keystone[3] species found within the area that might be strongly or moderately associated with seascapes.

In 2001 the Atlantic Canada Conservation Data Centre (ACCDC) received funding from the Gulf of Maine Council on the Marine Environment to map occurrence information for rare, endangered and keystone marine vertebrates in the Bay of Fundy against WWF's seascape classification for the Bay. Based in Sackville, New Brunswick, the not-for-profit ACCDC exists to assemble and provide information and expertise on species and natural communities of conservation concern in Atlantic Canada, in support of decision making, research and education.

[1] Broad, oceanographic and biophysical areas characterized by particular water-mass characteristics and sea-ice conditions.
[2] Marine areas that have a distinctive combination of enduring features as defined at scales of 1:250,000 to 1:500,000.
[3] Keystone species are species that play a critical role in maintaining food web relationships and the structure of biological communities.

Identification of Rare, Endangered and Keystone Marine Vertebrates in the Bay of Fundy

Conservation data centres, including the ACCDC, determine the rarity status of species that occur in their jurisdiction. Through the international network of conservation data centres (CDCs), species rarity ranks are assigned at three geographic levels: global (G-rank), national (N-rank) and sub-national (S-rank), where sub-national refers to provincial or state-level rarity ranks, which are assigned by individual CDCs for species in their jurisdictions. Species rarity ranks are established on a basic scale of 1 to 5, with 1 being the most rare and 5 being the most common, but they also take into account other factors that reflect a species' status in a jurisdiction, such as extirpated or exotic status (see <http://www.accdc.com>). In Atlantic Canada, the ACCDC assigns S-ranks for five jurisdictions (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland, and Labrador). Rarity ranks are usually developed in co-operation and collaboration with provincial natural resource departments and numerous species experts. Rarity ranks for *anadromous* fish species in New Brunswick were assigned this way. ACCDC has not yet assigned rarity ranks to exclusively *marine* fish species. The ACCDC assigned marine mammal rarity ranks using the same process outlined above, but based geographically on six ocean regions comprising Atlantic Canada waters, rather than on a provincial jurisdictional basis.[4]

A rare or endangered marine or anadromous fish or marine mammal species was considered for occurrence mapping within Bay of Fundy seascapes if: 1) it received an ACCDC rarity rank of S1 to S3 (i.e. extremely rare, rare, or uncommon throughout its range in the Bay of Fundy); or 2) was listed as *endangered, threatened* or *special concern* by the Committee on the Status of Wildlife in Canada (COSEWIC); or 3) if it was listed as *endangered, threatened, vulnerable* or *conservation dependant* by the American Fisheries Society (AFS) (see Musick et al. 2000). Table 1 lists rare or endangered fish and marine mammals in the Bay of Fundy, along with COSEWIC status, ACCDC rarity rank (S-rank), and the AFS status for the population segment present in the Bay, that were mapped against Bay of Fundy seascapes.

A *keystone* species plays a crucial role in its community (Norse 1993), or a pivotal role in the trophic structure of an ecosystem (Paine 1966, in Costanza et al. 1995). Through consultation with Michael Dadswell at the Acadia Centre for Estuarine Research, Acadia University, the following species were identified as keystone marine fish species in the Bay of Fundy: Spiny Dogfish *(Squalus acanthias*), American Shad *(Alosa sapidissima),* Atlantic Herring (*Clupea harengus*), Rainbow Smelt (*Osmerus mordax*), Atlantic Cod (*Gadus morhua*), Haddock (*Melanogrammus aeglefinus*), Pollock (*Pollachius virens*), and Winter Flounder (*Pleuronectes americanus*) (and see Dadswell et al. 1984). No individual marine mammal species were considered keystone in the Bay of Fundy although taken as a group, the baleen whales may play an important role in ecosystem processes.

---

[4] The six ocean regions are Labrador Shelf, Newfoundland Shelf, Grand Banks, Scotian Shelf, Bay of Fundy, and the Gulf of St. Lawrence: marine mammal rarity ranks have so far been assigned for the Scotian Shelf and the Bay of Fundy.

Seascapes

Seascape data were obtained from World Wildlife Fund Canada (see Day and Roff 2000). Day and Roff (2000) overlaid seven levels of abiotic parameters to create spatial areas differentiated by those attributes; thirty-two seascapes were identified within the Bay of Fundy. Seascapes were mapped to show unique sets of values for the following abiotic parameters: 1) Climatic Zone (Boreal, Temperate, Subtropical); 2) Benthic temperature (Cold Subarctic(<6°C), Moderate Temperate (6-9°C), Warm Gulf Stream (>9°C)); 3) Vertical Segregation Pelagic Realm (Epipelgic (0–200m), Mesopelagic (200–1000 m), Bathypelagic (1000–2000 m), Abyssal (>2000 m)); 4) Vertical Segregation Benthic Realm (Euphotic (0–50 m), Dysphotic/ Aphotic (50–200 m)); 5) Mixing and Wave Action: Pelagic Realm (Well-mixed (non-stratified), Frontal, Stratified); 6) Exposure and Slope Classes (Exposed – subject to exposure (depth < 50 m), Low Slope (<2%), High Slope (>2%)); and 7) Benthic Substrate (Mud, Mostly sand (20–80% sand), Partially sand (0–20% sand), Partially gravel (5–50% gravel), Mostly gravel (>50% gravel)).

Data Sources

Locational data for rare, endangered and keystone marine fish species were obtained from demersal (groundfish) research trawl surveys conducted on the east coast of North America by the Department of Fisheries and Oceans (DFO) in Canada and by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS) in the United States (Brown et al. 1996). Trawl survey data were combined into a single database structured by data from individual trawl sets at different geolocations, thereby permitting locational analysis for various species. Data were obtained from DFO and were downloaded from the Gulf of Maine Biogeographic Information System (GMBIS) website: http://cephbase.biology.dal.ca/gmbis/aconscripts/GroundfishSurveyMap.html>.

Locational data for rare and endangered marine fish were also obtained from the literature, and from specimen records at the ARC at the Huntsman Marine Science Centre in St. Andrew's, New Brunswick. We received data for larval Atlantic Herring, Atlantic Cod and Haddock from DFO's three Ichthyoplankton Survey Programs, one of which, the Larval Herring Program, covered the Bay of Fundy (see Hanke et al. 2000, 2001). The larval data are in units of density for an aggregate cell of three miles and are expressed as number of larvae/100 m^3 water (filtered), averaged for the number of samples in that aggregate three mile cell. Cetacean data were obtained from the North Atlantic Right Whale Consortium curated at the University of Rhode Island. This dataset is comprised of sightings of marine mammals (including the Basking Shark, *Cetorhinus maximus*) using a variety of sighting methods including aerial surveys, opportunistic and historical sightings, and sightings from a wide variety of vessels including ferries, US Coast Guard vessels, whale watch vessels and research vessels.

Mapping Species onto Seascapes Using Percent of Total Catch, Classed by Natural Breaks

Georeferenced point data of species' catches from trawl surveys, or observations in the case of marine mammals, were linked to the seascape polygon layer. For each species, maps of percent total catch per seascape were produced. Seascapes were ranked into five groups based on percent total catch per seascape using the Natural Break algorithm, available within MapInfo, the geographic information system (GIS) software used to create the maps.

Natural Break identifies breakpoints between classes using a statistical formula (Jenk's optimization) which reduces error by minimizing the sum of the variance within each of the classes. Natural Break emphasizes inherent clustering of scores, producing chloropleths (coloured map polygons) that may better approximate ecological preferences of a species than an arbitrary numerical division would produce. For mapping purposes, seascapes were coloured according to their rank (i.e. according to the percent total catch within them): First ranked seascapes (with the highest percent total catch) were coloured red, second ranked seascapes were coloured orange, third ranked seascapes were coloured yellow-green, fourth ranked seascapes were coloured teal, and fifth ranked seascapes were coloured blue.

In the main series of maps, catch data were pooled for all seasons of the entire year, however, since the great majority of survey sets were conducted in the summer (June to August, 1970–2001) maps were biased towards summer distributions. If there were adequate data for keystone fish species for spring (March to April, 1979–1984) and fall (September to November, 1978–1984) surveys, and if there was a suggestion of a shift in distribution between seasons as determined from exploratory maps downloaded from the GMBIS website, we produced seasonal distribution maps of seascapes by total catch.

Results and Discussion

Keystone Marine Fish Species Distribution with Bay of Fundy Seascapes

Two seascapes captured much of the locational information for five species of groundfish (see, for example, Figures 2-4). Atlantic Cod, Winter Flounder, Haddock, Pollock, and Spiny Dogfish were all most abundant in seascapes **21** and **23**. Although seascapes **21** and **23** do encompass most of the mid-Bay, and distribution within these seascapes may be an artifact of a general abundance of groundfish throughout the central area of the Bay, it is interesting to note that groundfish were not abundant in seascape **19**, also in mid-Bay. Seascape **19** is one of thirteen *frontal* seascapes in the Bay—areas where there is upwelling caused by sudden changes in water temperature or salinity, or where there are convergences towards which surface waters flow from different or opposing directions, tending to sink at the areas where they meet (Gross 1977). American Shad were also most abundant in seascape **21** and in seascape **67**, another frontal seascape with potential areas of upwelling. As American Shad are plankton feeders, they may favour frontal areas where copepods and mysids are brought to the surface due to upwelling.

Seasonal movements and feeding habits of fish species appear to be related to seascape use. Atlantic Herring were most abundant in seascape **11**, a primarily coastal seascape that encompasses the summer feeding area for herring off Brier Island, NS. Rainbow Smelt, an anadromous species, were most abundant in seascape **29**, close to major spawning rivers; no other species were found predominantly in this seascape. In autumn, Pollock were most frequently caught in seascape **72**, a frontal seascape with potential areas of upwelling near the mouth of the Bay. This may be a reflection of the fact that Pollock in the Bay of Fundy move south in fall or early winter to spawn in the southern Gulf of Maine (Steele 1963). In the spring, Haddock were most highly correlated with seascape **72**.

Spawning Areas and Larval Retention Locations for Selected Keystone Species

Larvae of three keystone species, Atlantic Herring, Atlantic Cod and Haddock, were most abundant off the southwest shore of Nova Scotia, south of Brier Island, in the lower sector of seascape **23**. This ocean area is known to be a major spawning location for these species (Stephenson et al. 2000, Hanke et al. 2000, 2001). Oceanographic larval retention factors (e.g., temperature gradients) may be a stronger determinant of larval fish distribution than seascape per se, since few larvae were present in the upper sector of seascape **23**. (In the event of future analyses, geographically disparate sectors of the same seascape should be separated.)

Rare and Endangered Marine Fish Distribution with Bay of Fundy Seascapes

The distribution of rare fish species, as a group, in the Bay of Fundy did not clearly correspond with just a few seascapes, as was the case, for example, for the keystone groundfish species. The rare fishes were a more disparate group, differing substantially in feeding and life history characteristics, than the keystone fish group, which included five species of groundfish (including Spiny Dogfish) and two members of the family Clupeidae (herring and shad). Rare fish distribution in the Bay of Fundy was more related to habitat preferences of individual species rather than to preferences of the group as a whole. For example, Halibut, a rare groundfish, showed the same preference for seascapes **21** and **23**, as for the keystone groundfish species.

Because sufficient locational data were lacking for some rare and endangered species in the Bay of Fundy due to their rarity, attempting to demonstrate patterns of seascape for these species was not warranted. And, most of the georeferenced data for the anadromous species Shortnose Sturgeon *(Acipenser brevirostrum)*, Atlantic Sturgeon *(Acipenser oxyrinchus),* and Atlantic Salmon (*Salmo salar*), were for river and estuarine locations and would be unrelated to marine seascape parameters.

The greatest number of Basking Shark sightings occurred in seascape **29** and seascape **27**, a *frontal* seascape where upwelling is likely to bring plankton to the surface for the sharks to feed on. Relatively few Barndoor Skate (*Dipturus laevis)* were caught during groundfish surveys, indicative of the precipitous decline of this species throughout the North Atlantic in the last two decades (Casey and Myers 1998). Greater numbers of Thorny Skate (*Amblyraja radiata)* were caught throughout the mid to lower part of the Bay, primarily in seascapes **21**, **27** and **23**. Atlantic Wolffish (*Anarhichas lupus)* prey upon a variety of bottom invertebrates (Scott and Scott 1988) and were most highly represented in seascape **21** and in seascape **23,** similar to the distribution of groundfish. Acadian Redfish (*Sebastes fasciatus)* were most abundant at the mouth of the Bay in seascapes **72** and **67**, frontal seascapes with potential areas of upwelling likely to produce an abundance of pelagic zooplankton upon which this species feeds.

Rare and Endangered Marine Mammal Distribution with Bay of Fundy Seascapes

The distribution of most marine mammal species in the Bay of Fundy occurred within three seascapes, **21**, **27** and **29**, situated at the mouth of the Bay. However, the majority of the cetacean sighting data was collected during surveys directed at North Atlantic Right Whale (*Eubalaena glacialis*) identification and research, and is thus concentrated in the Right Whale high-use area in the lower Bay. Although this data collection bias influenced the correlation of cetacean distribution with seascape, some interesting species-specific patterns emerged.

The most frequently sighted cetacean species in the Bay of Fundy was the Harbour Porpoise (*Phocoena phocoena*), which is consistent with a recent population estimate for the Bay of Fundy-Gulf of Maine stock of 89,000 animals (Palka 2000). As for other cetaceans, Harbour Porpoises were most abundant in the lower Bay in seascapes **29** and **21**, though with more systematic surveys they would likely be found more widely in the Bay.

Long-finned Pilot Whale (*Globicephala melas*) distribution was different from other cetacean species in that they were most frequently sighted further out of the Bay in seascape **67** and off Digby Neck in the lower sector of seascape **21**. Their distribution at sea is usually determined by their main prey, squid, which frequently occur southwest of Brier Island and at the mouth of the Bay of Fundy (see maps in Simon and Comeau 1994), in an area close to these Pilot Whale sightings.

Sightings of Atlantic White-sided Dolphins (*Lagenorhynchus acutus)* were concentrated in the area between northern Grand Manan Island and Digby Neck, where their main prey, small schooling fish such as Atlantic Herring and Rainbow Smelt were abundant (see above) (Katona et al. 1993). White-beaked Dolphins (*Lagenorhynchus albirostris)* and Killer Whales (*Orcinus orca*) are rare in the Bay of Fundy and were infrequently sighted.

Humpback Whales (*Megaptera novaeangliae*), with their coarser baleen, tend to feed on small schooling fish to a greater degree than other baleen whale species. They were overwhelmingly concentrated in the lower sector of seascape **21** off Digby Neck, where small schooling fish such as herring and juvenile cod are concentrated (see above). Fin Whales (*Balaenoptera physalus)* occurred in an almost continuous line across the mouth of the Bay in the lower part of seascape **21** and in seascapes **29**, **27**, and **51**. Fin Whales eat both krill and schooling fish, and seemed to be frequenting both the herring rich areas off Digby Neck, as well as the areas of upwelling at the mouth of the Bay with their rich concentrations of zooplankton (Daborn 1997). The few Sei Whales (*Balaenoptera borealis)* that were seen in the Bay of Fundy were concentrated on the Nova Scotia side off Digby Neck, and in the area of upwelling at the mouth of the Bay. Sei Whales will also eat small schooling fish and krill and their distribution in the Bay corresponds with areas rich in both prey sources. North Atlantic Right Whales were most abundant in the *frontal* seascape **27**, where upwelling produces rich concentrations of zooplankton that baleen whales feed upon. They were also sighted in seascape **29** and **51**, in the centre of the Grand Manan Basin. The Grand Manan Basin is a critical area for North Atlantic Right Whales in the summer and fall, functioning in part as a nursery where most of the cows bring their calves, but also as a juvenile and adult feeding area (Brown and Kraus 1997).

Conclusions and Future Steps

One way to circumvent the frequent inadequacies of single-species occurrence data for conservation planning, especially in the marine realm, is to adopt an ecosystem-based conservation process, such as the WWF seascape approach. The addition of biological data layers to physical and oceanographic seascape information, as was done for this project, results in a set of enhanced seascapes and enables the identification and prediction of biologically important marine areas. These *biologically important seascapes* can be seen as conservation targets to be considered for possible future protection through MPAs planning. The development of a scheme of MPAs that protects *biologically important seascapes* can provide a surrogate for protection of individual marine species for which we lack adequate knowledge for conservation.

Two seascapes, for example, emerged as significant to the distribution of the keystone groundfish species assemblage. If additional biological data layers were added, such as data on benthic invertebrate seascape associations, the resulting set of enhanced seascapes would be more powerful predictors of biologically important ocean regions. Some types of invertebrate information would probably correlate more closely with seascapes because many marine invertebrate taxa are lower in the food chain and more directly tied to oceanographic and physiographic factors. As layers of biological information are added and the seascapes are further refined (e.g., by incorporating seasonal values of seascape parameters), their ability to predict distinct ocean areas with rich species assemblages, i.e. targets for MPAs planning, will increase.

There are various ways seascape correlation with biological data could be taken further. Although statistical analyses were beyond the scope of this project, spatial statistics (e.g., cluster analysis) could be applied to further elucidate patterns of species-seascape relationships. Our maps of percent occurrence per seascape failed to correct for seascape area, so that species occurrence in small seascapes was underrepresented, though they could be of prime biological importance (e.g., frontal seascape number **57** to baleen whales). Determining a way to correct for this bias is critical. There were also several cases where seascapes existed as more than one discrete geographic area, but the clustering of species records was skewed towards only one of the areas. If the current set of seascapes was to be subdivided in those cases where a seascape exists as more than one spatially discrete object, a reiteration of this exercise would produce finer and more clearly defined linkages of species to seascape. And, it would be enlightening to apply this methodology to a larger ocean area with a greater variety of seascapes, such as the Scotian Shelf or the Gulf of Maine, using a larger set of biological data, most of which are readily available.

References

Brown. M. W. and S. D. Kraus. 1997. North Atlantic Right Whales. Pages 92–94. In: *Bay of Fundy Issues: A Scientific Overview. Workshop Proceedings, Wolfville, NS January 29 to February 1, 1996*. J. A. Percy, P. G. Wells and A. J. Evans (Eds.). Environment Canada – Atlantic Region Occasional Report No. 8, Environment Canada, Sackville, NB. 191 pp.

Brown, S. K., R. Mahon, K. C. T. Zwanenburg, K. R. Buja, L. W. Claflin, R. N. O'Boyle, B. Atkinson, M. Sinclair, G. Howell, and M. E. Monaco. 1996. *East Coast of North America Groundfish: Initial Exploration of Biogeography and Species Assemblages*. National Ocean and Atmospheric Administration, Silver Spring, MD, and Department of Fisheries and Oceans, Dartmouth, NS. 111 pp.

Casey, J. and R. Myers. 1998. Near extinction of a large widely-distributed fish. Science 281: 690–692.

Costanza, R., M. Kemp, and W. Boynton. 1995. Scale and biodiversity in coastal and estuarine ecosystems. In: *Biodiversity Loss: Economic and Ecological Issues*. C. Perrings, K.-G. Maler, C. Folke, C. S. Holling, and B.-O. Jansson (Eds.).Cambridge University Press, Cambridge. 332 pp.

Daborn, G. R. 1997. Zooplankton. Pages 66–69. In: *Bay of Fundy Issues: A Scientific Overview. Workshop Proceedings, Wolfville, N.S. January 29 to February 1, 1996*. J. A. Percy, P. G. Wells and A. J. Evans (Eds.). Environment Canada – Atlantic Region Occasional Report No. 8, Environment Canada, Sackville, NB. 191 pp.

Dadswell, M. J., R. Bradford, A. H. Leim, D. J. Scarratt, G. D. Melvin, and R. G. Appy. 1984. A review of research on fishes and fisheries in the Bay of Fundy between 1976 and 1983 with particular reference to its upper reaches. In: Update on the Marine Environmental Consequences of Tidal Power Development in the Upper Reaches of the Bay of Fundy. D. C. Gordon, Jr., and M. J. Dadswell (Eds.). Canadian Technical Report of Fisheries and Aquatic Sciences 1256. 686 pp.

Day, J. C. and J. C. Roff. 2000. *Planning for Representative Marine Protected Areas: A Framework for Canada's Oceans*. Report prepared for World Wildlife Fund Canada, Toronto.

Gross, M. G. 1977. *Oceanography: A View of the Earth*. 2nd ed. Prentice-Hall, Englewood Cliffs, NJ. 497 pp.

Hanke, A. R., F. H. Page, and J. Neilson. 2000. Distribution of Atlantic Cod (*Gadus morhua*) Eggs and Larvae on the Scotian Shelf. Canadian Technical Report of Fisheries and Aquatic Sciences 2308. Department of Fisheries and Oceans, St. Andrews, NB. 140 pp.

Hanke, A. R., F. H. Page, and J. Neilson. 2001. Distribution of Haddock (*Melanogrammus aeglefinus*) Eggs and Larvae on the Scotian Shelf, Eastern Gulf of Maine, Bay of Fundy and Eastern Georges Bank. Canadian Technical Report of Fisheries and Aquatic Sciences 2329. Department of Fisheries and Oceans, St. Andrews, NB. 133 pp.

Katona, S. K., V. Rough and D. T. Richardson. 1993. *A Field Guide to Whales, Porpoises, and Seals from Cape Cod to Newfoundland*. 4th ed., revised. Smithsonian Institution Press, Washington, DC. 316 pp.

Musick, J. A., M. M. Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, G. R. Sedberry, H. Weeks, and S. G. Wright. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific Salmonids). Fisheries 25(11): 6–30.

Norse, E. A. (Ed.) 1993. Global Marine Biological Diversity. Island Press, Washington, DC. 383 pp.

Palka, D. 2000. Abundance of the Gulf of Maine/Bay of Fundy Harbor Porpoise Based on Shipboard and Aerial Surveys During 1999. Northeast Fisheries Science Center Reference Document 00-07. NMFS, Woods Hole, MA.

Scott, W. B. and M. G. Scott. 1988. Atlantic Fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. 731 pp.

Simon, J. E., and P. A. Comeau. 1994. Summer Distribution and Abundance Trends of Species Caught on the Scotian Shelf from 1970-92, by the Research Vessel Groundfish Survey. Canadian Technical Report of Fisheries and Aquatic Sciences 1953. Department of Fisheries and Oceans, Dartmouth, NS. 145 pp.

Stephenson, R. L., M. J. Power, K. J. Clark, G. D. Melvin, F. J. Fife, T. Scheidl, C. Waters, and S. Arsenault. 2000. DFO Canadian Stock Assessment Secretariat Research Document 2000/065. 2000 evaluation of 4VWX herring. 114 pp.

Steele, D. H. 1963. Pollock (*Pollachius virens* (L.)) in the Bay of Fundy. Journal of the Fisheries Research Board of Canada 20: 1267–1314.

Table 1. Various status ranks for marine and anadromous fish and marine mammals

Common Name	**Scientific Name (and synonyms)**	**COSEWIC**	**AFS status for relevant distinct population segment (DPS)**	GRANK	NRANK	AC CDC S-RANK
MARINE FISH						(NS or NB)
Sand Tiger	*Carcharias taurus, Odontaspis taurus*		vulnerable (w. Atlantic)			
Basking Shark	*Cetorhinus maximus*		conservation dependent (w. Atlantic)			
White Shark; Great White Shark	*Carcharodon carcharias*		conservation dependent (w. Atlantic)			
Barndoor Skate	*Dipturus laevis; Raja laevis; Raja granulata*		vulnerable			
Thorny Skate	*Amblyraja radiata; Raja radiata; Raja scabrata; Raja clavata*		not assessed (Canadian stocks) vulnerable (US stocks).			
Shortnose Sturgeon	*Acipenser brevirostrum*	special concern	conservation dependent (Saint John River)			S3 (NB); S2 (NS)
Atlantic Sturgeon	*Acipenser oxyrinchus Acipenser oxyrhynchus; Acipenser sturio*		endangered (N. Canadian rivers, St. Lawrence River); threatened (Saint John River)			S3 (NB); S2 (NS)
Atlantic Salmon	*Salmo salar*	endangered (inner Bay of Fundy populations)	Endangered (Inner Bay of Fundy Rivers); threatened (St. Croix R. to Saint John R.)			S3 (NB); S2 (NS)
Atlantic Cod	*Gadus morhua, Gadus morhua morhua*	special concern	vulnerable (LB, NF, Grand Banks, Gulf of St. Lawrence.); not at risk (though overfished, other DPSs)			
Atlantic Wolffish	*Anarhichas lupus*	special concern				
Spotted Wolffish	*Anarhichas minor*	threatened				
Acadian Redfish	*Sebastes fasciatus*		conservation dependent (Gulf of Maine)			
Atlantic Halibut	*Hippoglossus hippoglossus*		threatened (US, eg Gulf of Maine) vulnerable (Canada & Maritimes)			

Figure 1, continued

MARINE MAMMALS						S-RANK for the Bay of Fundy
White-beaked Dolphin	*Lagenorhynchus albirostris*	Not at Risk (1998)		G4	N4	S1
Atlantic White-sided Dolphin	*Lagenorhynchus acutus, Leucopleurus acutus*	Not at Risk (1991)		G4	N4	S3S4
Killer Whale	*Orcinus orca*	Data Deficient (1999)		G4G5	N3	S1
Long-finned Pilot Whale	*Globicephala melas*	Not at Risk (1994)		G5	N4N5	S2S3
Harbour Porpoise	*Phocoena phocoena*	Threatened (NW Atlantic population)		G4G5	N4N5	S4
Fin Whale	*Balaenoptera physalus*	Special Concern		G3G4	N3	S2S3
Sei Whale	*Balaenoptera borealis*			G3	N3	S3
Humpback Whale	*Megaptera novaeangliae*	Special Concern		G3	N3	S3
North Atlantic Right Whale	*Eubalaena glacialis*	Endangered		G1	N1	S1

Table 2. Percent catch of keystone marine fish by seascape – data pooled for 1970–2001, year round

Seascape Number	Spiny Dogfish	Atlantic Herring	American Shad	Rainbow Smelt	Atlantic Cod	Haddock	Pollock	Winter Flounder
5	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--
11	4.87	52.84	2.61	30.52	2.34	0.64	3.3	7.27
17	0.41	0.42	0.98	4.47	0.87	0.24	0.18	2.1
18	0.23	--	--	--	0.01	--	--	0.03
19	1.98	0.13	9.56	0.82	5.05	1.7	3.05	1.16
21	29.58	6.01	33.88	3.86	44.87	20.22	24.91	35.1
23	23.21	19.31	8.74	2.27	20.71	57.17	13.92	47.32
25	0.58	0.14	0.25	--	0.09	0.01	--	0.26
27	14.04	5.05	4.01	11.25	3.69	0.96	1.72	0.44
28	--	--	--	--	--	--	--	--
29	7.37	9.46	4.26	46.8	7.29	1.81	9.72	1.25
33	--	--	--	--	0.39	0.09	0.17	0.04
35	--	--	--	--	--	--	--	--
38	--	--	--	--	--	--	--	--
39	0.03	0.01	--	--	0.85	0.59	4.07	--
41	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--
47	0	--	--	--	0.19	0.04	--	--
51	0.3	0.01	--	--	0.77	0.2	0.16	0.01
52	--	0	--	--	0.47	--	0.02	--
54	0.38	0.01	0.12	--	1.16	0.36	5.53	0.02
59	0.07	0.13	--	--	0.23	0.02	0.3	0.04
62	--	--	--	--	--	--	--	--
67	6.47	1.59	28.14	--	2.62	0.67	4.43	0.05
72	7.31	3.95	5.78	--	4.05	2.41	20.3	0.05
73	1	0.2	0.52	--	3.65	11.73	4.91	4.82
74	1.58	0.14	0.28	--	0.11	0.1	1.78	--
75	--	--	--	--	0.04	0.04	0.02	--
76	0.07	0.06	0.87	--	0.45	0.92	0.83	0.04
79	0.47	0.57	--	--	--	0.05	0.48	--
80	0.01	--	--	--	0.1	0.02	0.11	--
83	0.05	--	--	--	--	--	0.07	--

Figure 1. Seascapes in the Bay of Fundy and the northern Gulf of Maine. As the Bay of Fundy Seascapes were extracted from all seascapes for the Scotian Shelf, the numbering system reflects this total set, rather than those for just the Bay of Fundy.

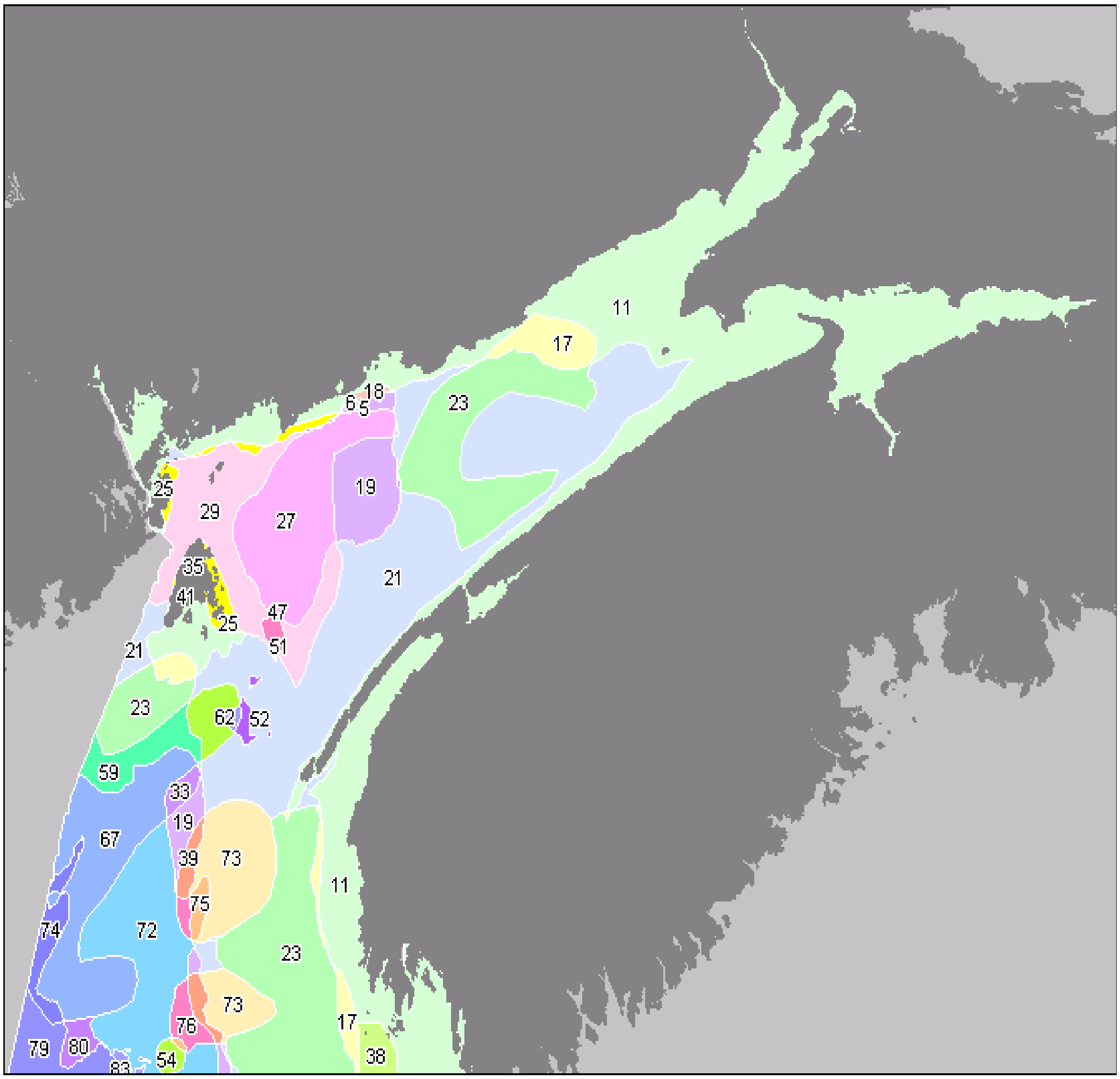


Figure 2. Total number of Atlantic Cod per trawl station from all groundfish surveys conducted from 1970 to 2001. Map dots are scaled according to the total **number** of fish caught at each trawl station. Seascapes are coloured according to the **percent** of the total number of fish caught within their boundaries, with percent total catch per seascape indicated. The legend shows the range of percent total catch falling within each colour category and the number of seascapes of each colour.

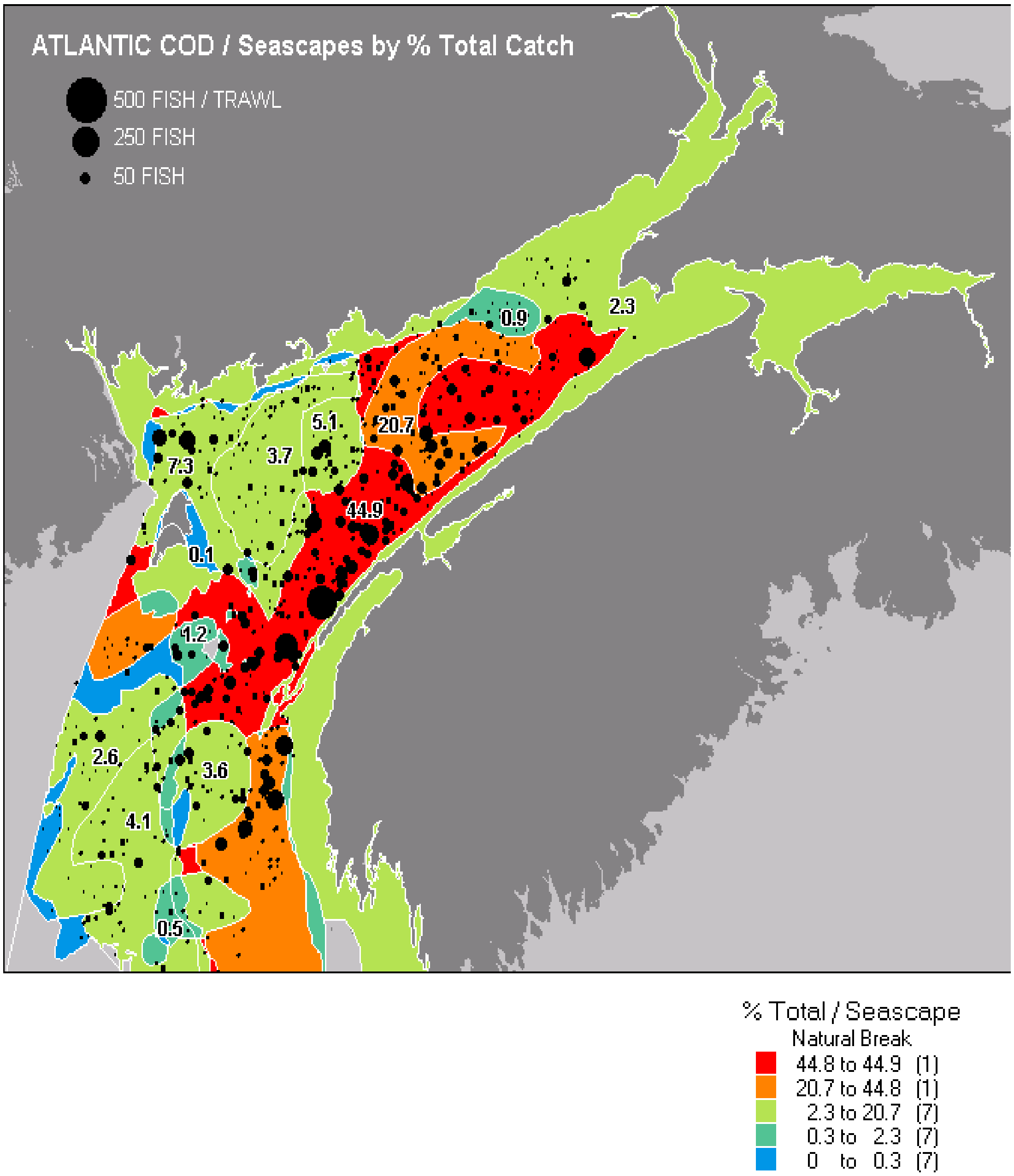


Figure 3. Total number of Pollock per trawl station from all groundfish surveys conducted from 1970 to 2001. Map dots are scaled according to the total **number** of fish caught at each trawl station. Seascapes are coloured according to the **percent** of the total number of fish caught within their boundaries, with percent total catch per seascape indicated. The legend shows the range of percent total catch falling within each colour category and the number of seascapes of each colour.

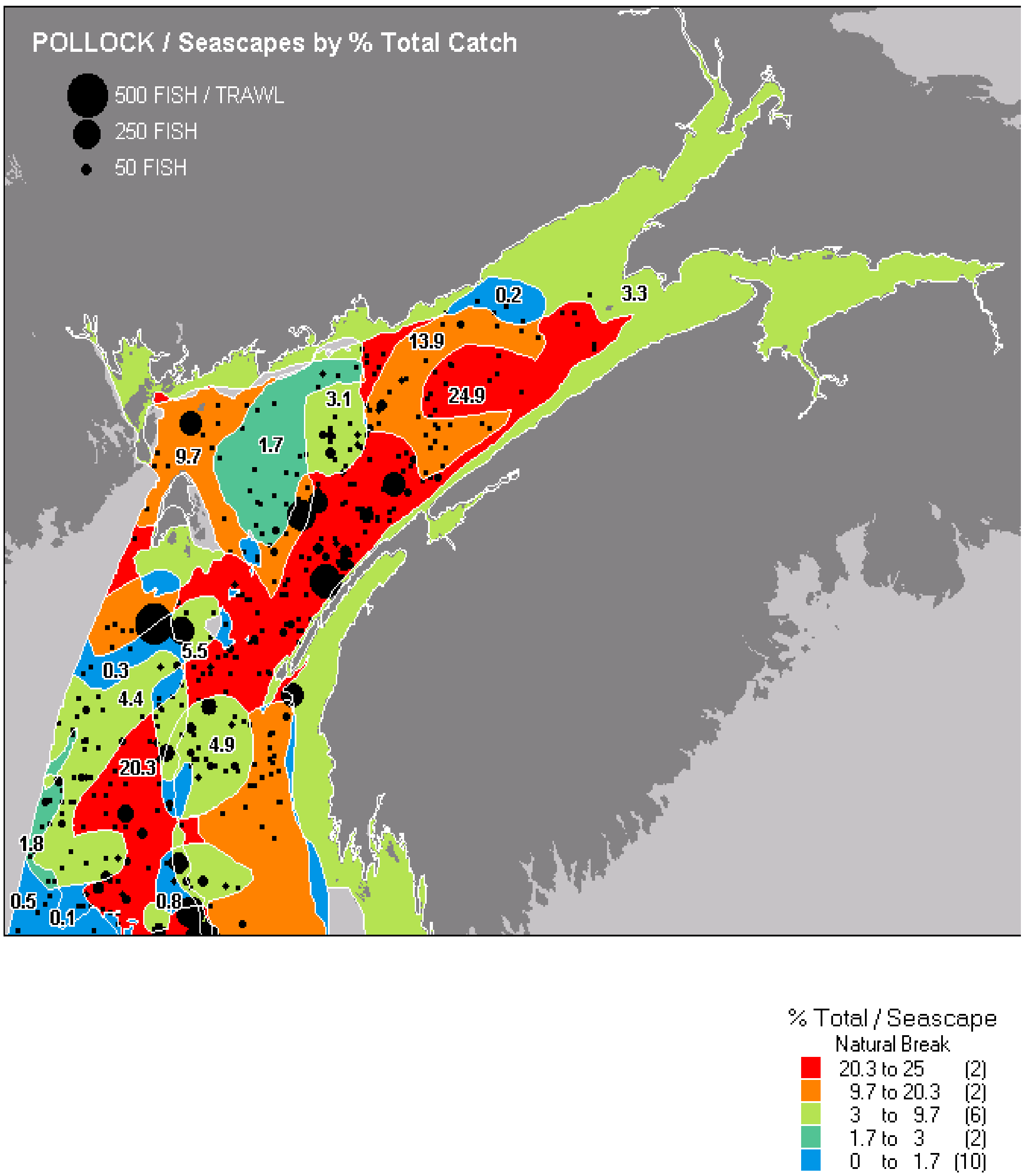
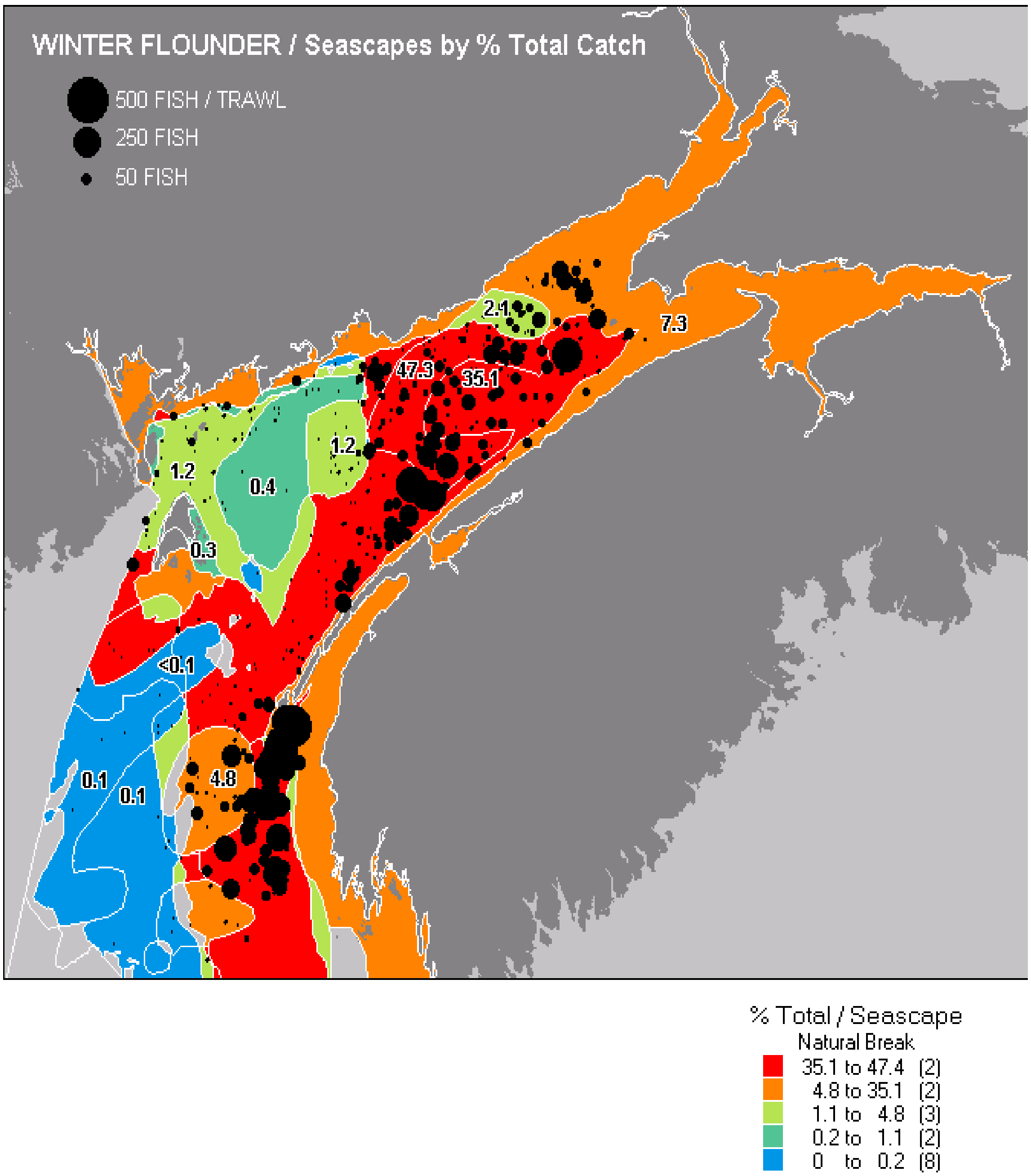


Figure 4. Total number of Winter Flounder per trawl station from all groundfish surveys conducted from 1970 to 2001. Map dots are scaled according to the total **number** of fish caught at each trawl station. Seascapes are coloured according to the **percent** of the total number of fish caught within their boundaries, with percent total catch per seascape indicated. The legend shows the range of percent total catch falling within each colour category and the number of seascapes of each colour.



CHANGES IN THE BROWN SEAWEED *Ascophyllum nodosum* (Le Joly) PLANT STRUCTURE AND BIOMASS PRODUCED BY CUTTER RAKE HARVESTS IN SOUTHERN NEW BRUNSWICK

Raul A. Ugarte[1] and Glyn Sharp[2]

[1] Acadian Seaplants Limited, Dartmouth, NS. rugarte@acadian.ca
[2] Invertebrate Fisheries Division, Fisheries and Oceans Canada, Dartmouth, NS
sharpg@mar.dfo-mpo.gc.ca

The harvest of the commercial brown seaweed *Ascophyllum nodosum* (Rockweed) in southern New Brunswick completed its seventh year in 2001. Under a joint federal/provincial management strategy, several restrictions such as maximum exploitation rate, cutting height, gear type, and protected areas were implemented to minimize risks to the resource and habitat. Though the maximum allowed exploitation rate in a given sector cannot exceed 17% of the harvestable biomass, it has been determined that due to several physical and environmental factors, the harvest is not homogenous, creating patches of higher exploitation rates within a rockweed bed.

Since 1996 we have monitored rockweed population structure in several harvesting experiments designed to evaluate the impact of the cutter rake on the plant's size structure under different exploitation rates. A novel technique to measure plant biomass before and after harvest was used to complement existing impact data. There was a direct relationship between plant vulnerability relative to weight and length. The gear rarely impacts plants below 100 g or 60 cm in length and if the rake contacts smaller plants, the changes in biomass or length were not significant. As plants increase in weight and length there was an increased impact on their length and biomass, with length being reduced up to 40% and 60% of the biomass in plants larger than 130 cm and 300 g. The overall impact of the harvest is discussed in light of existing information on biomass, population structure and productivity rates.

BIOLOGICAL REFERENCE POINTS FOR BAY OF FUNDY ALEWIFE FISHERIES

Jamie F. Gibson[1] and Ransom A. Myers[2]

[1] Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS. jamie.gibson@acadiau.ca
[2] Department of Biology, Dalhousie University, Halifax, NS. ransom.myers@dal.ca

Abstract

Alewife, *Alosa pseudoharengus*, is an anadromous species of fish indigenous to many rivers in eastern North America. Within the Bay of Fundy, they support commercial and recreational fisheries of local economic importance, are biologically important as both predators and prey, and can serve as vectors for nutrient transport from marine to freshwater ecosystems. Biological reference points (BRPs) are indices, based on the biological characteristics of a fish stock, that are used to gauge whether specific management objectives, such as maintaining stocks at a level capable of producing long-term maximum sustainable yield (MSY), are being achieved. Using a meta-analysis of eight alewife populations in North America, including data for two rivers flowing into the Bay of Fundy, we have estimated several BRPs that can be used to assess the status of alewife fisheries in this region. Using a simulation model, we found that an $F_{35\%}$ strategy would produce greater than 90% MSY for populations in this region, and was more precautionary than F_{msy} if the maximum reproductive rate of a population is overestimated. This rate corresponds to an exploitation rate of 38% for the Mactaquac Headpond population and 42% for the Gaspereau River population.

Introduction

Alewife, *Alosa pseudoharengus,* is an anadromous member of the herring family that reproduces in many rivers in eastern North America. Adults of this species ascend rivers during the spring to spawn in lakes, pools or stillwaters within the watershed. Young-of-the-year remain in freshwater until mid-summer to late fall when they migrate to the sea. Fish mature at two to six years of age, and maturity schedules vary among populations and years. The species is iteroparous and may spawn up to five times over a lifespan of about ten years (these values can vary from river to river).

Within the Maritime provinces, alewife support both recreational and commercial fisheries. They are also taken in both directed and by-catch commercial fisheries during coastal migrations along the eastern seaboard (Rulifson 1994). They are a prey species both at sea and in freshwater and are a predator that can alter zooplankton composition within lakes. They may also serve as a vector for nutrient transport from the oceans to inland waters (Durbin et al. 1979; Garman and Macko 1998). As a result, over-exploitation or extirpation of alewife populations may alter the productivity of their natal watersheds, including production of freshwater and other anadromous fish.

Using questionnaires mailed to fisheries biologists, Rulifson (1994) found that alewife occupied 59 of 62 Bay of Fundy rivers included in the survey. Only one of these populations was identified as increasing, while 53 were thought to be in decline. Causes were identified for 21 of these rivers and dams were the primary cause (20 rivers). Overfishing was not included in the survey.

Within the Maritime provinces, landings of this species are reported as river herring, and include the combined landings of Blueback Herring, *Alosa aestivalis*, and alewife. Reported landings in the Bay of Fundy averaged 2,493 t during the 1960 to 1999 time period, and ranged from 870 to 6,700 t (DFO 2001). Since 1990, landings have been 50 to 70% of this average. The largest fishery in the Bay of Fundy is located on the Saint John River (1950 to 1999 mean landings = 2,303 t), with smaller fisheries in the Shubenacadie (1960 to 1999 mean landings ~ 130 t) and Gaspereau Rivers (1964 to 1999 mean landings = 208 t). At the mouth of the Bay of Fundy, the Tusket and Annis Rivers also support river herring fisheries (1960 to 1999 mean landings = 331 t). Several smaller fisheries are located around the Bay of Fundy (Jessop 1999).

Biological reference points (BRPs) are indices, based on the biological characteristics of a fish stock, that are used to gauge whether specific management objectives, such as maintaining stocks at a level capable of producing long-term maximum sustainable yield, are being achieved. Many of the commonly used BRPs are derived from spawner-recruit (SR), spawner per recruit and yield per recruit analyses, although alternative approaches have been suggested for situations where little or no data exist for the population of interest.

Gibson and Myers (in review) derived a production model for alewife and estimated several reference points for four alewife populations in the Maritime provinces. They found that an $F_{35\%}$ strategy (fish at a rate that reduces the spawning biomass produced per recruit to 35% that produced in the absence of fishing) appeared reasonable for these populations. Additionally, Gibson and Myers (in press[a]) carried out a meta-analysis of the population dynamics of eight anadromous alewife populations in eastern North America, and found little variability in the empirical Bayes estimates of the maximum reproductive rates among populations. Together, these analyses suggest that the dynamics of most alewife populations are sufficiently similar that given a common management objective, target exploitation rates will also be similar.

In this paper, we present a summary of these analyses using the Gaspereau River, Nova Scotia, population as an example. First, we find the maximum likelihood estimate of the exploitation rate and spawner biomass that produces maximum sustainable yield for this population. We find that this dataset (as well as most other alewife datasets) contains only limited information about this reference point, and that the data do not preclude the possibility of larger catches than at present. We then use Bayesian and decision theoretic methods that explicitly include estimation uncertainty to find the exploitation rate that maximizes the expectation of the catch. Process variability (variability around the SR relationship and variability in maturity schedules) can also alter the size of in-river spawning migrations from year to year. Finally, we describe a simulation model that can be used to evaluate the effects of process variability on the performance of target exploitation rates.

Gaspereau River Alewife Data

Data for the Gaspereau River alewife population consist of the annual catch of the years 1964 to 2001, spawning escapement counts at a fish ladder for the years 1970, 1982 to 1984 and 1997 to 2001, and estimates of the run composition by age, sex and previous spawning history during 1982 to 1984 and 1997 to 2001 (Gibson and Myers 2001). These data were used to estimate the spawner abundance in each year, the number of age-3 recruits in each year, annual exploitation rates, maturity schedules, and natural mortality using a statistical, life history-based, age-structured, stock assessment model designed specifically for *Alosa* (Gibson and Myers in press[b]). The model output was used for the following analyses. The catch for the Gaspereau River, reported as the number of 50 lb pails (about 120 to 135 fish/pail), is shown in Figure 1. The catch peaked in 1978 at just over 20,000 pails, followed by very low catches in the early 1980s. While the catch has fluctuated since then, each peak catch is smaller than the preceding peak. The median catch from 1964 to 2001 is 5,600 pails. Spawning escapement counts on the Gaspereau River have ranged between 50,400 in 1982 to 238,842 in 2001 (Table 1). Exploitation rate estimates range between 38.5% and 89.4%.

Alewife Population Dynamics and Production

In order to analyze their population dynamics, we divided the life cycle of alewife into two parts. First we analyzed the rate at which spawners produce recruits. We chose three years of age as the age of recruitment, the earliest age at which we see mature fish in the Gaspereau River. We modelled the number of recruits produced in each year as a function of spawner abundance using a Beverton-Holt spawner-recruit (SR) model, which gives the number of recruits in yearclass t, R_t as a function of the spawning biomass in year t, SSB_t:

$$R_t = \frac{\alpha SSB_t}{1 + (\alpha SSB_t / \mathrm{R}_0)}$$

Here, α is the slope at the origin, and in the deterministic model is the maximum rate at which spawners can produce recruits at low population sizes (Myers et al. 1999). R_0 is the asymptotic recruitment level (expressed as the number of age-3 recruits), and is the limit approached by R_t as SSB_t approaches infinity (Beverton-Holt models are often written in terms of the half saturation constant, K, which is related to to R_0 by: $R_0 = \quad K$). Parameter estimates for each population were obtained by using maximum likelihood assuming a lognormal error structure (Myers et al. 1995).

Second, we modelled the rate at which recruits produce spawners (the inverse of the slope of the replacement line) by calculating the spawning biomass per recruit (SPR) as a function of fishing mortality, F, maturity schedules, growth and natural mortality (Gibson and Myers in press[a]). For a given value of F, the spawning biomass produced by the number of recruits in year t is $SSB = SPR_F \cdot R_t$.The corresponding equilibrium spawning biomasses, recruitment levels and catches (C), denoted with asterisks, are then:

$$SSB^* = \frac{(\alpha SPR_F - 1)R_0}{\alpha}, \qquad R^* = \frac{\alpha SSB^*}{1 + \frac{\alpha SSB^*}{R_0}}, \text{ and } C^* = R^* \cdot YPR_F.$$

Here, YPR_F is the yield per recruit at a given F and is found analogously to the spawning biomass per recruit at a given F. From this equilibrium model, the fishing mortality rate that produces maximum sustainable yield, F_{msy}, and the corresponding spawner biomass, SSB_{msy} and catch, C_{msy}, are found using a grid search across F.

The spawner recruit relationship for Gaspereau River alewife is shown in Figure 2. The maximum likelihood estimate (MLE) of the maximum annual reproductive rate is 96.1, which, in the deterministic model is the maximum number of age-3 fish produced per kilogram of spawner biomass in a single year in the absence of density dependent mortality. The MLE of the asymptotic recruitment level is 1.56 million age-3 fish. The coefficient of variation is 0.43. The replacement line is also shown in Figure 2. In the absence of fishing mortality, a single age-3 recruit produces about 0.36 kg of spawner biomass ($SPR_{F=0}$) throughout its life. The population equilibrium occurs where the replacement line intersects the spawner-recruit relationship. As fishing mortality increases, the slope of the replacement line also increases, and the population equilibrium decreases (shifts to the left on the graph). If the slope of the replacement line is steeper than the slope at the origin, the population equilibrium goes to zero. The MLE of the exploitation rate that produces MSY is 0.63 and that of the rate that produces stock collapse is 0.93. Two things are evident from Figure 2: most spawner abundances are below the level that produces MSY, and there is considerable variability about the SR relationship. Clearly, the reference points derived from this model are only as good as the SR parameter estimates for this model.

Uncertainty in the Spawner-Recruit Parameters

We evaluate the uncertainty of the SR relationship examining the joint log-likelihood surface for the SR parameters (Figure 3). The likelihood gives the probability of the observed data given a set of parameter values (we display the log-likelihood because likelihoods can be very small). The likelihood surface contains an "L"-shaped ridge along which parameter combinations are not significantly different from each other at a 95% confidence level. The data do not preclude the possibility that larger recruitments are possible at lower estimates of the maximum reproductive rate, or the possibility that the maximum reproductive rate is being under estimated.

Gibson and Myers (in press[a]) carried out a meta-analysis of the maximum lifetime reproductive rates and habitat carrying capacities of alewife. We used the results of this analysis to derive probability distributions for the SR parameters, and then used these probability distributions to assess the plausibility of the different combinations of SR parameters. These distributions suggest that the MLE of the maximum reproductive rate for the Gaspereau River population is high relative to other alewife populations, while the MLE of the asymptotic recruitment level is low relative to other populations. Using Bayesian and decision theoretic methods, these probability distributions can be combined with the likelihood surface to obtain a probability surface for the SR parameters that include both the stock specific information and information from other populations. The equilibrium catch can be calculated for a set of SR parameters and exploitation rates, which can then be combined with the probability surface to find the exploitation rate that maximizes the expectation of the catch. For the Gaspereau River, this rate (0.56) is less than the MLE of the exploitation rate at MSY (0.63). This approach to estimating a target exploitation rate is preferable to finding the maximum likelihood estimate of F_{msy} because (for this population) the MLE is not well determined by the data, this uncertainty is explicitly included when maximizing the expectation of the catch, and information from other populations is also included in the analysis.

An alternative perspective on reference points for fisheries when the spawner-recruit relationship is uncertain is to find the fishing mortality rate that reduces the spawning biomass produced by a recruit to some percentage of that in the absence of fishing (Mace and Sissenwine 1993). This reference point is called $F_{x\%}$, where x is the percentage remaining. Typical values of x for many fisheries are in the range of 30 to 45%. For Gaspereau River alewife, the exploitation rate corresponding to $F_{35\%}$ is 0.42 (Gibson and Myers in review), slightly higher than those for the Mactaquac Headpond (0.40), the Miramichi River (0.39) and the Margaree River (0.37).

Using a simulation model, Gibson and Myers (in review) compared the performance of several reference points for alewife, and found that, on average, an $F_{35\%}$ strategy produced greater than 90% of the median catch when fishing at F_{msy}. $F_{35\%}$ was less than the rate that maximized the exploitation of the catch. They concluded that that this reference point was precautionary if the maximum annual reproductive rate (and hence F_{msy}) was being overestimated, but was not overly conservative because it provided a large portion of catch if the estimate of maximum annual reproductive rate was correct. They also used the simulation models to compare average catches and spawning escapements for exploitation rates ranging from 0 to 99% (Figure 4). The data points form a curve called the frontier, which separates the region of the possible from the region of the not possible. The best strategies fall along this frontier (from any point within the region of the possible, either catches or spawning escapements can be improved by moving towards the frontier), and the most favourable strategies are closest to the upper right corner (both high catches and high spawner escapements). The simulations suggest that both the equilibrium catch and spawning escapement would increase if the fishing mortality rate was decreased from recent levels. Additionally, the model results suggest that the equilibrium catch at spawning escapements of about 500,000 fish would be similar to the equilibrium catch at current levels of spawning escapement (typically less than 200,000 fish). Using similar models for three other populations, Gibson and Myers (in review) concluded that the $F_{35\%}$ performed well for all populations.

While this paper shows that fishing mortality rates have been high for Gaspereau River alewife, the outlook for this population is presently very positive. A fishery advisory committee has been established for the Gaspereau River alewife, and new regulations have been introduced in 2002 to reduce exploitation rates on this population. The population is not only affected by fishing, but also by hydroelectric development. New fish passage facilities (both upstream and downstream) were constructed on this river system in 2001, and water management strategies have been developed to reduce the impacts of hydroelectric generation on fish populations in this watershed.

References

Department of Fisheries and Oceans (DFO). 2001. *Gaspereau Maritime Provinces Overview*. DFO Science Stock Status Report D3-17 (2001). Fisheries and Oceans Canada, Ottawa.

Durbin, A. G. S., S. W. Nixon and C. A. Oviatt. 1979. Effects of the spawning migration of the alewife on freshwater ecosystems. Ecology 60: 8–17.

Garman, G. C., and S. A. Macko. 1998. Contribution of marine-derived organic matter to an Atlantic coast, freshwater, tidal stream by anadromous clupeid-fishes. Journal of the North American Benthological Society 17: 277–285.

Gibson, A. J. F., and R. A. Myers. 2001. Gaspereau River alewife stock status report. CSAS Res. Doc. 2001/061. Canadian Science Advisory Secretariat, Fisheries and Oceans Canada, Ottawa.

Gibson, A. J. F., and R. A. Myers. In press[a]. A meta-analysis of the habitat carrying capacity and the maximum lifetime reproductive rate of anadromous alewife in eastern North America. Transactions of the American Fisheries Society.

Gibson, A. J. F., and R. A. Myers. In press[b]. A statistical, age-structured, life history based, stock assessment model for anadromous *Alosa*. Transactions of the American Fisheries Society.

Gibson, A. J. F., and R. A. Myers. In review. Biological reference points for anadromous alewife (*Alosa pseudoharengus*) fisheries in the Maritime Provinces. Canadian Technical Report of Fisheries and Aquatic Sciences.

Jessop, B. M. 1999. The status (1960-1997) of alewife and blueback herring stocks in the Scotia-Fundy area as indicated by Catch-Effort Statistics. CSAS Res. Doc. 1999/117. Canadian Science Advisory Secretariat, Fisheries and Oceans Canada, Ottawa.

Mace, P. M. and M. P. Sissenwine. 1993. How much spawning per recruit is enough? Pages 101–118. In: *Risk Evaluation and Biological Reference Points for Fisheries Management*. S. J. Smith, J. J. Hunt and D. Rivard (Eds.) Canadian Special Publication of Fisheries and Aquatic Sciences 120.

Myers, R. A., K. G. Bowen, and N. J. Barrowman. 1999. The maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences 56: 2404–2419.

Myers, R. A., J. Bridson, and N. J. Barrowman. 1995. Summary of Worldwide Spawner and Recruitment Data. Canadian Technical Report of Fisheries and Aquatic Sciences 2024. Department of Fisheries and Oceans, St. John's, NL. 327 pp.

Rulifson, R. A. 1994. Status of anadromous *Alosa* along the east coast of North America. Anadromous *Alosa* Symposium, 1994, Tidewater Chapter, American Fisheries Society. pp. 134–158.

Table 1. Summary of alewife counts at the White Rock fish ladder, estimated stock size, and the annual catch and exploitation rates of the alewife fishery.

Year	Alewife Count	Catch (number of fish)	Stock Size	Exploitation Rate (%)
2001	238,842	149,422	388,264	38.5
2000	98,883	754,585	853,468	88.4
1999	81,326	698,600	770,926	89.4
1998	171,639	372,400	544,039	68.5
1997	95,433	611,520	706,953	86.5
1995	126,933 (partial)	954,960	>1,081,893	<88.3
1984	111,100	212,966	324,066	69.9
1983	114,800	150,408	265,208	56.7
1982	50,400	254,068	304,468	80.9
1970	60,527	480,000	540,527	88.9

Figure 1. The reported alewife catch in the Gaspereau River, NS, from 1964 to 2001.

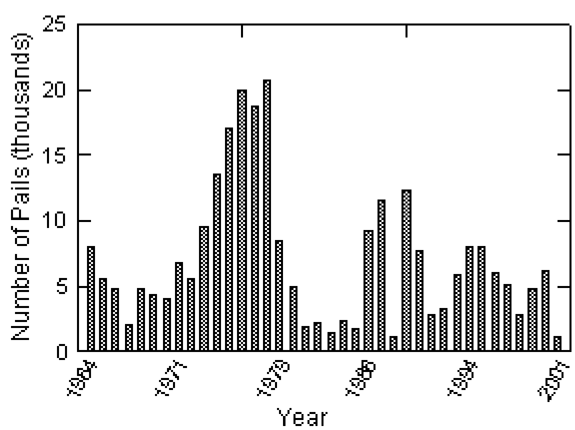


Figure 2. The spawner-recruit relationship and the production model reference points for the Gaspereau River alewife population. The solid line is the spawner-recruit relationship and the dotted line is the replacement line in the absence of fishing mortality. The dashed lines are the replacement lines corresponding to fishing at MSY and at stock collapse.

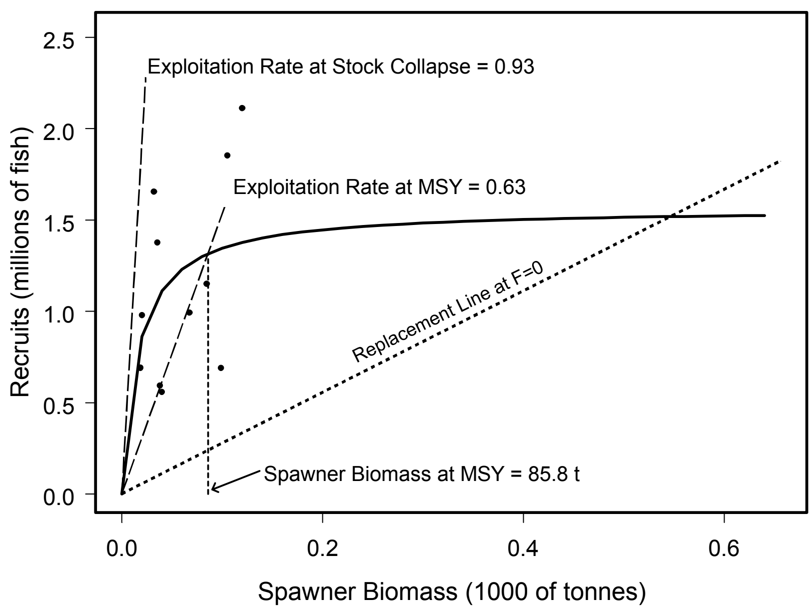


Figure 3. The lower left panel is the log-likelihood surface for the maximum reproductive rate and the asymptotic recruitment level for the Gaspereau River alewife population. The black square shows the point where the log-likelihood is maximized. The contour interval is -1 and the grey shaded area is a 95% confidence region for the two parameters. The top and right panels show probability distributions for the maximum reproductive rate and the asymptotic recruitment for alewife at the species level.

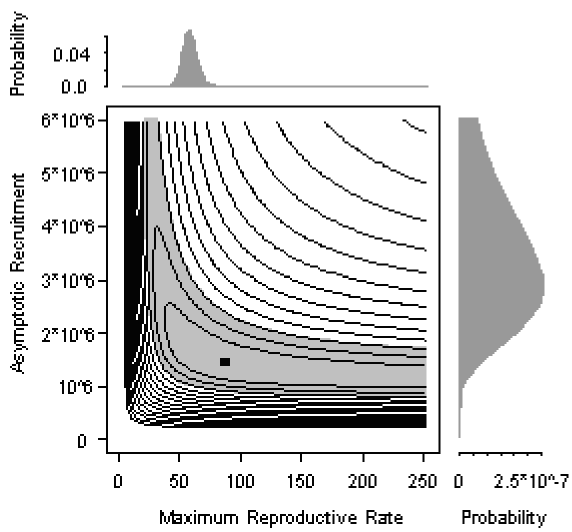
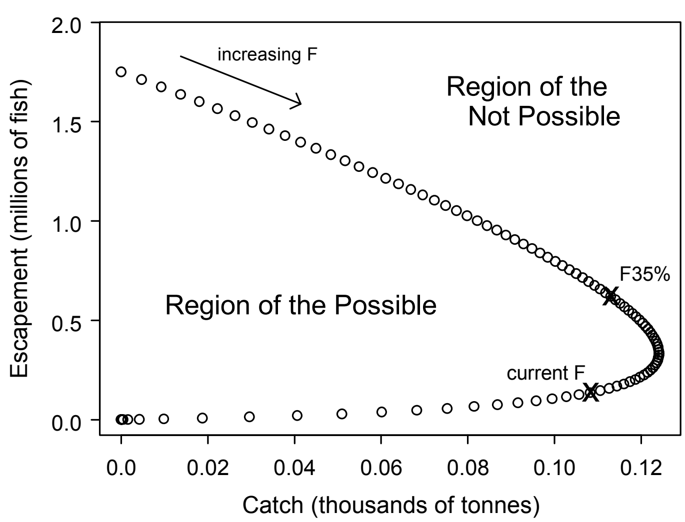


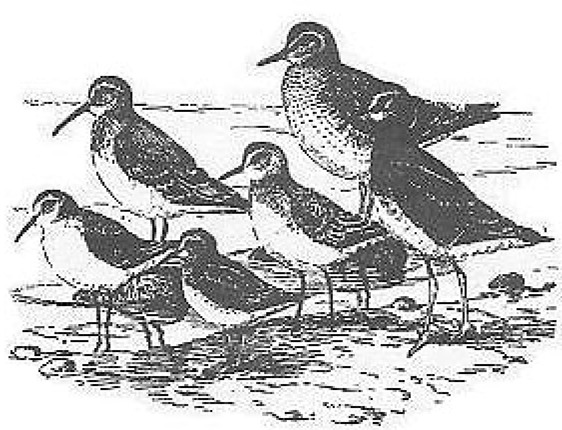
Figure 4. A summary of the simulation model results showing how spawning escapement and catch vary with exploitation rate (u). The uppermost point is $u = 0.00$, and u increases by 0.01 to a maximum of 0.99 in the lower left corner. Each point shows the mean spawning escapement and catch of 100 50-year Monte Carlo projections at the given exploitation rate. The "x"'s mark the mean exploitation rate on the Gaspereau River for the years 1982–1984 and 1997–2000, and the exploitation rate corresponding to $F_{35\%}$.



Session Four

WILDLIFE AND HABITAT CONSERVATION

Chair: Al Hanson, Canadian Wildlife Service, Sackville, New Brunswick



THE SEMIPALMATED SANDPIPER IN THE BAY OF FUNDY, 1981–2001: DECLINES IN THE EASTERN POPULATION

Peter W. Hicklin and John W. Chardine

Canadian Wildlife Service, Environment Canada, Sackville, NB. peter.hicklin@ec.gc.ca

Introduction

Since the initiation of the of the Maritimes Shorebird Surveys in 1974 (see Howe et al. 1989), the populations of some species of North American migratory shorebirds have been in decline (Morrison et al. 1994). Over the past three decades, six species of migrant shorebirds, including the Semipalmated Sandpiper, have been undergoing significant population declines. The other five species are: Red Knot, Least Sandpiper, Short-billed Dowitcher, Dunlin and Spotted Sandpiper. During the course of the annual southward migration to wintering grounds in South America, over 75% of the world population of the Semipalmated Sandpiper stop in the Bay of Fundy prior to completing the final leg of their migration across the Atlantic to the northeastern coast of South America. Since 1981, before the birds departed from the Bay of Fundy to their wintering grounds, approximately 32,000 sandpipers have been captured and banded in Johnson's Mills in Chignecto Bay; of these, the morphometrics (wing and bill lengths) of slightly more than 15,000 birds were measured (see Table 1). Since the bill lengths of Semipalmated Sandpipers display a cline of longer-billed to shorter-billed birds from east to west (Morrison and Harrington 1979), populations of this species can be distinguished on the basis of bill length. During the 1980s, early arrivals to the Bay of Fundy tended to be the long-billed eastern breeders with mean bill lengths greater than 20.0 mm.

Study Area and Methods

The birds were captured at Johnson's Mills, N.B., along the beach bordering the Grande Anse mudflat, near Dorchester Cape. During the first three field seasons (1981, 1982 and 1986), we captured sandpipers at Johnson's Mills using mist nets and captured, on average, 74 birds/high tide (Table 1). In order to determine where the birds overwintered, larger numbers needed to be captured and banded. Consequently, we invented the Fundy Pull Trap (see Hicklin et al. 1989) and increased our daily capture rates to 209 birds/high tide period. In the course of putting bands and leg flags on the birds, the fresh weights and bill and wing lengths of all the birds captured were recorded. Bill lengths were measured with dial-metric calipers (150 mm capacity; 0.1 mm divisions) from the base of the bill, at the edge of feathering, to the bill tip; a 15 cm (right-handed) wing rule (Avinet Inc.) was used to measure wing lengths.

Results and Discussion

Chronology of Migration

The movements of Semipalmated Sandpipers through the Bay of Fundy during the birds' southward migration is rapid. Their numbers peak quickly through late July and early August and decline equally rapidly through the latter part of August (Figure 1).

The Capture of Birds and Morphometric Measurements

Over eleven field seasons, a total of 31,792 sandpipers were captured; of these, 15,252 were banded and measured (all years except 1988), 15,446 were banded only (1987, 1988 and 1989) and 1,094 were banded and weighed only (Table 1).

Based on museum specimens, Harrington and Morrison (1979) showed that the bill and wing lengths of Semipalmated Sandpipers varied along a cline of declining lengths from east to west: those birds from the easternmost breeding areas (Belcher Islands and Hudson Bay) had significantly longer bills and wings than those of populations breeding west of Hudson Bay (e.g., Alaska and Banks Island) (Figure 2). Therefore, knowing the relevance of these morphometric measurements as a means of distinguishing between eastern and western populations, we plotted the bill lengths of all the sandpipers captured in the Bay of Fundy for which data on bill lengths were available. The results illustrate clear declines in both the bill and wing lengths of Semipalmated Sandpipers captured at Johnson's Mills (Figures 3 and 4, respectively). It may be noteworthy to point out a slight increase in mean bill length in 2001 (Figure 3) although the significance of this cannot be recognized until a few more field seasons can show if this is the beginning of a significant trend or simply a sampling error. The next few years should clarify this. Along with five other species of migrant shorebirds in North America, the population of Semipalmated Sandpipers is known to be undergoing significant declines (Morrison and Hicklin 2001). The evidence presented here suggests that this decline may be principally due to declining numbers of the eastern breeding population (i.e., the long-billed birds).

The Role of the Bay of Fundy

The banding and measuring of Semipalmated Sandpipers has continued intermittently in the Bay of Fundy since 1981. Furthermore, the amphipod *Corophium volutator*, which constitutes the main prey of the sandpipers during their stay in the Bay of Fundy, has been sampled fairly consistently in Minas Basin since 1976 (see Hicklin 1981) and annually in Chignecto Bay since 1997 (Hicklin unpublished). Over the eleven years that banding has occurred, the fresh body weights of the sandpipers have been recorded. In all years up to the present, average fresh weights of <30.0 grams have only occurred once (in 1999; see Figure 5) and, except for significant reductions at the Grande Anse mudflat since 1993, densities of *Corophium* remain high on all the major mudflats used by the sandpipers for foraging (see Shepherd et al. 1995).

The Bay of Fundy could only be considered as a source of mortality for the sandpipers if they were unable to deposit, i.e. store, the sufficient levels of fat during their stay in Fundy. It is these stored epidermal lipids accumulated by the birds which fuel the non-stop migratory flight over the Atlantic Ocean between the Maritime Provinces and wintering grounds in the Guyanas in northeastern South America. However, all the available data indicate that, overall, *Corophium* densities remain high in both Chignecto Bay and Minas Basin and the birds' fresh weights also continue to attain high levels prior to departure from Fundy. These data all suggest that the birds have not encountered any significant difficulties to deposit fat reserves in the Bay of Fundy during the southward migration. Therefore, since we know that the species is undergoing significant population declines in North America and that there appear to be no evident problems of food supply in the Bay of Fundy which might be impacting on the world's population of this species, the observations of declining bill and wing lengths of Semipalmated Sandpipers at Johnson's Mills in Chignecto Bay suggest that problems may lie north or south of Fundy and within the species' boundaries in the Western Hemisphere. Since the long-billed birds appear to be the group most affected, it would appear that research in the birds' easternmost breeding areas (northern Quebec, Ontario and Manitoba) or wintering grounds in the Guyanas and Brazil (i.e. long-billed birds) would be the most promising regions to conduct studies which would uncover the reasons for these severe population declines.

Acknowledgements

Nev Garrity, Julie Paquet and many volunteers (especially Paul Donahue and Teresa Wood) have assisted with capture, banding and data entry and analysis. Graham Daborn has always provided interesting insights about the Bay of Fundy and Nancy Roscoe-Huntley did everything possible to ensure the success of the 5th Bay of Fundy Science Workshop for which many of us are extremely grateful. Richard Elliot has been a source of support since the beginnings of shorebird studies in the Bay of Fundy.

References

Harrington, B. A. and R. I. G. Morrison.1979. Semipalmated Sandpiper migration in North America. In: *Shorebirds in Marine Environments*. F. Pitelka (Ed.). Studies in Avian Biology No. 2. A publication of the Cooper Ornithological Society, Alien Press Inc., Lawrence, KS. 261 pp.

Howe, M. A., P. M. Geissler and B. A. Harrington. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation 49: 185–199.

Morrison, R. I. G. and P. W. Hicklin. 2001. Recent trends in shorebird populations in the Atlantic Provinces. In: *Bird Trends,* Number 8, Winter. J. Kennedy (Ed.). Canadian Wildlife Service, Environment Canada, Ottawa, ON. 52 pp.

Shepherd, P. C. F., V. A. Partridge and P. W. Hicklin. 1995. Changes in Sediment Types and Invertebrate Fauna in the Intertidal Flats of the Bay of Fundy Between 1977 and 1984. Technical Report No. 237, Canadian Wildlife Service, Atlantic Region, Sackville, NB. 165 pp.

Table 1. The numbers of Semipalmated Sandpipers captured at Johnson's Mills, 1981–2001 (n=31,792)

Year	Banded and Measured	Banded Only	Banded and Weighed Only
1981	1,239	-	-
1982	1,795	-	-
1986	2,438	-	-
1987	1,624	4,805	-
1988	-	9,738	-
1989	304	903	781
1997	1,800	-	-
1998	1,604	-	-
1999	1,600	-	-
2000	932	-	313
2001	1,916	-	-
11 years	**15,252**	**15,446**	**1,094**

Figure 1. The chronology of the migration of Semipalmated Sandpipers in the Bay of Fundy. The solid line represents the peak number of sandpipers roosting at Mary's Point in Chignecto Bay over an 8-year period (1978–1986) while the dotted line represents the average number over that time period.

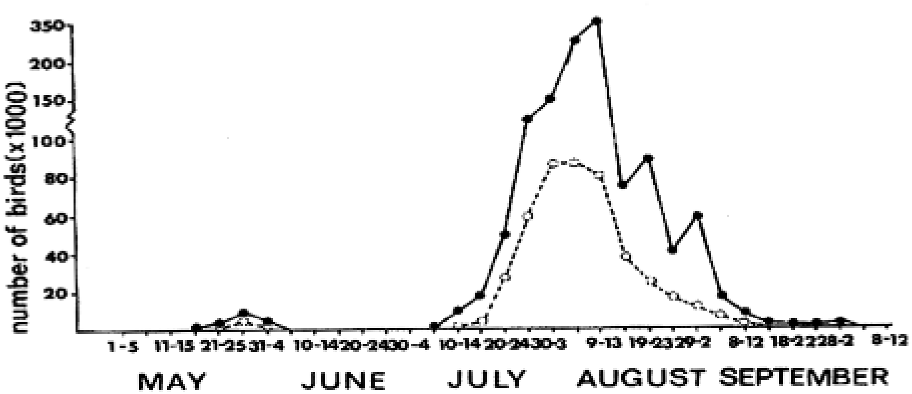


Figure 2. Mean bill lengths of male and female Semipalmated Sandpipers. Locations are ordered from west to east. Data are taken from Harrington and Morrison (1979).

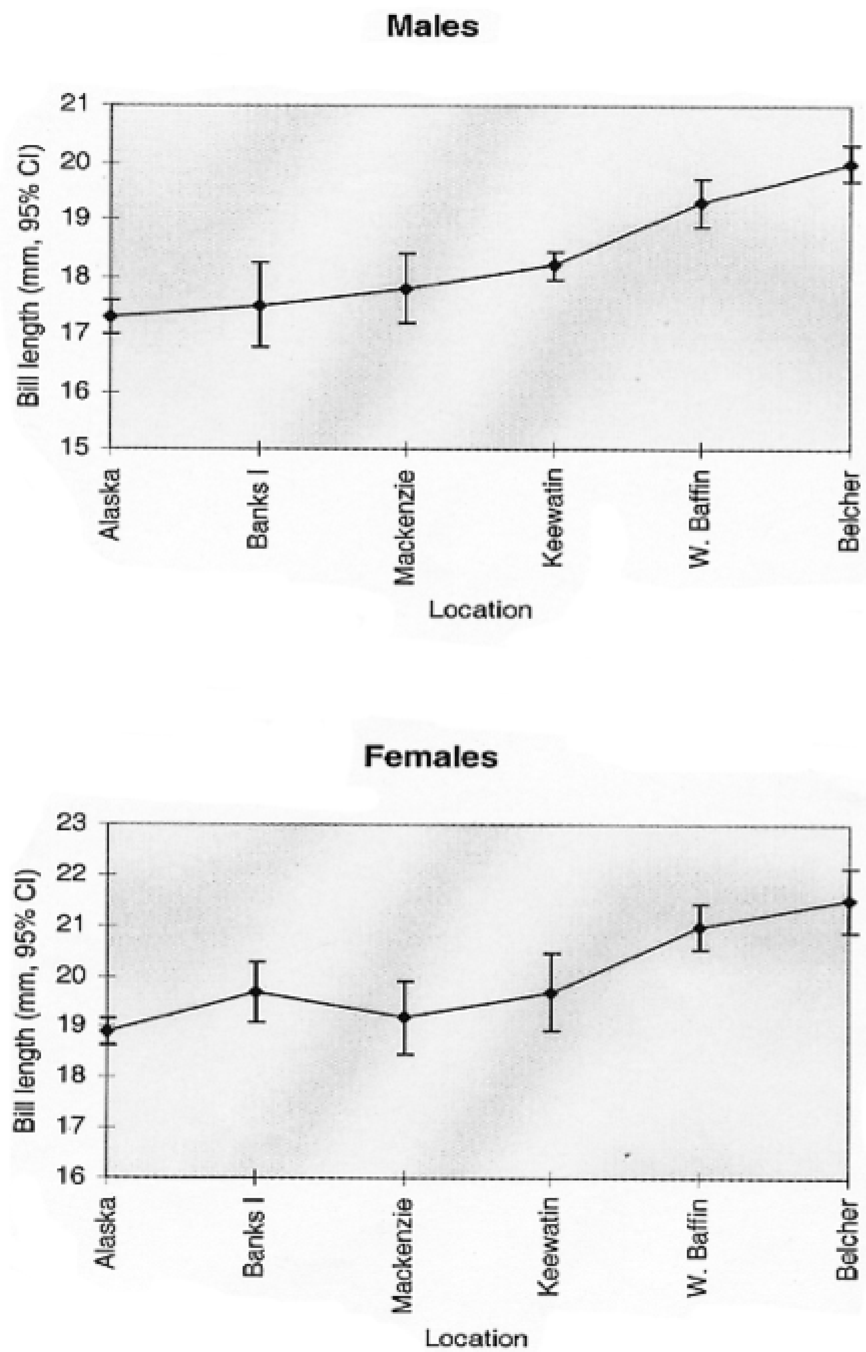


Figure 3. Annual mean bill lengths of adult Semipalmated Sandpipers captured at Johnson's Mills

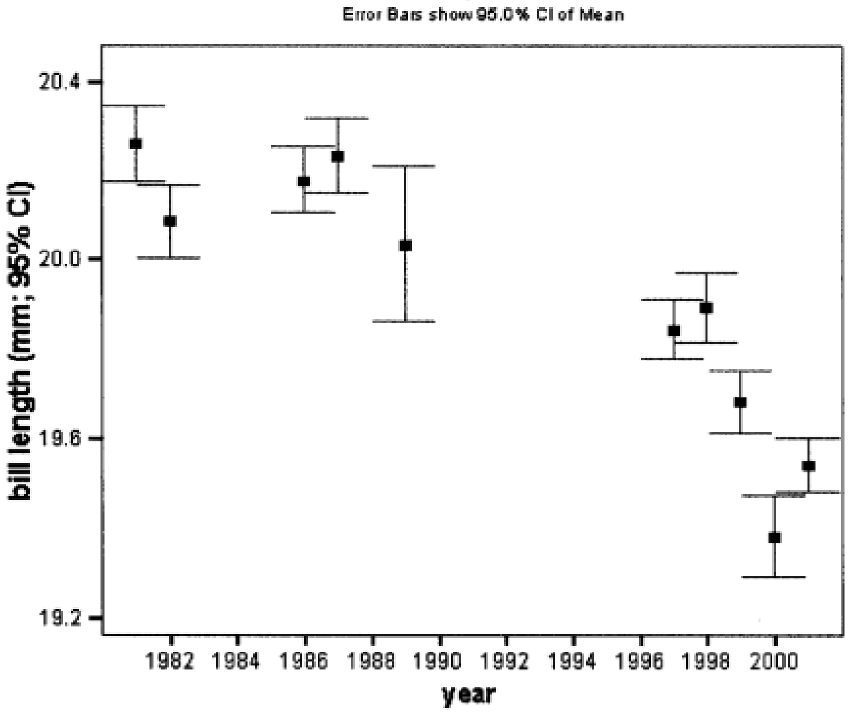


Figure 4. Annual mean wing lengths of adult Semipalmated Sandpipers captured at Johnson's Mills

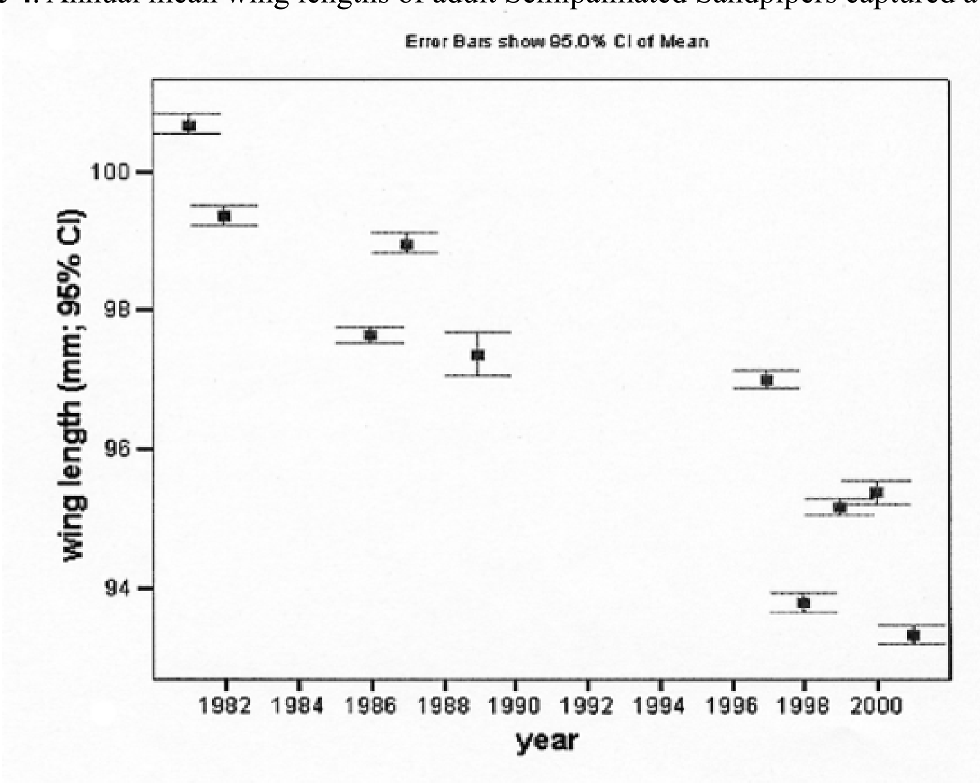
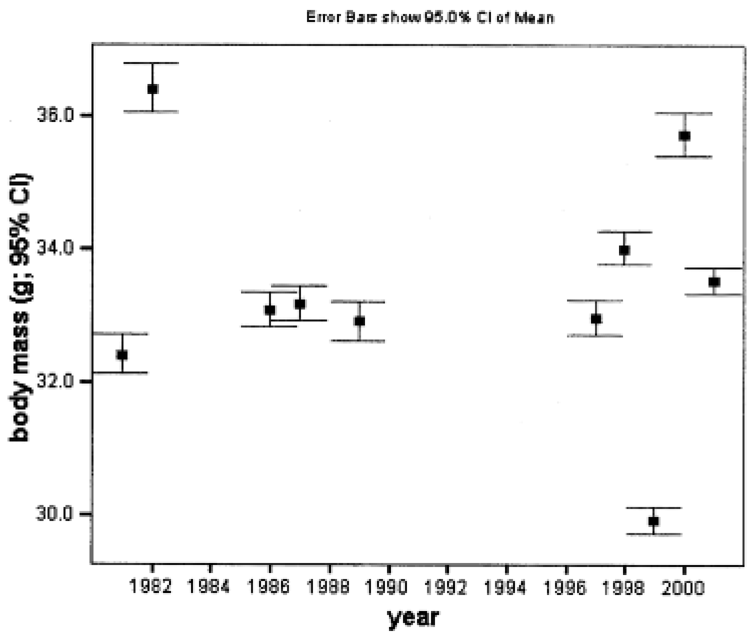


Figure 5. Annual mean body mass of adult Semipalmated Sandpipers captured at Johnson's Mills



THE NATURE CONSERVANCY OF CANADA–UPPER BAY OF FUNDY PROJECT

Josette Maillet

The Nature Conservancy of Canada, Atlantic Region, Fredericton, NB.
josette.maillet@natureconservancy.ca

Shepody and Chignecto Bays in New Brunswick and the Southern Bight of the Minas Basin in Nova Scotia are characterized by extremely high tides, extensive mudflats, and the largest concentration of salt marshes in the Bay of Fundy. Over 75 percent of the world population of Semipalmated Sandpipers (*Calidris pusilla*) leave their breeding grounds in Canada's arctic and subarctic regions and fly non-stop to the upper Bay of Fundy, converging on the nutrient-rich mudflats. The inter-tidal and sub-tidal areas are undeeded and technically under the jurisdiction of the provinces. However, roosting beaches and the adjacent upland habitat, critical to the shorebirds at high tide, are under private ownership and have strong recreation and development potential.

The Nature Conservancy of Canada (NCC) is dedicated to the creation of nature preserves and the conservation of ecologically significant lands through outright purchase, donation, and conservation agreements. NCC, in co-operation with the Canadian Wildlife Service, the New Brunswick Department of Natural Resources and Energy and the Nova Scotia Department of Natural Resources, is working with willing landowners to secure critical shoreline properties throughout the Chignecto and Shepody Bays and the Southern Bight of the Minas Basin. Three hundred acres of habitat have been secured and efforts to secure additional land are ongoing.

The NCC uses a strategic, science-based approach to land securement which defines conservation goals and measures of success across multiple geographic scales. Conservation planning is applied to individual properties, as well as property assemblages (sites) that are ecologically connected, and site assemblages (portfolios) within a common environmental zone (ecoregion). The initial phase of the process is developing an Ecoregional Plan called a Conservation Blueprint. It establishes biodiversity conservation priorities across jurisdictional, administrative and ownership boundaries.

The next phase is the design of a Site Conservation Plan. The goal of Site Conservation Planning is the maintenance or enhancement of the long-term survival of species and habitats (conservation targets) through science-based strategic planning. It is based on the Five-S Framework for Site Conservation designed by the Conservation Science Division of the The Nature Conservancy (TNC), our sister organization in the United States. The process evaluates information about a particular site, i.e. systems (conservation targets), stresses and sources of stress resulting in two specific products – conservation strategies and measures of conservation success, all of which are documented in a completed plan. This approach to land conservation allows a more comprehensive examination of sites and potential threats, in order to implement more effective and efficient conservation efforts.

The first Site Conservation Plan for the NCC Atlantic Regional office is currently under way for the upper Bay of Fundy, with a focus on shorebirds and their habitat requirements as conservation targets. It is anticipated that other Site Conservation Plans will be undertaken for priority conservation areas identified through the ecoregional planning process.

BIRD COMMUNITIES OF BAY OF FUNDY COASTAL WETLANDS

Al Hanson

Canadian Wildlife Service, Environment Canada, Sackville, NB. al.hanson@ec.gc.ca

Volunteers and Canadian Wildlife Service (CWS) staff are currently conducting a study to determine the abundance and diversity of birds using salt marshes and coastal wetlands in the Maritimes. A second objective is to identify habitat factors that explain the observed patterns of distribution.

The loss of coastal wetlands (salt marshes, barachois ponds, brackish marshes) in Atlantic Canada is one of the most severe and publicized cases of wetland loss in Canada. It has been estimated that 65 percent of salt marshes have been lost in the upper Bay of Fundy. Recently, there has been much public support for the conservation and restoration of coastal wetlands, including salt marshes in the Maritimes. However, there is little information on how these activities should be directed in order to conserve and restore wildlife populations that use these habitat types.

Whereas the loss of coastal wetlands has been severe, there may have also been declines in populations of birds that are dependent on coastal wetlands. Bird surveys conducted for this project provide valuable information required for updated population estimates. Special wetland conservation and restoration projects may be required for species such as Willet (*Catoptrophorus semipalmatus*) and Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*) whose populations may only be 2,500 and 750 pairs respectively in the Maritimes (Erskine 1992).

The abundance and species of birds using coastal wetlands is determined using standard methods developed by the Audubon Society for synoptic surveys of salt marshes in the US Gulf of Maine. Using the same methodology will allow for valid comparisons between the Maritimes and New England. CWS staff collect habitat data on local and landscape scales. Local data include information on wetland size, vegetation, number and size of ponds, and frequency of flooding. Landscape-level data include information on adjacent natural features such as estuaries, rivers, mudflats, as well as disturbance features such as dwellings and roads. Preliminary results suggest that Nelson's Sharp-tailed Sparrows will use dykeland habitats, especially if large patches of *Spartina pectinata* are present. Habitat for Willets appears to be limited in many areas of the Bay of Fundy.

Reference

Erskine, A. J. 1992. *Atlas of Breeding Birds of the Maritime Provinces*. Nimbus Publishing, Halifax.

MONITORING OF COMMON LOON (*Gavia immer*) BREEDING SUCCESS ON WOLFE LAKE, FUNDY NATIONAL PARK

Douglas Clay[1], Shirley Butland[2], Ewan Eberhardt[2] and Joseph Kerekes[3]

[1] 135 Edgehill Dr. NW, Calgary, Alberta T2A 3W5 (formerly Fundy National Park)
[2] Fundy National Park, Parks Canada, Alma, NB
[3] Canadian Wildlife Service, Environment Canada, Dartmouth, NS. joe.kerekes@ec.gc.ca

The reproductive success of the Common Loon (*Gavia immer*) on Wolfe Lake (22 ha) has been continuously monitored since 1989. A pair of breeding loons has regularly occupied the lake in the last two decades (Clay and Clay 1997). Eggs were laid in 12 years, chicks hatched in 11 years and the young fledged in 9 years during the 14 years of the study. Two young fledged in 7 years and one young fledged on two occasions. Two adult loons and a juvenile were banded on Wolfe Lake in 1995. One adult female was recaptured in both 1996 and 1997 and a new juvenile was banded in those years (Neil Burgess, CWS, pers. com).

There are no lakes larger than Wolfe Lake within a 20-km distance from the park boundary. It was noted that all suitable and even marginal habitats (smaller lakes) are occupied by loons in the summer in the Bay of Fundy areas of New Brunswick and Nova Scotia (Kerekes 1999).

This small oligotrophic lake (total phosphorus concentration 5-7 Fmg L^{-1}) does not have enough fish to support a family of loons with two young. It has been shown that for oligotrophic lakes, such as that of Wolfe Lake, at least 40 ha in area is required to support a pair of loons with one chick to fledging on a sustained basis (Kerekes 1990; Kerekes et al. 1994).

However, small oligotrophic lakes (–20 ha) are known to support loons to fledging if other lakes are near by (e.g., Kejimkujik National Park), or close to the sea (e.g., Terra Nova National Park) where the adults can fly regularly to feed (Kerekes et al. 2000). Apparently Wolfe Lake is an example of a small lake not producing enough fish that may support young loons to fledging where the adults are using other lakes or the sea to supplement their nutritional requirements.

References

Clay, D. and H. Clay. 1997. Reproductive success of the Common Loon (*Gavia immer*), on a small oligotrophic lake in Eastern Canada. Can. Field Nat. 111(4): 586–590.

Kerekes, J. 1990. Possible correlation of Common Loon population with the trophic state of water body. Internat. Verein. Limnol. Verh. 24: 349–353.

Kerekes, J. 1999. The loons the of Bay of Fundy. Pages 27–28. In: Proceedings of the 3rd Bay of Fundy Science Workshop, "Understanding change in the Bay of Fundy Ecosystem", Mount Allison

University, Sackville, New Brunswick, April 22-24, 1999. J. Ollerhead, J., P. W. Hicklins, P. G. Wells and K. Ramsey (Eds.). Environment Canada - Atlantic Region. Occasional Report No. 12. Environment Canada, Dartmouth, NS.

Kerekes, J., R. Tordon, A. Nieuwburg. and L. Risk. 1994. Fish Eating Bird Abundance in Oligotrophic Lakes in Kejimkujik National Park, Nova Scotia, Canada. In: J. Kerekes and B. Pollard (eds.). Proc. Symp. Aquatic Birds in the Trophic Web of Lakes. Sackville, N.B., Canada. August 19-22, 1991. Hydrobiol. 279/280: 57-61.

Kerekes, J., R. Knoechel, P. M. Ryan and G. Stroud. 2000. Common Loon breeding success in oligotrophic lakes in Newfoundland, Canada. Verh. Internat. Verein. Limnol. (Proceedings of the International Association of Theoretical and Applied Limnology) 27: 171–174.

WILDLIFE HABITAT STEWARDSHIP IN THE AGRICULTURAL LANDSCAPE OF NOVA SCOTIA

James Ferguson

Wildlife Division, Department of Natural Resources, Kentville, NS.

Beginning with European settlement and continuing over approximately 400 years, wildlife and their habitats have been impacted by a variety of human development activities. Intensive agriculture, urban expansion, and other development pressures have dramatically altered the landscape of Nova Scotia. For example, approximately 60% of the original salt marsh habitat in Kings County has been dyked and drained since the early 1600s, 50% of the Annapolis Valley in Kings County has been cleared for agriculture production, and an estimated 80% of the freshwater wetlands of the area have been lost.

Currently the Wildlife Division, Nova Scotia Department of Natural Resources is co-operating with other government and non-government organizations involved in the agricultural and wildlife communities to develop a strategy to promote the stewardship of wildlife habitat within the agricultural landscape of Nova Scotia. Some of the information in this strategy will be relevant to the Bay of Fundy and could be used to address important agriculture/habitat issues that relate directly or indirectly to the issues facing the Bay.

WETLAND AND RIPARIAN EDGE CONSERVATION IN THE AGRICULTURAL LANDSCAPE

Reg B. Newell

Wildlife Division, Department of Natural Resources, Kentville, NS. newellrb@gov.ns.ca

Wetlands and riparian edges are an intricate and important component to the agricultural landscape. Riparian edges are generally natural areas at the edges of wetlands/waterways where upland and aquatic processes/vegetation meet and, to some extent, overlap. In addition to providing essential habitats for wildlife species (both plants and animals), wetlands and riparian edges act as filters and water control structures to reduce surface water contamination, erosion, flooding, and water runoff. The removal of wetlands or riparian edges from the ecosystem may result in the loss of wildlife habitat, increased erosion, increased surface water contamination, as well as increased flooding and more rapid water runoff.

Since 1989, the Eastern Habitat Joint Venture (EHJV), a partnership of government and non-government agencies, has been involved in wetland conservation throughout Nova Scotia. Although there are many partners in the NS-EHJV, the central core consists of the Canadian Wildlife Service, the Nova Scotia Department of Natural Resources, Ducks Unlimited, Wildlife Habitat Canada, and the Nature Conservancy of Canada. Since 1997, the NS-EHJV has been focussing much of its conservation effort on the agricultural landscape throughout the province. One of these efforts has been a riparian fencing project that is designed to assist livestock producers in their efforts to fence livestock out of wetlands and waterways. Between 1997 and 2001, over 1,700 acres of wetland/riparian edges have been protected on 60 sites in 10 counties. Concurrently, Ducks Unlimited, one of the NS-EHJV partners, has been delivering a small marsh project designed to re-establish wetlands in the agricultural landscape. Eighty-two (82) projects have been completed with 455 acres of wetlands constructed throughout the agricultural regions of the province. Each of these projects has successfully protected and restored wildlife habitat, however, as they are spread over the entire province, they are not concentrated enough to have a major impact on water quality or to provide connective wildlife corridors. In an attempt to address this concern, several government and non-government organizations have formed the Kings Agricultural Wetland Conservation Initiative (KAWCI). The partnership includes the Valley Watershed Stewardship Association (VWSA), Friends of the Cornwallis River Society, Municipality of Kings, NS-Eastern Habitat Joint Venture (including the Nova Scotia Department of Natural Resources and Ducks Unlimited Canada), and the agricultural community along with the several other potential partners.

Kings County was selected for the pilot project as it is the most intensively farmed county in Nova Scotia. Fifty-eight percent (58%) of the agricultural activities in the county are in the agricultural district located on the valley floor and includes the watersheds of the Cornwallis, Canard, Habitant, and Pereau Rivers. Both the agriculture effort and the greatest population densities are centred around these four east-flowing rivers which ultimately enter in the Bay of Fundy through the Southern Bight of the

Minas Basin, a Ramsar site and a Western Hemisphere Shorebird Reserve. Although residential, industrial, and agricultural activities all affect these watersheds, this project focusses on assisting the agricultural community to reduce their impact. Irrigation, pesticide and nutrient applications, livestock access to waterways, and agricultural waste runoff are common practices in these watersheds that can have a negative impact on both wildlife habitat and water quality. KAWCI partners have developed a multifaceted approach to address these issues at the watershed level. This initiative, which will focus on the eastern flowing watersheds of Kings County, is primarily an incentive project with three different components: riparian fencing, riparian leasing and small marsh/constructed wetlands.

Riparian Fencing

This component is designed to encourage livestock producers to fence off livestock access to wetlands (including salt marshes) and waterways and to leave a buffer strip (riparian edge) around these areas. The minimum setback is 5 m. The fencing projects, including alternative water systems and stream crossings, is a cost sharing effort in which the partners in KAWCI will pay up to 40% of the initial total cost of an approved project (maximum contribution is $5,000 per project). The producer is expected to contribute the remaining 60% either financially or in kind and to maintain the fencing for 15 years. This project will be undertaken in close association with the NS-EHJV Stewardship Coordinator and will follow the guidelines and agreements currently used by the NS-EHJV in their Riparian Management Project.

Riparian Leasing

This component focusses primarily on crop farmers in the Pereau, Cornwallis, Canard, Habitant, and Gaspereau watersheds. Crop producers along the waterways will be approached with an offer to lease their riparian lands for 10 years at a reduced rate (much of the riparian edge, in terms of farming, is marginal land). The minimum setback from the stream/river edge will be 5 m (1 acre of a 5 m setback is essentially 1 km). The setback distances will be established using semi-permanent markers and the landowner will sign an agreement to allow the natural vegetation to reclaim the area. In addition, the agreement would allow VWSA personnel and volunteers to re-introduce natural vegetation and native tree species and to monitor the area on a regular basis. (The landowner will still retain access to the waterways for irrigation purposes.) Farmers/landowners would be paid in full on signing the agreement. This method provides the farmer/landowner with a more appealing financial offer and eliminates the need for yearly tracking and payments. The VWSA will hold the lease agreements.

Small Marsh/Constructed Wetland Component

(For this component, the Ducks Unlimited Canada will take the lead. DUC is one of the leading agencies in Atlantic Canada in the development of small marshes and constructed wetlands.)

This component is designed for the enhancement, restoration and construction of small marshlands, and the establishment of constructed wetlands throughout the five Kings County watersheds.

Ducks Unlimited Canada (one of the NS-EHJV partners) has been providing a Small Marsh Project throughout Nova Scotia for several years that involves the restoration, enhancement or development of small marshes under 5 ha in size (generally in agricultural settings). Generally, DUC absorbs most of the cost of the construction and the landowner signs a management agreement to maintain the area as wildlife habitat for 20+ years. Although the marshes are not normally large enough for irrigation purposes, they can and have been used as a water supply for livestock. In addition, KAWCI will work with DUC, the NS-EHJV and crop producers in Kings County to install several experimental irrigation ponds/marshes that can provide both wildlife habitat and a source of irrigation water.

In Kings County, there are a variety of uses for both small marshes and constructed wetlands in addition to providing water sources for livestock and treating wastewater from intensive livestock operations. Ducks Unlimited Canada has already been involved in the enhancement and restoration of a wetland in King's County to provide an emergency holding area should the holding lagoons fail to contain the liquid manure. Although not designed to handle large volumes of waste, this type of system may be able to contain the waste material long enough to prevent a major contamination of the river/watershed. Intensive livestock producers will be encouraged with financial incentives to develop and maintain constructed wetlands, where possible, to treat wastewater runoff or as emergency holding areas.

Crop producers will also be encouraged with financial incentives to construct wetlands/holding ponds to help treat the runoff from their fields. Much of the crop land in Kings County is tile drained. These tiles are designed to drain the water into ditches that are connected to the waterways. If the drainage ditches were altered somewhat so that they ran through a constructed wetland to a holding pond, the potential runoff of contaminants may be reduced to a level that the water could be reused for irrigation. Constructed wetlands for assisting in the treatment of potential runoff would also complement one of the agriculture industry's current endeavours to address runoff concerns from a nutrient (fertilizer and manure) management perspective.

By focussing conservation efforts on a relatively small area such as the watersheds on the valley floor of Kings County, there is the potential to not only restore and protect wildlife habitat in the agricultural landscape, but to also improve water quality in the river systems. KAWCI currently has some funds to undertake this project but additional funds and partners are required to re-establish sufficient riparian edges/wetlands to have a major impact on water quality.

Session Five

CONTAMINANTS AND ECOSYSTEM HEALTH

Chairs: Thierry Chopin, Centre for Coastal Studies and Aquaculture, Saint John, New Brunswick

and

Larry Hildebrand, Sustainable Communities and Ecosystems Division, Environment Canada

AN EMPIRICAL MODEL OF MERCURY CYCLING IN PASSAMAQUODDY BAY

Elsie M. Sunderland and Frank A. P. C. Gobas

School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC.
ems@sfu.ca and gobas@sfu.ca

Abstract

We have collected data on the concentrations of mercury in water, sediment and biota in Passamaquoddy Bay. Our field research suggests that the majority of mercury is contained within the sediment compartment. Production of methyl mercury, the form of mercury that is readily accumulated in organisms, also occurs primarily in the sediment phase. Thus, processes taking place at the sediment-water interface are extremely important as a vector for mercury entry into the food chain. Past research has demonstrated that a number of environmental factors can significantly influence the speciation and distribution of mercury in sediments, which affects the rate of mercury accumulation in organisms. Our research looks at several of these variables and examines their importance as controls on the speciation and mobility of mercury in Bay of Fundy sediments. Information on the fate and bioaccumulation of mercury in Passamaquoddy Bay is used to develop our understanding of the bioaccumulation of mercury in the larger Bay of Fundy food web, currently being investigated by researchers at the Department of Fisheries and Oceans at the Bedford Institute of Oceanography (see Dalziel et al. poster session, this volume).

Introduction

Mercury is an ongoing environmental problem in the Northeast United States and Eastern Canada. Despite reductions in mercury emission of more than 50% since the 1970s (Sunderland and Chmura 2000), there is no evidence that concentrations in aquatic organisms have fallen. Consumption advisories for human populations eating fish are in place throughout the Northeastern United States and Eastern Canada due to elevated levels of mercury (NESCAUM et al. 1998), and sensitive sub-populations such as Aboriginal communities and pregnant women that consume large quantities of fish are believed to be at risk.

The dynamics and speciation of mercury in the sediment compartment are critical for understanding its overall fate and accumulation in the food web. The concentration of mercury in coastal sediments is, in general, several-fold greater than that in water, thus the overall reservoir of mercury contained in the sediment compartment is relatively larger (Benoit et al. 1998; Gill et al. 1999). This means that the dynamic processes occurring in the sediment phase (e.g., resuspension, settling and burial) are critical in determining the rate of response of coastal systems to changes in total mercury loading, particularly those with a relatively short water-residence time. Sediments are also the principal site of methyl mercury (MeHg) production, the form of mercury that bioaccumulates in the food web

(Mason et al. 2000; Benoit et al. 1999a and 1999b). It has been postulated that in estuarine systems, methyl mercury enters the food chain through benthic organisms and is a function of the concentrations in sediments and pore waters (Lawrence et al. 1999; Lawrence and Mason 2000; Lawson and Mason 1998). Thus, the geochemical conditions that facilitate conversions between inorganic and organic mercury in estuarine sediments are also important for understanding how mercury enters the base of the food web.

We present seasonal, spatial and stratigraphic data on the bulk phase and dissolved concentrations of total and methyl mercury in sediments from Passamaquoddy Bay and the outer Bay of Fundy. Our long-term objective is to identify and quantify the dominant environmental controls on speciation and distribution of mercury in Bay of Fundy sediments to estimate the fraction of mercury available for uptake into the food web, and ultimately incorporate this information into environmental models. The majority of data presented in this study were collected in Passamaquoddy Bay, a coastal embayment located on the southwestern coast of New Brunswick, near the mouth of the Bay of Fundy.

Analytical Methods

Bulk phase sediment samples for total mercury analysis were digested in 5:2 nitric-sulfuric acid solution to ensure complete digestion of organic matter. Under cleanroom conditions, samples were oxidized with bromine monochloride (BrCl). The excess oxidant was neutralized with 10% hydroxylamine hydrocholoride immediately prior to analysis. Aqueous samples were digested with BrCl at least 12 hours prior to analyses and then neutralized with equivalent volume hydroxylamine hydrochloride immediately before running. All samples were then reduced by tin chloride, purged, and trapped on gold in elemental form. Quantification was by dual-stage gold amalgamation/cold-vapor atomic fluorescence spectroscopy (CVAFS). The procedure used was based on EPA Method 1631 (U.S. Government Institutes 1996), Gill and Fitzgerald (1987) and Bloom and Fitzgerald (1988). MeHg was determined by steam distillation, aqueous phase ethylation using sodium tetraethylborate, purging onto tenax, gas chromatography separation and CVAFS detection following a technique modified from Bloom and Fitzgerald (1988) and Horvat et al. (1993), developed by Branfireun et al. (1999).

Total Mercury (Hg_T)

A preliminary mass budget for total mercury in Passamaquoddy Bay (Figure 1) indicates that >95% of the mercury in this system is contained in the sediment compartment. The estimates presented are annual averages based on measured mercury concentrations in water and sediments, hydrodynamic data from the major freshwater tributaries, incoming tidal waters and atmospheric monitoring stations (Dalzeil 1992 and 1995; Dalzeil et al. 1998; Gregory et al. 1993; Showell and Gaskin 1992).

Presently, there are no large point sources of mercury in Passamaquoddy Bay. However, in the 1970s several pulp and paper and one chlor-alkali facility discharged mercury into the catchments of the St. Croix Estuary (Fink et al. 1976). Present local sources of mercury include diffuse discharges from municipal water, golf courses and agriculture, as well as atmospheric deposition originating from both local and long-range sources of contamination. Much of the mercury associated with freshwater discharges into Passamaquoddy Bay is expected to be the result of leaching of atmospherically deposited mercury from the major river catchments.

Concentrations of Hg_T in the surface sediments are enriched in areas with a greater proportion of muddy fine-grained sediments and low in sandy erosional regions, matching depositional areas predicted by hydrodynamic and sediment transport models developed for the region (Greenberg and Amos 1983; Greenberg et al. 1997). Maximum concentrations (>100 ppb) are found at the head of the St. Croix River, likely due to the presence of residual contamination associated with historical discharges of mercury from a chlor-alkali facility that closed in the 1970s and present day anthropogenic discharges filtering through the river catchments (Figure 2). Overall, the Hg_T concentration distribution in these sediments indicates that this is not a highly impacted system, as levels in sediments are approximately an order of magnitude lower than contaminated systems discussed in the literature (e.g., Baltimore Harbour, Lavaca Bay, Scheldt Estuary). The percentage of fine-grained sediment solids is strongly correlated with the organic carbon content of the surficial sediments (Loring et al. 1998), and accordingly there is a strong and significant correlation between total organic carbon content and Hg_T.

Methyl Mercury (MeHg)

Bulk phase methyl mercury concentrations showed both spatial (Figure 3) and seasonal variation in Passamaquoddy Bay. Methyl mercury concentrations are enriched at the head of the St. Croix River, but relatively homogenous on a seasonal basis in the well-mixed areas of Passamaquoddy Bay. Similar to the distribution of total mercury, areas with fine-grained, organic-rich sediments showed the highest concentrations. Accordingly, both organic carbon and total mercury are significantly correlated with methyl mercury concentrations in the bulk phase sediments. The redox potential of the surface sediments and sulfide concentrations show much weaker relationships, indicating that these variables may not be the dominant controls on mercury speciation in Passamaquoddy Bay sediments.

Sediment Cores

The profile of methyl mercury in the upper 15 cm of sediments at various sampling stations indicates that the mechanism of methyl mercury formation varies between the well-mixed and depositional sites (Figure 4). At well-mixed sites, organic-rich anoxic "pockets" in the sediments appear to be integrated within the oxic surface sediments of Passamaquoddy Bay (Figure 5). We hypothesize that the resulting geochemical environment provides an increased volume of sediments with the specific conditions required by sulfate reducing bacteria (the principal methylators of mercury) where methylation can occur, resulting in an increased overall mass of MeHg produced in this system. Mixing of the surface sediments in Passamaquoddy Bay as the result of the dynamic tidal forces in the Fundy region also appears to increase the depth of the active sediment layer in this system.

Hypotheses/Conclusions

Mixing of benthic sediments in Passamaquoddy Bay appears to increase the active sediment layer in this system to approximately 15 cm. Thus, there is a large reservoir of total mercury available in the surface sediments that is integrated with incoming mercury from present-day sources. Given that the burial rate of sediments in the Bay is estimated to be on the order of 1 $mm.yr^{-1}$, the time response of this system to lowered anthropogenic emissions of mercury is expected to be slow (Figure 6). In addition, the physical mechanisms of mixing and resuspension of benthic sediments where methylation is occurring *in situ* may provide a vector for methyl mercury entry into the food chain for organisms feeding at the sediment-water interface and also for entry into the water column.

References

Benoit, J. M., C. C. Gilmour, R. P. Mason, G. S. Riedel, and G. F. Reidel. 1998. Behaviour of mercury in the Patuxent River estuary. Biogeochemistry 40: 249–265.

Benoit, J., C. C. Gilmour, R. P. Mason, and A. Heyes. 1999a. Sulfide controls on mercury speciation and bioavailability to methylating bacteria in sediment pore waters. Environmental Science and Technology 33: 951–957.

Benoit, J. M., R. P. Mason, and C. C. Gilmour. 1999b. Estimation of mercury-sulfide speciation in sediment pore waters using octanol-water partitioning and implications for availability to methylating bacteria. Environmental Toxicology and Chemistry 18: 2138–2141.

Bloom, N. and W. F. Fitzgerald. 1988. Determination of volatile mercury species at the picogram level by low-temperature gas chromatography with cold-vapor atomic fluorescence detection. Analytica Chemica Acta 208: 151–161.

Branfireun, B., N. T. Roulet, C. A. Kelly, and J. W. M. Rudd. 1999. In situ stimulation of mercury methylation in a boreal peatland: Toward a link between acid rain and methyl mercury contamination in remote environments. Global Biogeochemical Cycles 13: 743–750.

Dalziel, J. A. 1992. Reactive mercury on the Scotian Shelf and in the adjacent Northwest Atlantic Ocean. Marine Chemistry 37: 171–178.

Dalziel, J. A. 1995. Reactive mercury in eastern North Atlantic and southeast Atlantic. Marine Chemistry 49: 307–314.

Dalziel, J. A., P. A. Yeats, and B. P. Amirault. 1998. Inorganic Chemical Analysis of Major Rivers Flowing into the Bay of Fundy, Scotian Shelf, and Bras d'Or Lakes. Canadian Technical Report of Fisheries and Aquatic Sciences 2226. Department of Fisheries and Oceans, Dartmouth, NS. 140 pp.

Fink, L. K. J., D. M. Pope, A. B. Harris, and L. L. Schick. 1976. *Heavy Metal Levels in Suspended Particulates, Biota, and Sediments of the St. Croix Estuary in Maine*. Land and Water Resources Institute, University of Maine at Orono, Orono, ME. 59 pp.

Gill, G. A., N. S. Bloom, S. Cappellino, C. T. Driscoll, C. Dobbs, L. McShea, R. Mason, and J. W. M. Rudd. 1999. Sediment-water fluxes of mercury in Lavaca Bay, Texas. Environmental Science and Technology 33: 663–669.

Gill, G. A. and W. F. Fitzgerald. 1987. Picomolar mercury measurements in seawater and other material using stannous chloride reduction and two-stage gold amalgamation with gas phase detection. Marine Chemistry 20: 227–243.

Greenberg, D., J. Shore, and Y. Shen. 1997. Modelling tidal flows in Passamaquoddy Bay. pp. 58–64. In: *Coastal Monitoring and the Bay of Fundy: Proceedings of the Maritime Atlantic Ecozone Science Workshop.* M. D. B. Burt and P. G. Wells (Eds.). Huntsman Marine Science Centre, St. Andrews, NB.

Greenberg, D. A. and C. L. Amos. 1983. Suspended sediment transport and deposition modeling in the Bay of Fundy, Nova Scotia – A region of potential tidal power development. Canadian Journal of Fisheries and Aquatic Sciences (Suppl. 1) 40: 20–34.

Gregory, D., B. Petrie, F. Jordan, and P. Langille. 1993. Oceanographic, geographic and hydrological parameters of Scotia-Fundy and southern Gulf of St. Lawrence inlets. Canadian Technical Report of Hydrographic Ocean Sciences 143. Department of Fisheries and Oceans, Dartmouth, NS. 248 pp.

Horvat, M., L. Liang, and N. S. Bloom. 1993. Comparison of distillation with other current isolation methods for the determination of methyl mercury compounds in low level environmental samples. Analytica Chemica Acta 282: 153–168.

Lawrence, A. L. and R. P. Mason. 2000. Factors controlling the bioaccumulation of mercury and methyl mercury by the estuarine amphipod, *Leptocheirus plumulosus*. Environmental Pollution 111: 199–208.

Lawrence, A. L., K. M. McAloon, R. P. Mason, and L. M. Mayer. 1999. Intestinal solubilization of particle associated organic and inorganic mercury as a measure of bioavailability to benthic invertebrates. Environmental Science and Technology 33: 1871–1876.

Lawson, N. M. and R. P. Mason. 1998. Accumulation of mercury in estuarine food chains. Biogeochemistry 40: 235–247.

Loring, D. H., T. G. Milligan, D. E. Willis, and K. S. Saunders. 1998. Metallic and Organic Contaminants in Sediments of the St. Croix Estuary and Passamaquoddy Bay. Canadian Technical Report of Fisheries and Aquatic Sciences 2245. Department of Fisheries and Oceans, Dartmouth, NS. 38 pp.

Mason, R. P., J.-M. Laporte, and S. Andres. 2000. Factors controlling the bioaccumulation of mercury, methyl mercury, arsenic, selenium, and cadmium by freshwater invertebrates and fish. Archives of Environmental Contamination and Toxicology 38: 283–297.

NESCAUM, NEWMOA, NEIWPCC and EMAN. 1998. *The Northeast States and Eastern Canadian Provinces Mercury Study: A framework for action*. Tatsutani, M. (Ed.). Northeast States/Eastern Canadian Provinces, Portland, ME.

Showell, M. A. and D. E. Gaskin. 1992. Partitioning of cadmium and lead within seston of coastal marine waters of the western Bay of Fundy. Archives of Environmental Contamination and Toxicology 22: 322–333.

Sunderland, E. M. and G. L. Chmura. 2000. An inventory of historical mercury pollution in Maritime Canada: Implications for present and future contamination. The Science of the Total Environment 256: 39–57.

U.S. Government Institutes. 1996. United States Environmental Protection Agency methods and guidance for analysis of water. CD-ROM compilation of analytical methods. Method 7131: Analysis of metal samples by furnace atomic absorption (GFAA). Method 1632: Analysis of arsenic by hydride generation GFAA. Method 1631: Mercury in water by oxidation, purge and trap and cold vapor atomic fluorescence spectrometry. Rockville, MD.

Figure 1. Preliminary mass budget for Hg_T in Passamaquoddy Bay

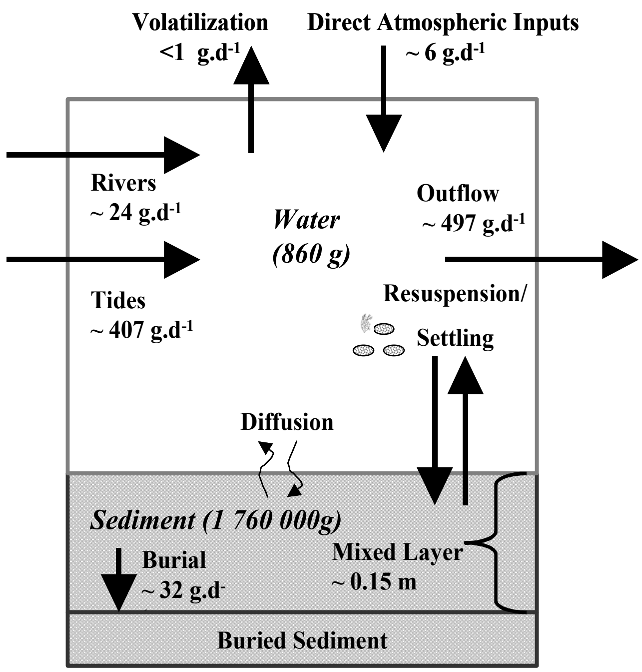


Figure 2. Spatial distribution of total mercury (Hg_T) in Passamaquoddy Bay

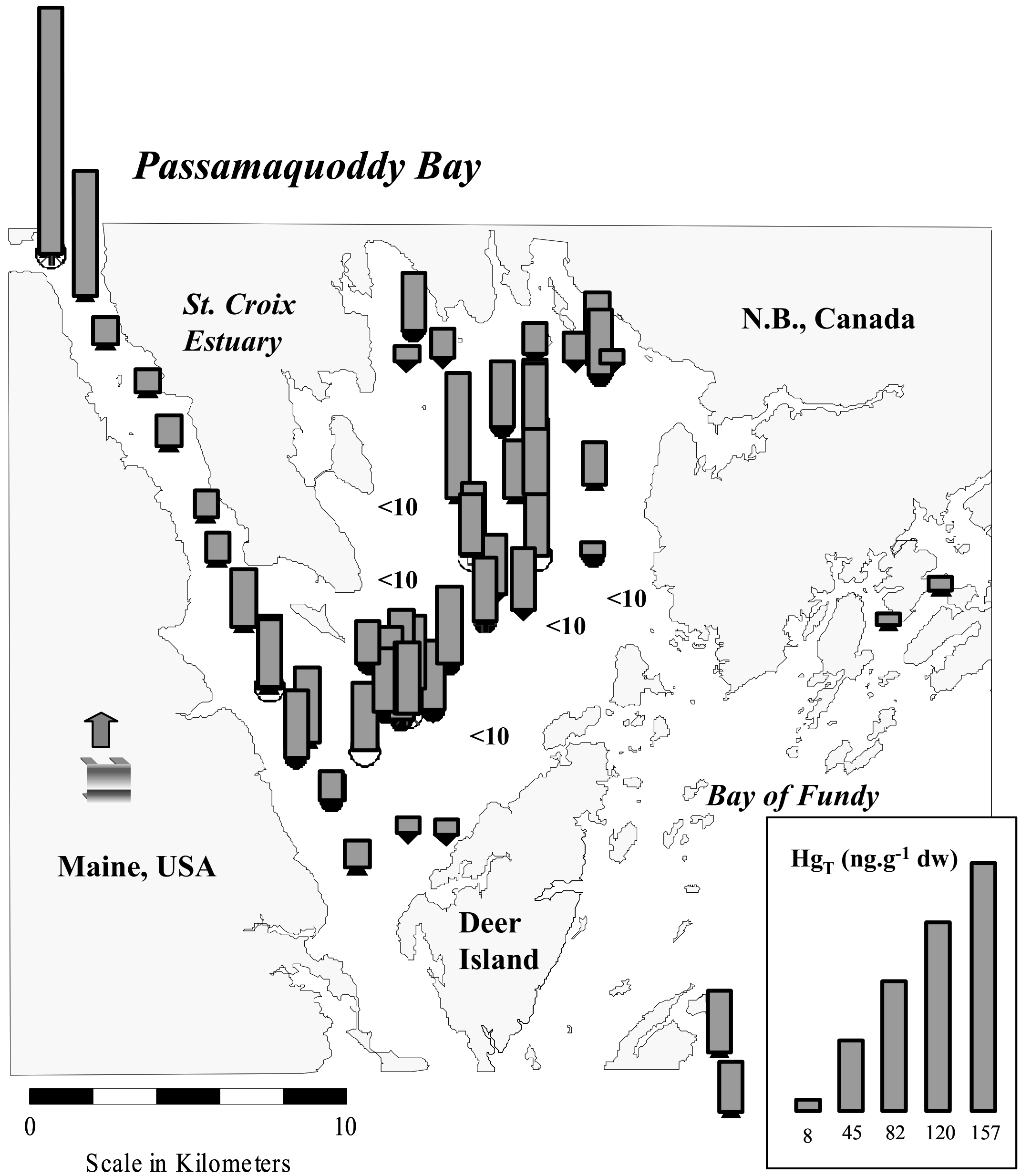


Figure 3. Spatial distribution of methyl mercury (MeHg) in Passamaquoddy Bay

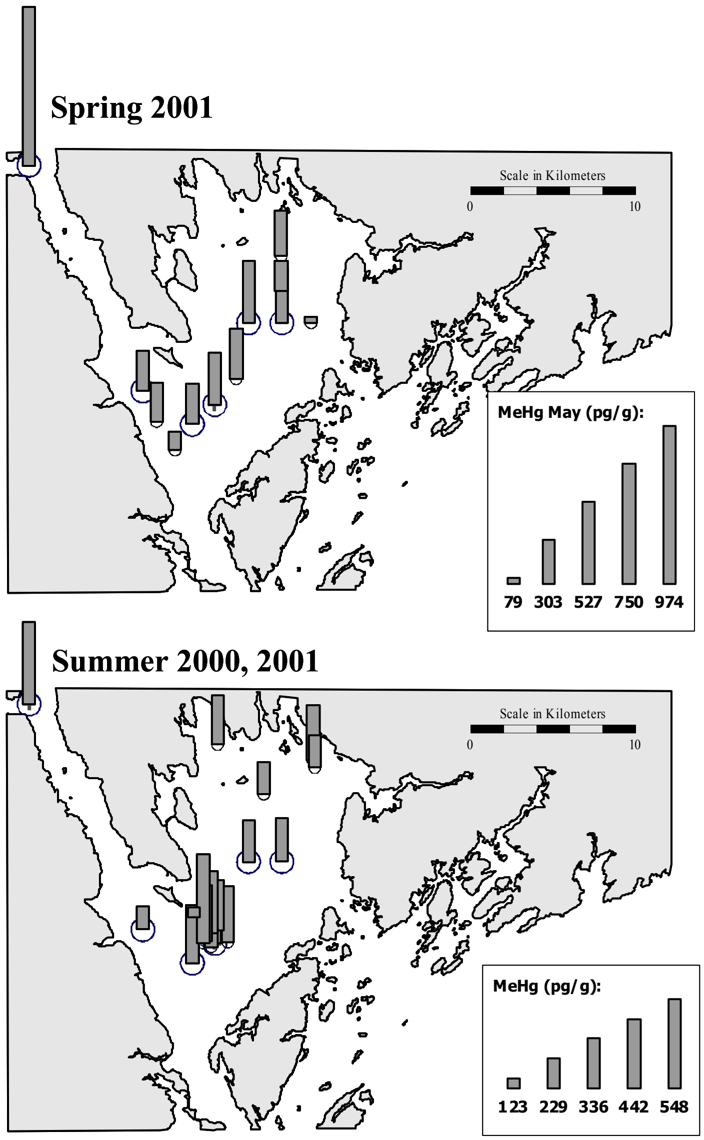


Figure 4. Stratigraphic profile of total and methyl mercury in push cores from contrasting depositional and well-mixed sediments from the St. Croix River and Passamaquoddy Bay

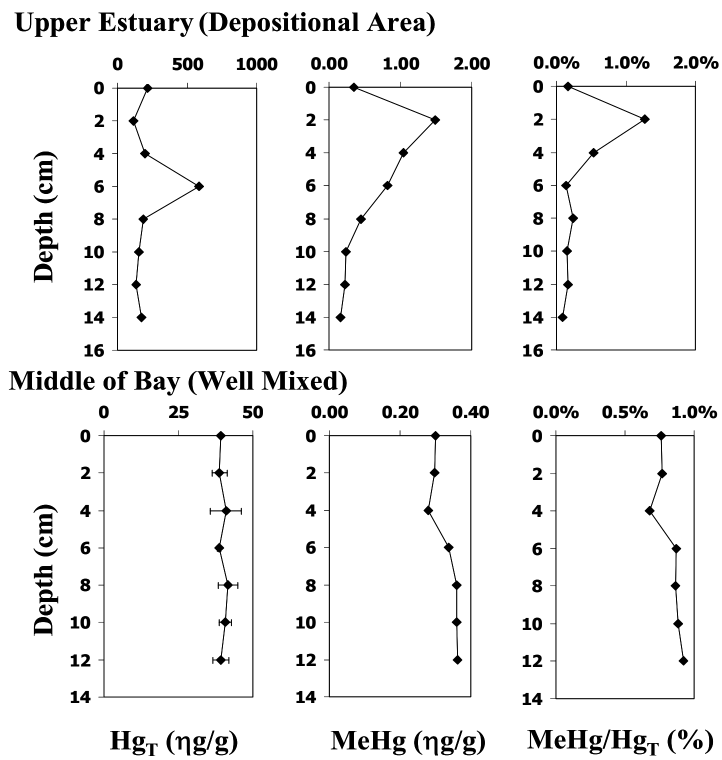


Figure 5. Conceptual model of the effects of mixing on a) the depth of the active sediment layer and b) the volume of sediment suitable for methyl mercury production

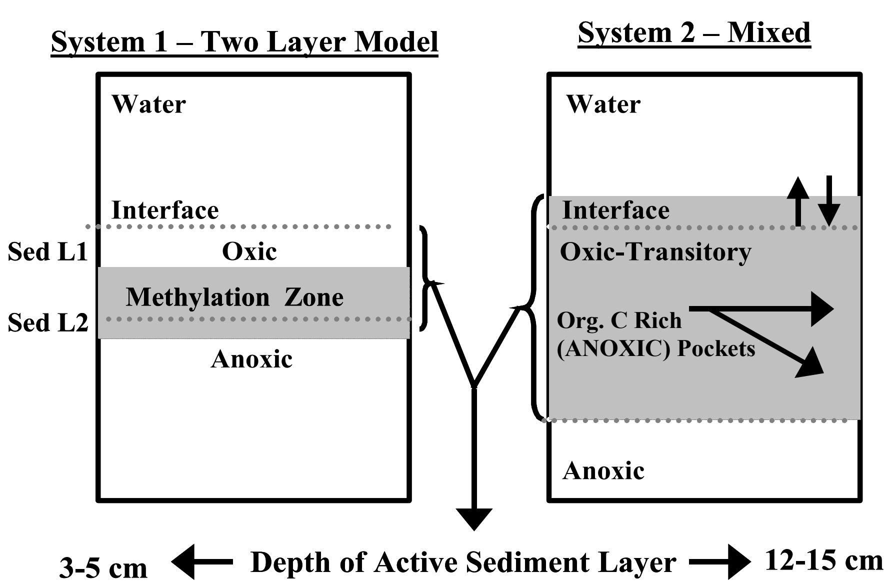
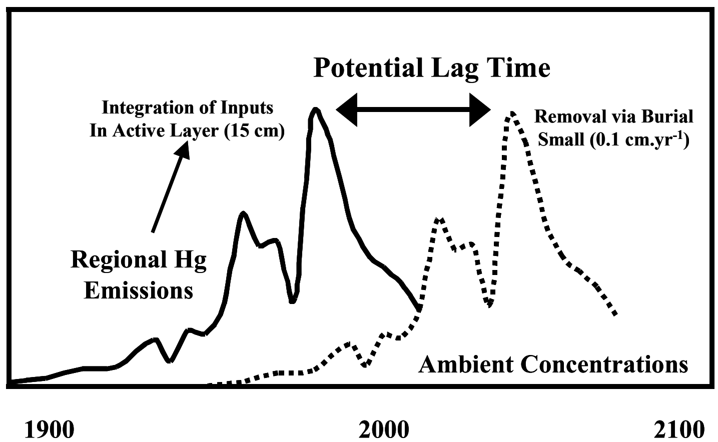


Figure 6. Hypothesized effects of mixing on the response time of sediments and biota from Passamaquoddy Bay to changes in total mercury inputs, where present and past inputs are integrated throughout the active sediment layer resulting in a large lag time between ambient concentrations and present-day inputs. Ongoing research will forecast the changes in mercury concentrations in the sediments and biota in response to variations in inputs through the application of a marine mercury cycling model.



MATHEMATICAL MODELS TO ESTIMATE THE FRESHWATER AND CONTAMINATION DISCHARGE TO COASTAL AREAS DUE TO ANTHROPOGENIC ACTIVITIES

Ghosh A. Bobba

National Water Research Institute, Environment Canada, Burlington, ON. ghosh.bobba@ec.gc.ca

Abstract

Virtually every surface water in coastal watersheds, including rivers, lakes, wetlands, and estuaries, interacts with adjacent subsurface water. This interaction affects the water quality and quantity in both surface water and subsurface water. Subsurface water and surface water interaction affects chemistry, especially acidity, temperature, dissolved solids oxygen, and reduction-oxidation potential. As land and water resource development increases in coastal watersheds, it is becoming readily apparent that subsurface water and surface water interaction must be considered in establishing water management policies. This interaction can take many forms, but the most common interactions are between subsurface water and stream water, lakes, and wetlands. In coastal areas, interactions between subsurface water and seawater occur. All these interactions occur in the Bay of Fundy and other coastal areas of Canada.

There are a wide range of reasons and applications for the study of subsurface water relationships in the coastal zone. This diversity, in combination with the range of disciplines and the time and space scales involved, complicate the use of data for purposes other than those envisioned by the original investigator. The challenge is particularly great in the case of local type or case studies designed for global or regional extrapolation since errors or inappropriate assumptions will be greatly magnified. Mathematical models have a wider range of application and are the concern of this paper. Due to the complex nature of the problem, each of these mathematical models is based on certain simplifying assumptions and approximations. This paper examines the approaches of different types of numerical models, and presents the results of application of models to two different sites.

Introduction

Canada is a nation bordering on three oceans with a coastline of over 244,000 km (Figure 1). A number of major cities and highways border on the ocean. There are also hundreds of fishing villages, over one thousand small craft harbours, and numerous fishing plants along the coast. Many native communities are also located close to the shore, near the marine natural resources upon which they traditionally depend for food. Various industries, such as pulp and paper mills, coastal shipping, container ports, and oil refineries, are also located at the shore for obvious marine transportation advantages.

In much of Canada, coastal impacts arising from higher ocean temperatures, changes to river runoff, and related changes to oceanography, circulation patterns, ice cover, and the hydrological cycle may be more important than those resulting from sea level rise (Figures 1 and 3). However, the ability to predict the impacts on natural ecosystems generally, and on marine ecosystems in particular, has not yet advanced very far, reflecting the complexities of those systems and the level of scientific ignorance.

Subsurface water contamination is becoming a common problem in coastal areas due to industrial and agricultural development (Figure 2). The contaminants travel to the coast with water and may cause considerable degradation of the coastal environment. Therefore, the discharge of contamination concentration at the beach face is an important parameter in assessing the impact of subsurface water contamination on the coastal zone. In particular, since strong mixing with ambient coastal water will occur once the contaminant enters the coastal area, the exit concentration at the breakthrough point will be higher than elsewhere in the coastal zone. That is, for coastal ecosystems, these points likely present the worst scenario in assessing risk associated with contamination. The same situation occurs for subsurface water discharging into a tidal estuary. Estuarine ecosystems involving subsurface water discharge regions will be affected by contaminant concentrations at the estuary-subsurface interface. To determine the exit of contamination concentration at the beach face, we need to understand and quantify the contamination transport and reaction processes in the coastal subsurface system. An essential feature of a coastal subsurface system is the influence of oceanic oscillations on flow and mixing processes in the mixing zone of the subsurface system. Hydrologic issues enter this process at two key points: in quantifying inputs to specific coastal budgets and in characterizing types of coastal environments in terms of behaviour that will support extrapolation to a global model. Both are important, and their combined requirements represent a significant challenge. Beyond the hydrologic questions are the key issues of geo-chemical fluxes, especially of nutrients, but also of carbon compounds and of other materials, natural or anthropogenic, that may affect biological and chemical cycles in the coastal zone. However, an understanding of solvent behavior is typically a prerequisite for predicting the action of solutes, so an initial focus on hydrology is essential.

Hydrological Setting of the Coast

A watershed is topographically defined as an area that water enters through precipitation and leaves as evapotranspiration, surface runoff and subsurface water discharge. In the case of a coastal watershed, runoff and subsurface water discharge enter the sea (Figure 3). Rainfall and potential rate of evapotranspiration are determined by climate. Actual evapotranspiration is limited by the climatically controlled potential rate, but vegetation and the wetness of the soil also affect it. Soil properties, topography, and the history of rainfall and evapotranspiration determine runoff and subsurface water discharge. For the purpose of this discussion, surface runoff includes both direct runoffs, which occurs as stream flow immediately following a rainstorm, and drainage of subsurface water into creeks, which accounts for stream flow between storms. The amount of direct runoff generated by a storm depends on the amount of rainfall and on the moisture conditions of the soil. In general, more runoff occurs when the soil is initially wet. Subsurface water discharge can be calculated by difference if rainfall, evapotranspiration, runoff and the change in the amount of water stored on the watershed are known.

A link between rising sea level and changes in the water balance is suggested by the general description of the hydraulics of subsurface water discharge at the coast. Fresh subsurface water rides up over denser saltwater in the subsurface system on its way to the sea (Figure 3), and subsurface water discharge is focused into a narrow zone that overlaps with the intertidal zone. The width of the zone of subsurface water discharge, measured perpendicular to the coast, is indirectly proportional to the discharge rate. The shape of the water table and the depth to the fresh/saline interface are controlled by the difference in density between freshwater and saltwater, the rate of freshwater discharge and the hydraulic properties of the subsurface system. The elevation of the water table is controlled by mean sea level through hydrostatic equilibrium at the shore.

Contamination and Water Pathways to the Coast

Figure 4 indicates two distinct subsets of the coastal zone environment. First, the estuarine zone is intended to represent the typically narrow width of the marine environment that is most influenced by land and which often has relatively high levels of variability as well as productivity. The estuarine zone includes true estuaries, but is further represented by a narrow band of nearshore water masses in locations where there are not streams adequate to form traditionally defined estuaries (Figure 5). The estuarine zone is, inevitably, the area of the ocean most subject to direct anthropogenic alteration. On average, this zone is not dominated by fluxes from the world's major rivers; advective processes are primarily oceanic, and terrestrial influences are often a mix of subsurface water and runoff from local watersheds. The remainder of the coastal zone environment is referred to here as the coastal shelf zone. This is the open-water part of the continental shelf that is dominated by oceanic advective processes and characterized by more nearly oceanic water characteristics.

Figures 4 and 5, considered together, illustrate both a conceptual and an operational problem in considering hydrologic inputs to the coastal zone. Conceptually, essentially all surface water flow enters the coastal zone through the estuarine zone. Although this is a convenient assumption for shallow subsurface water, it is not necessarily correct; confined aquifer systems, karst formations, etc., may result in either localized or distributed discharges of subsurface water relatively far out on the continental shelf or slope. This situation is illustrated in Figure 5, along with indications of processes that must be considered regarding subsurface water in the larger hydrological sense. These offshore discharges are likely to be insignificant in terms of the water budget of the coastal shelf zone. However, because this water is likely to be more highly mineralized, it may be bio-geo-chemically significant, and the flux of subsurface water may also have an amplified influence on pore water environments and the benthic community (Tribble et al. 1992; Tobias et al. 2001; Valiela et al. 1992).

The Saltwater Intrusion Process into Coastal Watersheds

The details of saltwater intrusion along coastal areas have been explained earlier by Bobba (1993a). The interface, consisting of the surface between the fresh and saline waters, has a parabolic form, with the saltwater tending to under ride the less dense freshwater. Figure 3 represents equilibrium between the seaward-flowing freshwater and seawater. Whatever the flow situation, a dynamic equilibrium tends to develop. It can be shown that the length of the intruded wedge of saltwater varies inversely with the magnitude of the freshwater flow to the sea. Thus, even a reduction of freshwater flow is sufficient to cause intrusion. The phenomenon of freshwater underlain by saltwater is quite complex. In reality the two fluids are miscible and are separated by a transition zone (Figure 6) with a continuous upward gradient of salt concentration from saltwater below to uncontaminated above. This results in a slight upward density gradient in the transition zone. The two fluids tend to mix by molecular diffusion and macroscopic dispersion. Because saltwater intrusion represents immiscible displacement of liquids in porous media, the processes of hydrodynamic dispersion and molecular diffusion tend to mix the two fluids. As a result, the idealized interfacial surface becomes a transition zone (Figure 6). The thickness of the zone depends upon the physical structure of the aquifer, the history of extractions from the aquifer, the variability of recharge, and the tides. The details of the mixture of freshwater and saltwater have been explained earlier (Bobba 1993a). To understand and solve the complicated practical saltwater intrusion problems, numerical modelling is very important before there can be exploitation of subsurface water along the coastal areas and small islands.

Application of Numerical Models to Coastal Watersheds

In the past four decades, modelling has become an important and powerful tool in many branches of science. Models allow engineers and scientists to test hypotheses in a manner that is removed and nondestructive to the actual problem at hand. In studies involving saltwater intrusion, modelling has been used for many purposes. A common goal of these models is to predict and characterize the movement of the transition zone in the aquifer where freshwater and saltwater meet. Another purpose of modelling is to predict the degree and extent of mixing that occurs in this transition region. In this way, models allow problems to be defined before they actually occur. The details of the models have been presented earlier by Bobba (1993a, 1996), Bobba and Singh (1995), and Bobba et al. (2000a).

This paper presents the application of finite element models applied for two case studies. One of the models is the SUTRA (Saturated - Unsaturated TRAnsport) model developed by Voss (1984). This model simulates fluid movement and the transport of either dissolved substances or energy in the subsurface system. The model can be applied areally or in cross section. It uses a two-dimensional, combined finite-element and integrated-finite difference method to approximate the equations that describe the two interdependent processes being simulated. When used to simulate saltwater movement in a subsurface system in cross section, the two interdependent processes are the densities-dependent saturated subsurface-water flow and the transport of dissolved solids in the subsurface water. Either local- or regional-scale sections having dispersed or relatively sharp transition zones between saltwater and freshwater may be simulated. The results of a SUTRA simulation of saltwater movement show both distributions of fluid pressures and dissolved-solids concentrations as they vary with time and the magnitude and direction of fluid velocities as they vary with time. Subsurface properties that are entered into the model may vary in value throughout the simulated section. Sources and boundary conditions may vary with time. The finite-element method using quadrilateral elements allows the simulation of irregular areas with irregular mesh spacing. The model has been applied to real field data and observed to give favourable results (Bobba 1993b, 1998a and 1998b; Bobba et al. 2000a and

2000b; Piggott et al. 1994 and 1996). Two examples are presented in this paper to identify subsurface water contamination to coastal areas.

Case Study 1: Port Granby radioactive disposal site (Bobba and Joshi 1988 and 1989)

Canada has a uranium refinery, at Port Hope, Ontario. The waste from the refinery was disposed at the Port Granby waste management site located on the north shore of Lake Ontario (Figure 7). In recognition of concern over the possible contamination of surface lake waters, the concentrations of radium and uranium were measured in water samples collected from the Lake Ontario coastal zone near the waste site. These data showed leachate infiltrating and seeping to the coastal zone of Lake Ontario. The plume moved parallel to the shoreline in the direction of the prevailing wind (Figure 7). Figure 8 shows the geology, hydrogeology and computed hydraulic heads. The finite element model was applied to calculate hydraulic head and contamination discharge to the lake shore. Figure 9 shows the predicted Ra-226 contamination concentration from the waste disposal site to the beach. Bobba and Joshi (1988 and 1989) present the details of the application of the model and interpret the results.

Case Study 2: Tongatapu Islands (Bobba 1999)

Tonga, with a population of about 96,000, is situated in the southwest Pacific Ocean some 1,600 km northwest of New Zealand. Tongatapu, the largest island in the kingdom of Tonga with a surface area of 250 sq km, is located to the southeast of Fiji in the South Pacific at 175 12' W 21. Bobba (1999) reports the details of geology and hydrogeology (Figure 10). A finite element grid was set up to represent the Tongatapu Island as shown in Figure 10B. The grid consisted of 137 nodes and 97 elements. The geometry is very similar to that used in Figure 10A. The results of the simulation were represented according to their three main characteristics, that is, water table levels, the position of interface between salt and freshwater, and the thickness of freshwater and saltwater available in the aquifer. Bobba et al. (2000a) present the details of the model application and interpretation.

In simulated areal contour maps representing the interface, the areas occupied by the interface of the freshwater and saltwater thicknesses are shown. Figure 11 shows the simulated hydraulic head and freshwater depth in the Tongatapu Island without sea level rise. The freshwater depth is greater in the centre of the island than in coastal areas. The freshwater depth was reduced due to sea level rise and tidal action from both the north and south. Figures 12 and 13 depict the influence of sea level rise variations and El Niño effects on Tongatapu Island.

Conclusions

Mathematical and numerical models are useful to estimate subsurface water and contamination discharge to coastal areas from point and non-point source areas (Bobba et al. 2000a). This paper presented applications of two types of numerical models. As an example, a finite element model, considering open boundary conditions for coasts and a sharp interface between freshwater and saltwater was applied under steady-state conditions to the phreatic aquifer for freshwater surplus and deficits at the coastline due to the El Niño effect. When recharges of saltwater occur at the coastline, essentially of freshwater deficits, a hypothesis of mixing for the freshwater-saltwater transition zone allows the model to calculate the resulting seawater intrusion in the aquifer. Hence, an adequate treatment and interpretation of the hydrogeological data that are available for a coastal aquifer are of main concern in satisfactorily applying the numerical model. The results of the steady-state simulations showed reasonable calculations of the water table levels and the freshwater and saltwater thicknesses, as well as the extent of the interface and seawater intrusion into the aquifer for the total discharges or recharges along the coastline. As a result of the present hydrogeological simulations on the subsurface system, a considerable advance in seawater intrusion would be expected in the coastal watershed if the sea level rises due to climate change and El Niño effects.

References

Bobba, A. G. 1993a. Mathematical models for saltwater intrusion in coastal aquifers: Literature review. Water Resource Management 7: 3–37.

Bobba, A. G. 1993b. Field validation of 'SUTRA' groundwater flow model to Lambton County, Ontario, Canada.Water Resource Management 7: 289–310.

Bobba, A. G. 1996. Environmental modelling of hydrological systems. Doctoral dissertation submitted for partial fulfillment of Doctor of Science, Lund University, Lund, Sweden.

Bobba, A. G. 1998a. Application of numerical model to predict fresh water depth in islands due to climate change effect: Agati island, India. Journal of Environmental Hydrology 6: 1–13.

Bobba, A. G. 1998b. Application of numerical model to predict fresh water depth due to climate change effect in Laccadive Islands, India. EOS, Transactions, American Geophysical Union 79(17): S75.

Bobba, A. G. 1999. Prediction of freshwater depth due to climate change in islands by numerical simulation. Pages 823–838. In: P*roceedings of the 1999 Canadian Coastal Conference, 19–22 May 1999, Royal Roads University, Victoria, BC*. C. J. Steward, Ed. Canadian Coastal Science and Engineering Association, Ottawa.

Bobba, A. G. and S. R. Joshi. 1988. Groundwater transport of Radium-226 and uranium from Port Granby waste management site to Lake Ontario. Nuclear and Chemical Waste Management 8: 199–209.

Bobba, A. G. and S. R. Joshi. 1989. Application of an inverse approach to a Canadian radioactive waste disposal site. Ecological Modelling 46: 195–211.

Bobba, A. G. and V. P. Singh. 1995. Groundwater contamination modelling. Pages 225–319. In: *Environmental Hydrology*. V. P. Singh, Ed. Kluwer Academic Publishers, Dordrecht.

Bobba, A. G., V. P. Singh, and L. Bengtsson. 2000a. Application of environmental models to different hydrological systems. Journal of Ecological Modelling 125: 15–49.

Bobba, A. G., V. P. Singh, R. Berndtsson, and L. Bengtsson. 2000b. Numerical simulation of saltwater intrusion into Laccadive island aquifers due to climate change. Journal of Geological Society of India 55: 589–612.

Piggott, A. R., A. G. Bobba, and K. S. Novakowski. 1996. Regression and inverse analyses in regional ground-water modeling. Journal of Water Resources Planning and Management 122: 1–10.

Piggott, A. R., A. G. Bobba, and J. Xiang. 1994. Inverse analysis implementation of the SUTRA model of groundwater flow and transport. Groundwater 32: 829–836.

Tobias, C. R., J. W. Harvey, and I. C. Anderson. 2001. Quantifying groundwater discharge through fringing wetlands to estuaries: Seasonal variability, methods comparison, and implications for wetland-estuary exchange. Limnology and Oceanography 46: 604–615.

Tribble, G. W., F. J. Sansone, et al. 1992. Hydraulic exchange between a coral reef and surface seawater. Geological Society of America Bulletin 104: 1280–1291.

Vailela, I., K. Foreman, M. LaMotagne, D. Hersh, J. Costa, P. Peckol, B. DeMeo-Andreson, C. D'Avanzo, M. Babione, C. Sham, J. Brawley, and K. Lajtha. 1992. Couplings of watersheds and coastal waters: Sources and consequences of nutrient enrichment in Waquoit bay, Massachusetts. Estuaries 15: 443–457.

Voss, C. I. 1984. *A Finite Element Simulation Model for Saturated-Unsaturated Fluid Density Dependent Groundwater Flow with Energy Transport or Chemically Reactive Single Species Solute Transport*. Water Resources Investigation Report 84-4369. U.S. Geological Survey, Reston, VA.

Figure 1. Sensitive coastal areas in Canada due to sea level rise (from Natural Resources Canada)

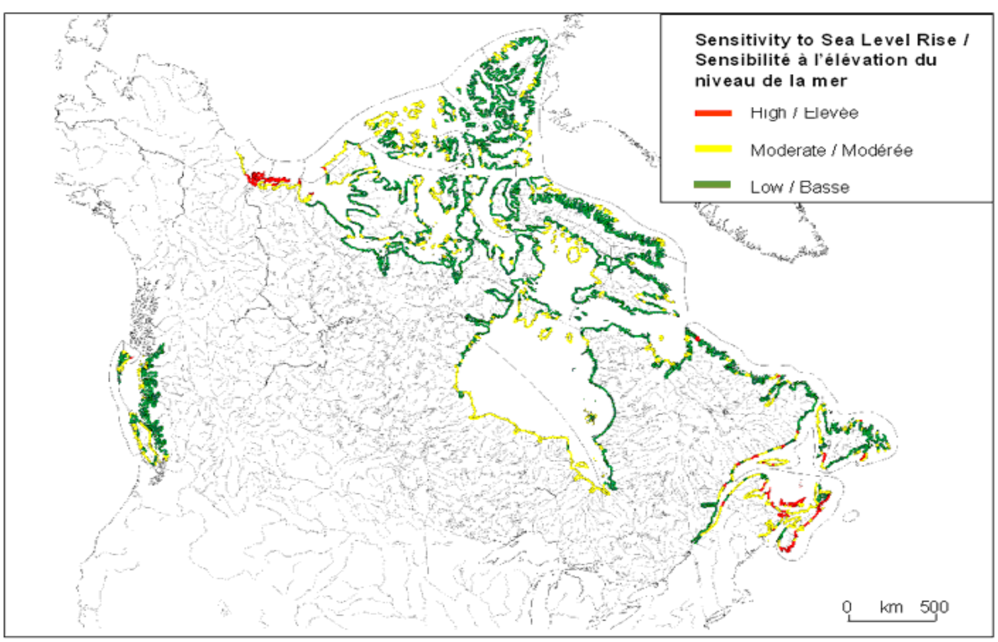


Figure 2. Different sources of contamination seepage to coastal zone

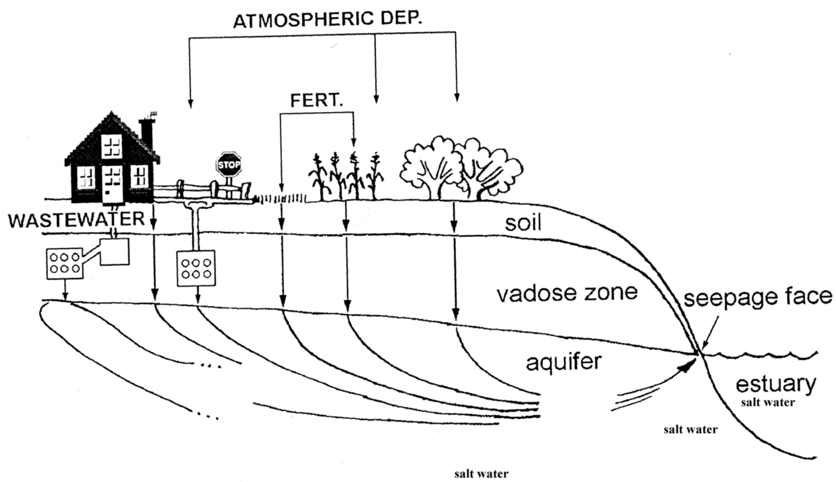


Figure 3. Conceptual model of water balance in a coastal watershed

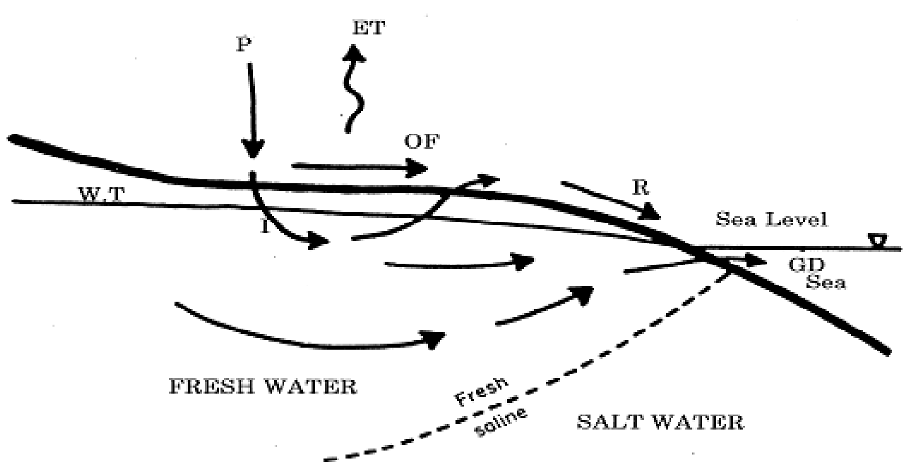


Figure 4. Conceptual model of the coastal zone, showing the different pathways of subsurface waters discharge and the distinctions among the terrestrial compartment and the estuarine zone and the open shelf zone

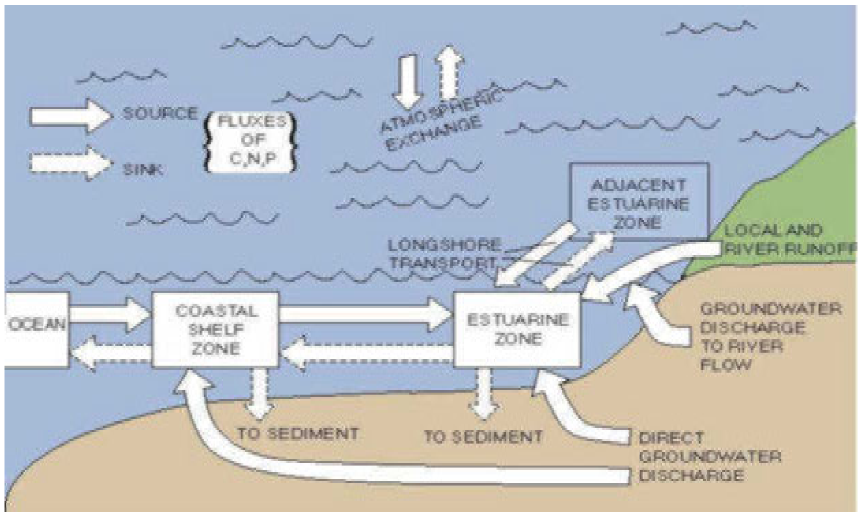


Figure 5. Plan view of the coastal zone showing the relationships among the estuarine zone, open shelf zone, streams, and subsurface water discharge to the ocean and streams

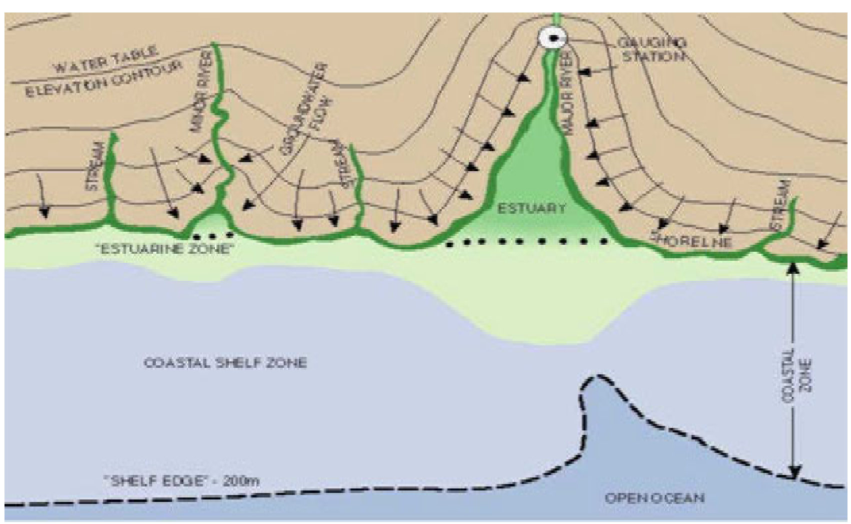


Figure 6. Schematic vertical cross section showing freshwater and saltwater in coast fluids of different densities

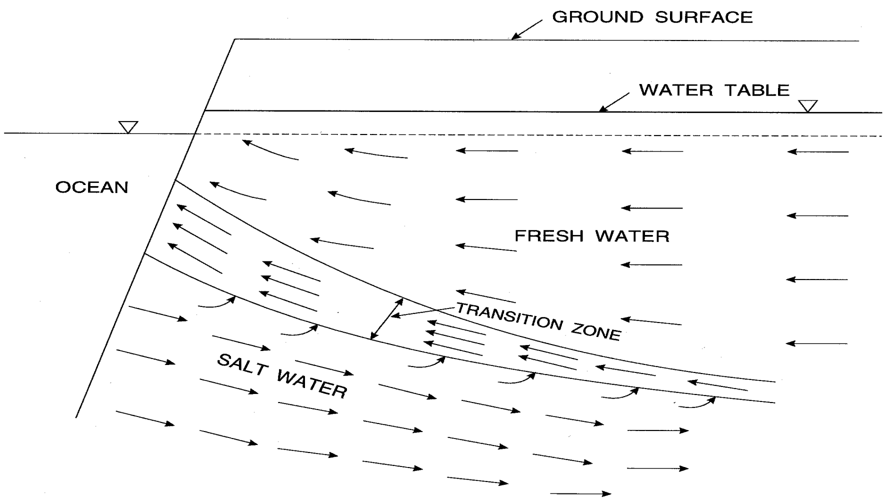


Figure 7. Location of waste site and Ra-226 concentrations in Lake Ontario

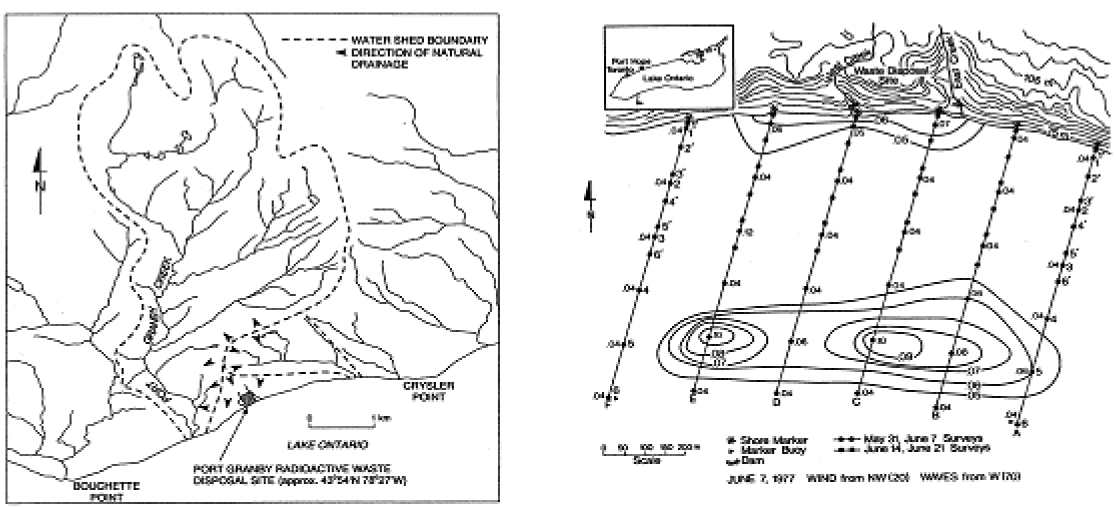


Figure 8. Geological cross section and simulated hydraulic head distribution of north-south geological cross section (Bobba and Joshi 1988 and 1989)

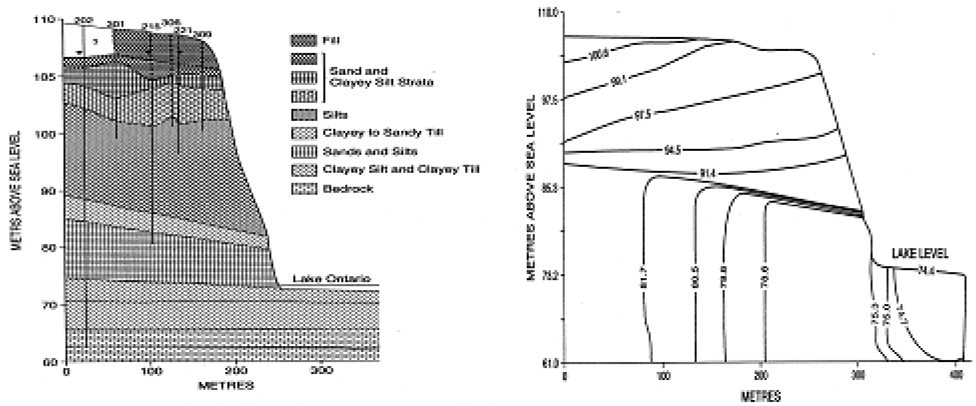


Figure 9. Computed Ra-226 concentration in waste site, beach and observed concentration at the coast (Bobba and Joshi 1988)

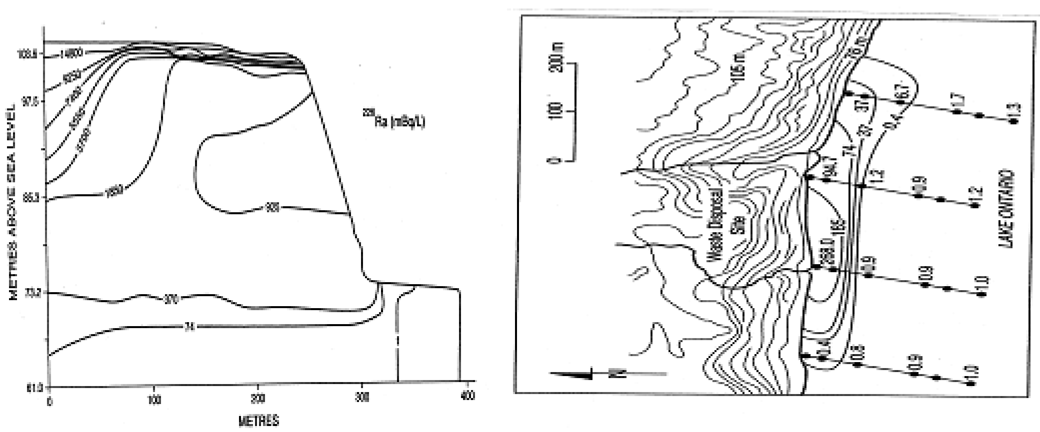


Figure 10. Hydrogeology (A) and finite element grid (B) to Tongatapu island

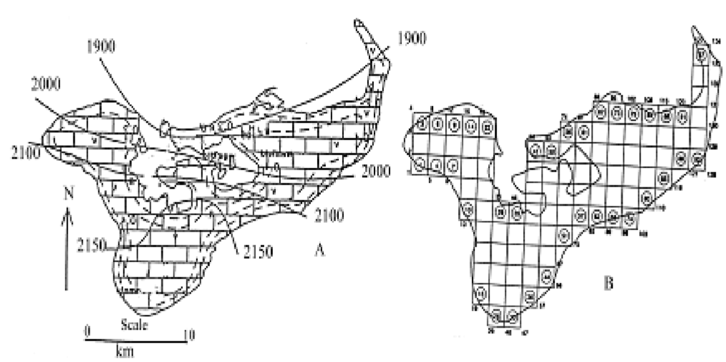


Figure 11. Comparison of simulated hydraulic head (A), freshwater depth (C) with observed hydraulic head and freshwater depth data (B) of Tongatapu island

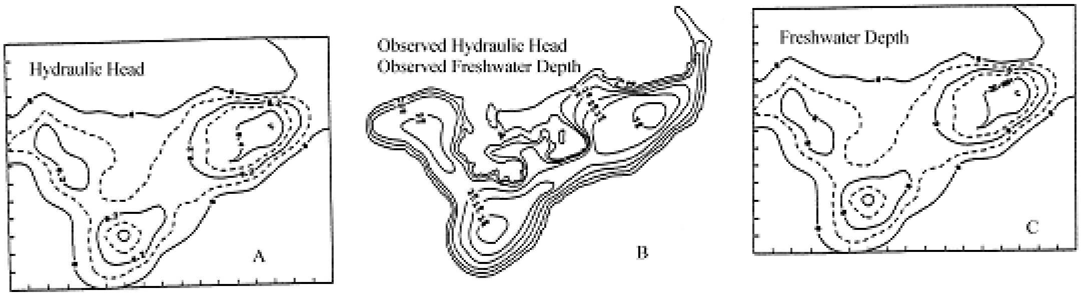


Figure 12. Simulated hydraulic head (A) and freshwater depth (B) due to tidal wave action from south and El Niño effect in Tongatapu island

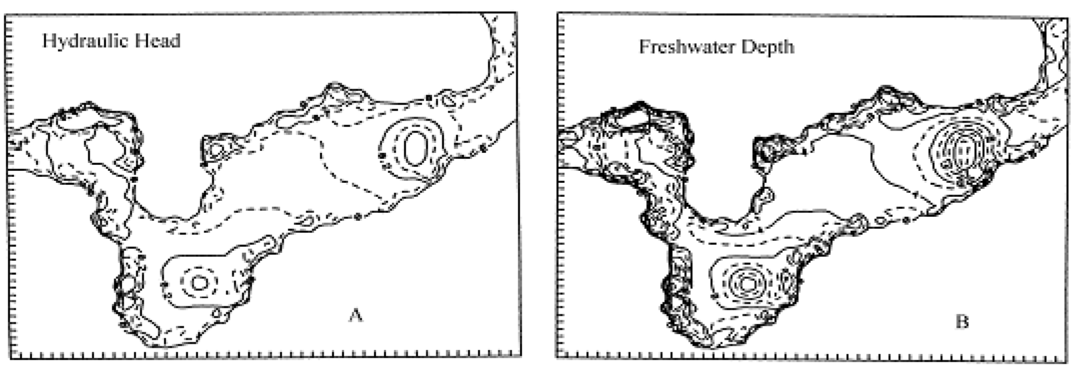
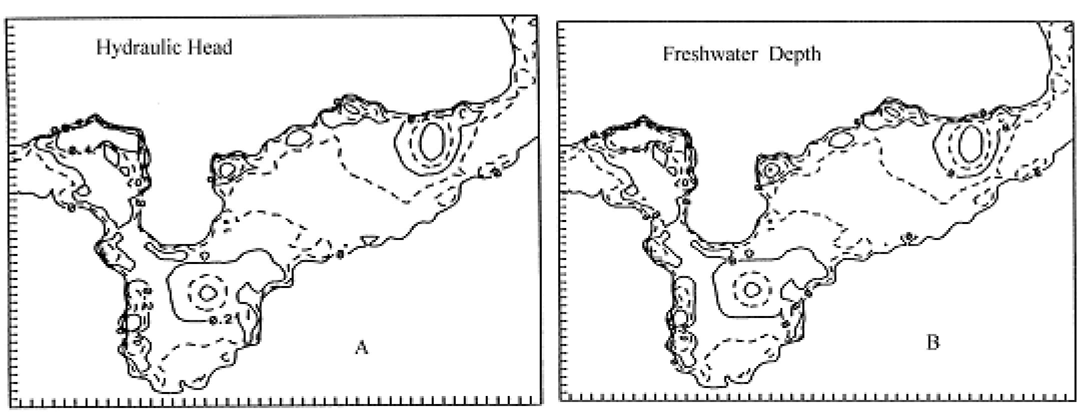


Figure 13. Computed hydraulic head (A) and freshwater depth (B) due to tidal wave action from north and El Niño effect in Tongatapu island (Bobba 1999)



ASSESSMENT OF THE ENVIRONMENTAL RISKS ASSOCIATED WITH CHEMICAL USE IN FINFISH AQUACULTURE

Bill Ernst, Roy Parker, Ken Doe, Paula Jackman, Gary Julien and Jamie Aube

Environment Canada, Atlantic Region, Dartmouth, NS. roy.parker@ec.gc.ca

The use of chemicals in aquaculture, particularly finfish aquaculture, has caused concern in the regulatory and public communities. One of the most contentious uses has been that of pesticide use for sea lice control which allegedly has caused commercial fisheries impacts (lobster kills). The emerging environmental fate and effects database indicates that the use of some products such as cypermethrin, which is used to control sea lice infestations, have the potential for area wide impacts because chemicals used in aquaculture are generally released freely to the environment. Recent inventory work by Environment Canada has revealed that a large number of chemicals are used in aquaculture, however their impacts remain uncertain.

Concerns about possible chemical residues in the sediments that accumulate under salmon net pens has prompted Environment Canada to participate in a series of studies to collect samples of these sediments and to analyze these samples for chemicals. Sampling surveys have been conducted since 1998. Samples have been analyzed for metals, mercury, PCB, DDT, pesticides, and PAHs. To date the results have indicated that copper and zinc were elevated at some salmon farm sites. Sediment toxicity tests have been conducted to assess the potential impact of the elevated metal levels.

ASSESSMENT OF BENTHIC COMMUNITY STRUCTURE NEAR MARICULTURE SITES IN PASSAMAQUODDY BAY AND THE LETANG INLET

Gerhard Pohle[1], Vicky Merritt[1], and Kats Haya[2]

[1] Huntsman Marine Science Centre, St. Andrews, NB. arc@dfo-mpo.gc.ca
[2] Department of Fisheries and Oceans, St. Andrews, NB.

A comparison of three salmon aquaculture sites was undertaken to assess the benthic community structure as a measure of environmental impact along a distance gradient over time. Results are interpreted based on findings of previous studies within the area. Depending on the site, data indicate effects ranging from high to relatively low impact at or near net pens, generally with decreasing impacts over distance. However, one site, within an area of muddy substrate showed the sludge worm *Capitella* abundant at stations beyond cages. This worm is indicative of highly enriched areas. Other impact indicators corroborate that the impacted area extended beyond the immediate vicinity of operations at that site. Another site with less silty substrate showed little impact on the benthos even near net-pens, demonstrating a wide range of site-dependent effects. Results are compared to site ratings based on the New Brunswick Environmental Monitoring Program.

HEAVY METALS IN ROCK CRAB (*Cancer irroratus*), LOBSTER (*Homarus americanus*) AND SEDIMENTS FROM THE INNER BAY OF FUNDY, ATLANTIC CANADA

Chiu L. Chou, Lisa A. Paon, John D. Moffatt and B. M. Zwicker

Marine Environmental Science Division, Oceans Branch, Department of Fisheries and Oceans, Maritimes Region, Bedford Institute of Oceanography, Dartmouth, NS.

Introduction

The Bay of Fundy, Atlantic Canada is a habitat for important commercial stocks of the American lobster, *Homarus americanus,* as well as a number of other marine species. In order to protect these valued resources, and consumers, information regarding contaminants and the associated environment is essential. With the exception of work conducted in Saint John, New Brunswick (Dadswell 1979), data for metal contaminants in marine biota are largely unavailable for the Inner Bay of Fundy. It has been shown that crustaceans can accumulate high concentrations of heavy metals (copper – Cu, cadmium – Cd, zinc – Zn and silver – Ag) in the digestive gland and thus are good indicators for monitoring changes in environmental metal levels (Chou et al. 1987; Chou and Uthe 1978). Accordingly, this research was undertaken to compile baseline data to assess the distribution of metals in lobster, crab and the associated environment, with regard to the eco-health of the Bay of Fundy.

Materials and Methods

Market size lobsters (*Homarus americanus*), thirty per site (15 male, 15 female), preferably weighing about 450 g, were purchased from lobster fishermen during the fishing season, May to July, 1999, at each of the sample sites in the Inner Bay of Fundy (Figure 1). Twenty rock crabs (*Cancer irroratus*) per site, captured in traps with lobster, were collected in 2000. They were transported live to the Bedford Institute of Oceanography, Dartmouth, NS, and held in tanks of running ambient seawater for 24 hours before dissection. Biological parameters were recorded, and upon dissection, digestive glands were weighed, placed in labeled Whirl-Pak® bags, and frozen at -27°C to await chemical analysis. Six to eight sediments were also collected at each of the lobster capture sites, using a VanVeen grab sampler (approximate capacity of 0.015 m^3). In preparation for sample digestion, thawed digestive glands were homogenized by hand-kneading the Whirl-Pak® bags. Digestive glands were digested in HNO_3 and sediment samples were prepared and digested following a HF and HNO_3 procedure (Chou et al. 2000). For quality assurance/quality control, certified reference materials, TORT-1 and LUTS-1 (lobster digestive gland) obtained from the National Research Council of Canada, were also prepared according to the sample procedure. Ag, Cd, Cu and Zn were determined using a Perkin-Elmer Model 403 flame atomic absorption spectrophotometer equipped with deuterium arc background correction (Chou et al. 1987). Concentrations determined for the metals are listed as Fg/g wet wt. for digestive glands and Fg/g dry wt. for sediment samples.

Results and Discussion

Table 1 shows the metal concentrations for lobster digestive glands (Ag, Cd, Cu, Zn). Lobster Cu values ranged widely over the different sites and were conspicuously elevated. Lobsters highly contaminated with Cu, were observed in Cobequid Bay (CBY, 856 Fg/g), Cumberland Basin (CMB, 836 Fg/g), Shepody Bay (SHB, 637 Fg/g), Minas Basin (MIB, 405 Fg/g), Saint John Harbour (SAJ, 317 Fg/g), and Minas Channel (MIC, 110 Fg/g). These values were extremely high compared with Cu levels reported to date for lobsters in the Maritimes Region, Canada (Chou and Uthe 1978). The Cu determined for lobsters from the Inner Bay of Fundy was 10–80 times higher than that found in lobsters from other non-industrialized sites such as Pubnico, N.S. (Chou et al. 1998). For most sites, Zn in lobster digestive gland varied from 28.0–40.9 Fg/g, with the exception of Minas Basin which had 129 Fg/g wet weight. MIB lobsters surpassed values of up to 50.8 Fg/g reported previously for Maritimes Region lobsters (Chou et al. 1998; Chou and Uthe 1978), and ~25–35 Fg/g (Cooper et al. 1987; Pecci 1987) in lobsters from the New England coast. Chou et al. (1987) reported that digestive gland Zn level was under biological control and independent of dietary Cd levels in juvenile lobster. At MIB, however, Zn may exceed a threshold, beyond which it can no longer be regulated as in other decapods (Nugegoda and Rainbow 1989). Further study on this point is required. Cadmium concentrations in Bay of Fundy lobsters (11.6–22.9 Fg/g) were also more elevated than those reported for lobsters from other areas (Prince Edward Island, New Brunswick, Newfoundland, and elsewhere in Nova Scotia): 3.67–12.9 Fg/g (Chou et al. 1998). However, exceedingly high levels, peaking at 223 Fg/g, have been previously reported in lobsters from a site near a lead smelter plant at Belledune, New Brunswick, Canada (Uthe and Chou 1985). The cause of the elevated Cd in Bay of Fundy lobsters, however, is unknown. Ag concentrations were also elevated and ranged from 2.5–11.5 Fg/g compared to 0.8-2.4 Fg/g (Chou et al. 1998) and 0.44–2.22 Fg/g (Chou and Uthe 1978) in previous surveys of Maritimes region harbours, Canada. Ag is known to interact highly with Cu in lobsters (Chou et al. 1987; Chou and Uthe 1978); as the uptake of Cu increases, Ag concentration is also observed to increase. This relationship remained intact for lobsters from the eastern and southern shores of Nova Scotia (Chou et al. 1998), and for some sites in this study.

Table 2 shows the concentrations of Ag, Cd, Cu and Zn (wet weight), in the digestive glands of rock crabs from the Inner Bay of Fundy, Victoria Beach, Nova Scotia and Dalhousie, New Brunswick. Inner Bay, Victoria Beach, and Annapolis Basin Cu was highly elevated compared with 7.98 Fg Cu/g observed in crabs sampled from Dalhousie, N.B. (unpublished data). In a study of Cu in crabs during the intermolt cycle, Martin (1975) reported 27 Fg Cu/g (wet wt.) in digestive glands. He also reported 19.9±11.8 Fg Cu/g (wet wt.) in whole crab samples from Terence Bay, Nova Scotia (1974). Victoria Beach, which is furthest from the Inner Bay, has the lowest Cu (69 Fg Cu/g) among the five study sites in the Bay of Fundy, but is still elevated. The pattern in geographic distribution of Cu in rock crab is consistent with the results for American lobster collected from the same study sites in the Inner Bay of Fundy (Chou et al. 2000). In comparison with Victoria Beach and Dalhousie, Zn is elevated in Inner Bay crabs. This is noteworthy as Zn is normally regulated in decapod crustaceans (Bryan 1968). This supports the finding of highest Zn in lobster from MIB (129 Fg/g), although Zn accumulation in crab is one-third that found in lobsters (Chou et al. 2000). Cadmium concentration in crab from CBY, MIB, and PARS (Parrsborro) are highly elevated compared with 7.53 Fg Cd/g in Dalhousie crab digestive glands, and are ~10–30 times the 2.02 Fg Cd/g found in Victoria Beach crabs. Cadmium in crab is much higher (2–3 times) than the levels in lobster from the same sites (16.0–22.9 Fg/g) (Chou et al., 2000). The pattern of distribution, however, is consistent with the lobster results, and indicates contamination, in particular at PARS, MIB, and CBY sites. Silver concentrations in crab from the Inner Bay of Fundy are more elevated than Ag in either Victoria Beach or Dalhousie crab, which also have low digestive gland Cu levels. The inter-relationship and the uptake of Ag in invertebrates is part of a detoxification mechanism for coping with high Cu concentrations in the environment (Chou et al., 1987).

Table 3 shows the results for sediment Cd, Cu and Zn; Ag was not detected in sediments at any site. Cu concentrations ranged from 9.3–19.2 Fg/g dry wt. and were comparable to Loring's survey results which showed an average of 15 Fg/g from the Bay of Fundy (range 5–32 Fg/g) (Loring 1979). Sediment Zn ranged from 35.1–69.4 Fg/g which compares with the average of 51 Fg/g (range 18–104 Fg/g) reported by Loring (1979). Our sediment Cd values ranged from 0.02–0.11 Fg/g which was also similar to Loring's range of 0.03–0.52 Fg/g for the Bay of Fundy. SAJ sediments had the highest levels for all metals. Relationships between sediment and digestive gland metals were not observed which agrees with our previous findings for biota and associated sediments (Chou et al. 1999; Chou et al. 1998). This suggests that the sediments are not the source of Cu in lobster and crab from the Bay of Fundy. This is consistent with reports from Francesconi et al. (1994) and Chou et al. (1987) that suggest the major intake of metals in lobsters is via the diet.

These results demonstrated high Cu, Cd, and Zn levels in crab and lobster from the Inner Bay of Fundy, which pose a serious concern requiring identification of the unknown source of discharge to the marine environment. Gulf of Maine Council Mussel Watch Program did not detect elevated metal levels in these areas (Chase et al. 1998) which suggests that better indicator species, such as crab and lobster are needed for monitoring contaminant discharges in the area. Although lobster and crab appear to be able to withstand and concentrate extremely high copper levels when it is presented in the diet, there must be an upper limit beyond which there is an adverse effect with ultimately toxic and potentially negative consequences for the biota. Thus there is a need to pinpoint the source of Cu, Zn, and Cd and their impact on lobster and crab. Studies of the fate, transport and distributions in other species including commercially valuable species such as scallops, fish and other marine biota are imperative.

References

Bryan, G. W. 1968. Concentrations of zinc and copper in the tissues of decapod crustaceans. Journal of the Marine Biological Association of the United Kingdom 48: 303–321.

Chase, M., P. Hennigar, J. Sowles, S. Jones, R. Crawford, G. Harding, J. Pederson, C. Krahforst, D. Taylor and K. Coombs. 1998. *Evaluation of Gulfwatch 1997: Seventh Year of the Gulf of Maine Environmental Monitoring Plan*. The Gulf of Maine Council on the Marine Environment. 68 pp., A1-F8.

Chou, C. L., J. D. Castell, J. F. Uthe, and J. C. Kean. 1987. Effect of dietary cadmium on growth, survival, and tissue concentrations of cadmium, zinc, copper, and silver in juvenile American lobster (*Homarus americanus*). Canadian Journal of Fisheries and Aquatic Sciences 44: 1443–1450.

Chou, C. L., L. A. Paon, J. D. Moffatt, and B. Zwicker. 1998. Concentrations of Metals in the American Lobster (*Homarus americanus*) and Sediments from Harbours of the Eastern and Southern Shores and the Annapolis Basin of Nova Scotia, Canada. Canadian Technical Report on Fisheries and Aquatic Sciences 2254. Department of Fisheries and Oceans, Dartmouth, NS. 69 pp.

Chou, C. L., L. A. Paon, J. D. Moffatt, and B. Zwicker. 2000. Copper contamination and cadmium, silver, and zinc concentrations in the digestive glands of American lobster (*Homarus americanus*) from the Inner Bay of Fundy, Atlantic Canada. Bulletin of Environmental Contamination and Toxicology 65: 470–477.

Chou, C. L., and J. F. Uthe 1978. Heavy metal relationships in lobster (*Homarus americanus*) and rock crab (*Cancer irroratus*) digestive glands. International Council for the Exploration of the Sea. C.M. 1978/E:15.

Chou, C. L., B. M. Zwicker, J. D. Moffatt, and L. Paon. 1999 Elemental concentrations in the livers and kidneys of winter flounder (*Pseudopleuronectes americanus*) and associated sediments from various locations in the Bras d'Or Lake, Nova Scotia, Canada. Canadian Technical Report on Fisheries and Aquatic Sciences 2284. Department of Fisheries and Oceans, Dartmouth, NS. 116 pp.

Cooper, R. A., A. Shepard, P. Valentine, J. R. Uzmann, and A. Hulbert. 1987 Pre and post drilling benchmarks and monitoring data of ocean floor fauna, habitats, and contaminant loads on Georges Bank and its submarine canyons. In: R. A. Cooper and A. N. Shepard (Eds) NOAA Symposium Series on Undersea Research 2(2): 17-48

Dadswell, M. J. 1979. Biology and population characteristic of the shortnose sturgeon, *Acipenser brevirostrum*, LeSueur 1818 (Osteichtheyes: Acipenseridae) in Saint John Estuary, New Brunswick. Canadian Journal of Zoology 57: 2186–2210.

Francesconi, K.A., E. J. Moore and J. S. Edmonds. 1994. Cadmium uptake from seawater and food by the Western rock lobster, *Panulirus cygnus*. Bulletin of Environmental Contamination and Toxicology 53: 219–223.

Loring, D. H. 1979. Baseline levels of transition and heavy metals in the bottom sediments of the Bay of Fundy. Proceedings of the Nova Scotian Institute of Science 29: 335–346.

Martin, J. L. M. 1974. Metals in *Cancer irroratus* (Crustacea: Decapoda): concentrations, concentration factors, discrimination factors, correlations. Marine Biology 28: 245–251.

Martin, J. L. M. 1975. Le cuivre et le zinc chez *Cancer irroratus* (Crustace: Decapode): metabolisme compare au cours du cycle d'intermue. Compartive Biochemistry and Physiology 51A: 777–784.

Nugegoda, D., and P. S. Rainbow.1989. Zinc uptake rate and regulation breakdown in the decapod crustacean *Palaemon elegans* rathke. Ophelia 30(3): 199-212.

Pecci, K. J. 1987. Levels of heavy metals, petrogenic hydrocarbons, and polychlorinated biphenyls in selected marine samples from the New England coast. In: R. A. Cooper and A. N. Shepard (Eds) NOAA Symposium Series on Undersea Research 2(2): 127–140.

Uthe, J.F., and C. L. Chou. 1985. Cadmium in American Lobster (*Homarus americanus*) from the Area of Belledune Harbour, New Brunswick, Canada – A Summary of Five Years Study. Canadian Technical Report on Fisheries and Aquatic Sciences 1342. Department of Fisheries and Oceans, Halifax, NS. 20 pp.

Table 1. Ag, Cd, Cu, and Zn concentrations (µg/g wet wt.) in the digestive glands (pooled samples) in each of the males, female, and total sample means for lobster from the Inner Bay of Fundy, Atlantic Canada

Metal		Location						Range
	Sex	SHB	SAJ	CMB	CBY	MIB	MIC	µg/g
Ag	Male	12.3±0.4	6.3±0.3	2.2±0.01	11.1±0.3	9.2±0.1	3.0±0.2	2.2-12.3
	Female	9.3±0.1	7.7±0.3	2.8±0.2	11.8±0.4	10.8±0.1	2.7±0.2	2.7-11.8
	Mean	10.8	7.0	2.5	11.5	10.0	2.9	2.5-11.5
Cd	Male	16.0±0.5	10.3±0.5	14.7±0.3	20.9±1.2	22.8±0.8	17.1±1.0	10.3-22.8
	Female	14.8±0.1	12.8±0.5	15.7±0.6	20.1±0.4	23.0±0.8	15.0±0.3	12.8-23.0
	Mean	15.4	11.6	15.2	20.5	22.9	16.0	11.6-22.9
Cu	Male	673±32	303±6.8	818±12.0	816±20.1	426±8.3	136±6.7	136-818
	Female	600±2.6	332±8.4	853±14.7	896±7.7	385±2.4	85±4.3	85-896
	Mean	637	317	836	856	405	110	110-856
Zn	Male	33.3±1.7	31.2±0.8	24.7±0.9	40.4±0.5	115±2.4	36.8±0.4	24.7-115
	Female	36.8±1.1	38.9±0.6	31.3±2.1	41.4±0.7	142±2.8	33.4±0.8	31.3-142
	Mean	35.1	35.1	28.0	40.9	129	35.1	28.0-129

Table 2. Ag, Cd, Cu, and Zn concentrations (µg/g wet wt.) in the digestive glands of Atlantic rock crab (*Cancer irroratus*) from the Inner Bay of Fundy, Atlantic Canada

Metal	MIC	CBY	MIB	PARS	Victoria Beach[a]	Dalhousie[b]
Ag	3.76±1.88 (0.60-8.42)	3.59±1.47 (1.99-6.61)	4.09±1.24 (0.57-6.50)	5.09±1.54 (2.29-8.24)	1.51 (0.47-2.47)	0.29
Cd	19.3±22.7 (2.27-99.5)	48.8±41.4 (8.76-187)	53.7±30.2 (13.1-112)	61.1±36.8 (8.37-143)	2.02 (0.54-20.6)	7.53
Cu	79.9±58.9 (8.8-286)	165±95.3 (17.8-421)	150±62.8 (20.6-294)	215±126 (56.9-528)	69.7 (21.8-192)	7.98
Zn	30.0±6.14 (23.2-46.4)	27.9±6.33 (19.7-46.4)	38.9±12.1 (21.7-69.6)	42.4±14.1 (23.7-70.4)	24.2 (13.0-41.0)	24.6

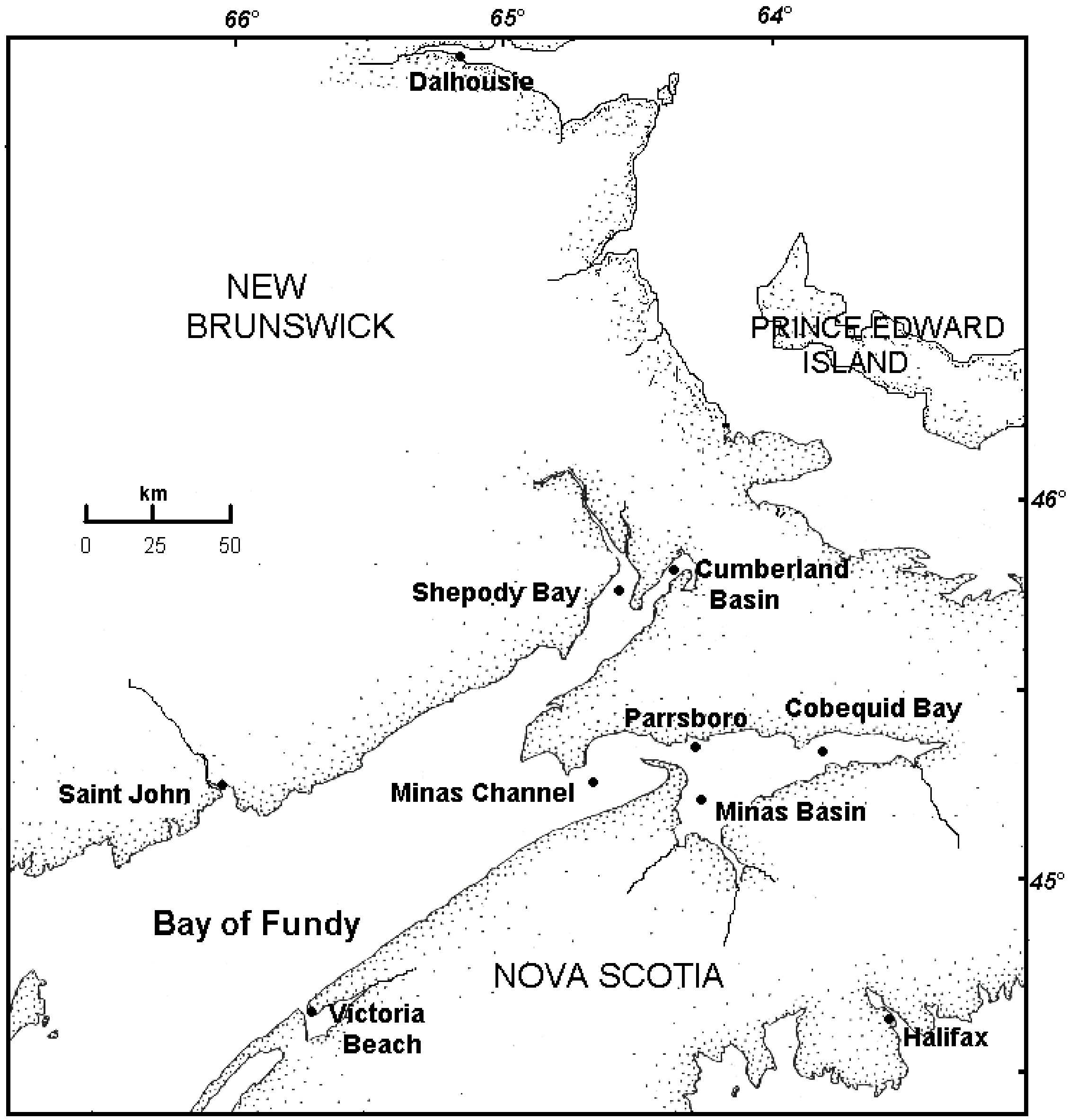
[a] Data originally published in Chou and Uthe (1978)
[b] 3 Pooled samples, collected in 2000, total = 80. Range of concentrations shown in brackets.

Table 3. Ag, Cd, Cu and Zn concentrations (µg/g dry wt.) in sediments from the Inner Bay of Fundy, Atlantic Canada

Metal	Location						Range
	SHB	SAJ	CMB	CBY	MIB	MIC	µg/g
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	0.03	0.11	0.03	0.02	0.03	0.02	0.02-0.11
Cu	15.0	19.2	16.8	17.0	9.3	16.2	9.3-19.2
Zn	58.6	69.4	65.5	48.9	35.1	46.1	35.1-69.4

N.D.: not detected

Figure 1. Lobster and crab sampling sites



ASSESSMENT OF PERSISTENT INDUSTRIAL MARINE DEBRIS: CHARLOTTE COUNTY, NEW BRUNSWICK

Christine Anne Smith

School for Resource and Environmental Studies, Dalhousie University
and EnviroSmith Atlantic, Halifax, NS. christine.smith@ns.sympatico.ca

Abstract

Accumulation of persistent industrial marine debris (PIMD) in the environment adversely impacts coastal wetlands, marine species, and water quality. This paper is based on an environmental assessment conducted in the coastal areas of Charlotte County, New Brunswick. The assessment studied persistent debris (including plastic, synthetics and chemically-treated materials) that originates from such marine industries as commercial fishing, aquaculture and marine transport. Findings are based on data collected during preliminary site visits and environmental field surveys conducted in the spring and summer of 2001. The preliminary assessment provided estimates on the type and amount of PIMD in areas subject to high coastal industry use. This was followed by a more detailed environmental survey and collection of data from 17 sites along the shoreline. Analysis indicates that the majority of PIMD was comprised of plastics, and that most material tends to accumulate above the high water line. The main methods of illegal PIMD disposal included burial or incineration along shorelines and ocean dumping. This study identified the type, amount, sources and impacts of PIMD at the interface between land and water in coastal watersheds. In a broader sense the results assist in developing effective waste management programs, regulations, and infrastructure that provide solutions to PIMD problems.

Introduction

The accumulation of domestic and industrial debris along the shore originates from land- and marine-based industry, recreational activities, and residential garbage disposal. Persistent industrial marine debris (PIMD) from aquaculture, commercial fishing, and other coastal industries is a growing problem in the Bay of Fundy. PIMD includes fishing nets, aquaculture pens, tarpaulin or plastic sheeting, 55-gallon drums, styrofoam floats, and pallets. Essentially these items originate from industries that use coastal resources, e.g., commercial fishing, aquaculture, recreational boating, marine transport, and fish packing plants. Many PIMD items consist of plastic and other synthetic materials that are not readily biodegradable.

Study Objectives

The purpose of the study was to survey marine industrial debris in the Passamaquoddy area in order to identify sources so that preventative strategies could be developed. The type, amount, distribution, and sources of PIMD in the Passamaquoddy study area were determined through field surveys and review of existing information. Study objectives address several questions. For example, How much

PIMD is in the study area? What are the potential and actual effects on the marine or coastal environment? What are the most prevalent types of PIMD? Can they be traced to their sources? Is it all generated locally or does some come from outside the area? The intent is to determine the nature and extent of the problem and then recommend solutions.

Definition of PIMD

PIMD is defined as persistent debris in the marine environment that originates from industrial activities that operate and use resources in coastal areas. The definition of PIMD targets specific materials that, due to composition and size, take a long time to degrade or break down in the marine environment. Studies indicate that monofilament fishing line, plastic bottles, and styrofoam buoys have a biodegradation time of 600, 450, and 80 years respectively (Mote 1993). Manufacturers claim that products such as plastic navigation or suspension buoys can endure Bay of Fundy conditions for hundreds and possibly thousands of years.

Environmental, Social and Economic Effects of PIMD

More than 50% of marine litter consists of plastics (Marine Conservation Society 2000). It is estimated that over one million birds and 100,000 marine mammals and sea turtles die every year from entanglement in, or ingestion of, plastics. Of the 115 species of marine mammals, 47 are known to become entangled in and/or ingest marine debris. Approximately 30,000 northern fur seals die annually due to entanglement, primarily in net fragments (Marine Conservation Society 2000). Estimates of marine life endangered by debris include most of the world's turtle species, 25 percent of marine mammal species, and more than 15 percent of seabird species. Plastic film and sheeting, can settle over plants and animals, covering ecosystem habitats such as coral reefs, effectively blocking out sunlight and nutrients (Sea Grant 2001). Economic losses include damage to nets, plastic sheets blocking water intake pipes, damage to boats due to collision with metal drums or wooden pallets, ropes or nets getting caught in boat propellers, lost fishing opportunities (ghost fishing), and lost tourism potential due to unsightly beach litter (Butler et al. 1989:6). A lack of material recycling perpetuates use of virgin materials in production, placing pressure on natural resources. For example, recycling metals and plastics reduces the need to mine or extract such material from the environment.

The study area overlaps Gulf of Maine watersheds. Four distinct environments are defined as:

1. The West Isles (Quoddy): island chain between Letete Passage extending south to Deer, Indian, and Campobello Islands
2. Passamaquoddy Bay: enclosed sea into which the St. Croix, Digdeguash, and Magaguadavic Rivers flow
3. Letang Harbour: includes shoreline and islands in the Letang Harbour and along the north side of the Letete Passage
4. Southwest New Brunswick Coast: extends from Pea Point northeast to Pocologan Harbour, along the Bay of Fundy to Maces Bay

Approach

The study methodology was essentially to gather data on PIMD at selected sites in the study area, to identify types of industries close to each site in the study area, and to determine the relationship between the PIMD and industrial operations in the study area. Between May 31 and June 8, 2001 a preliminary assessment was conducted to determine the type, location, and amount of PIMD at targeted sites in the study area. This assessment involved field visits to sites by car, DFO vessel (Pandalus and zodiac), and an aerial survey. Video footage of shoreline in the Passamaquoddy region was recorded on a hand-held camcorder during both ground visits and the aerial survey. Approximately three hours of videocassette footage was shot and converted to videotape for all site visits. In addition, a total of 323 photographs were taken at sites in the study region. Control sites (Figure 1) provided comparison in the presence or absence of certain features. The presence and amount of PIMD in areas with no coastal industry can be compared to areas close to coastal industry.

In this study, PIMD was broken down into five categories: plastic and synthetic fiber, polystyrene or styrofoam, rubber, metal, and wood. A PIMD data record card was created listing the items included in each of these categories. Minimum sizes counted under each category included pieces and scraps from a few centimeters to approximately 0.5 m in length and/or width. Types of wood include large or treated items that take longer to biodegrade, i.e. weir poles, aquaculture pens and floating docks. Domestic marine debris (DMD) consists of items that originate from household or residential use. DMD data cards collected information on plastic, foam, rubber, metal glass, wood, paper, and cloth. Since the focus of the study is on PIMD, only one DMD data card was filled out for each area and used to count and identify items at control sites.

Results

All preliminary site visits took place during low tides. During these preliminary studies it was also noted that PIMD tends to accumulate closer to residential areas and industry operations. Due to area size, resource, and time constraints, only 17 sites were selected for more detailed study (Table 1). Data were entered into spreadsheets, and tables were created to indicate the most prevalent items as a percentage of totals for each study area (Tables 2.1–2.5).

The total amount of PIMD items counted at the 13 PIMD study sites was 2,114 (Table 2). The average amount of PIMD at each study site was 163 items. The total amount of PIMD counted at the four control sites was 11 items. The average amount of PIMD at each control site was 2.75 items. The most common debris category is plastic. From 41.1% to 57.1% of all materials in each area consisted of plastic or PVC materials—with a total amount of 1,114 items counted at all sites collectively. Foam was the second most common PIMD type—with 19.6% to 31.6% of all material counted at each site identified as styrofoam.

The site with the highest variety of PIMD was Fraiser Beach where a total of 31 different types of PIMD items were found. Two other sites with highly diverse amounts of PIMD were Lords Cove and Indian Island with 28 and 27 different types of items respectively. Sites with the lowest variety of PIMD were Ship Harbour (7), Frye Island (7), and Beaver Harbour (11).

Sites with the highest amounts of PIMD were identified along with sites where the largest items were found (Table 3). The estimated number of fish weirs, aquaculture sites and fish processing plants within four kilometres of each site in the study area (Figure 1 and Table 3) are also indicated for each of the study areas. Other coastal resource use activities relate to net and line fishers, tourism, research, and transportation.

The total number of Riverdale coffee cups counted was 77. The highest amount was found in the West Isles with a total of 33. The lowest number were found in the Southwest New Brunswick area (total of four). No Riverdale cups were found at the Sandy Island, Dear Island Point, Timber Cove, Beaver Harbour, and Pocologan Harbour sites. Riverdale coffee cups are found in areas with higher residential populations and are closer to the Irving stores. This indicates that most floating debris is not transported very far from place of origin by currents, winds and tides.

Conclusions

Overall observations in the Quoddy area indicate that the amount of debris is greater on shorelines closer to municipal centres or with a greater industry presence nearby. The West Isles study area has the highest amount of PIMD on average. The average amount of items counted at each site in the West Isles was 204. This area also has the highest number of industry operations. The Southwest New Brunswick coast has the lowest amount of PIMD on average for each site. In this area industry was not as prevalent, and the average number of PIMD items counted at each site was 66. This suggests a correlation between amount of coastal-based industry in an area and amount of PIMD that washes up on shore. Selected locations are representative of the four study areas, so amounts at hundreds of other sites in this region may be similar to the 163-items per site average.

This suggests that an enormous amount of PIMD is accumulating in the study region. The dynamics of oceanographic winds, currents and tides may have some influence on movement of material from water to shore. However, all identifiable items appear to be generated locally. For example, sites directly beside aquaculture operations tended to have a higher amount of feedbags, flotation pipes, cages, and cage parts, e.g., Indian Island, Fraiser Beach and Cummings Cove. Lightweight PIMD items such as feedbags and styrofoam are transported into adjacent terrestrial ecosystems by wind. Heavy and entangled items may be lifted off shorelines and redistributed in the area by extreme tidal events. Potential impacts to the marine environment in the four study areas include release of toxins from incineration of PIMD, leachate from unauthorized landfills, ingestion by seabirds, entanglement of wildlife, and navigational hazards.

Table 4 indicates where evidence of incineration was found in the four study areas. From a total of 17 sites visited during the summer, eight were found to have evidence of PIMD incineration. This amount is high considering the fact that unauthorized open pit burning of waste material is not legal. The long-term impact of incineration on the local environment is not fully known—effects include the release of carcinogenic compounds such as vinyl chloride into the atmosphere. In addition, burning plastics and other items that can be recycled places pressure on the environment due to the fact that new materials must be extracted from natural resources.

Other adverse environmental impacts from inappropriate PIMD disposal include leachate from illegal landfill operations along the coast. Durable and buoyant plastic and foam items can carry colonies of bryozoans, barnacles, polychaetes, hydroids, and mollusks to distant locations. This is a threat to biodiversity since it encourages introduction of exotic marine flora and fauna to other areas of the world (BBC 2002). Furthermore, studies conducted by Department of Fisheries and Oceans scientists indicate that smaller marine animals such as sea urchins ingest plastic and foam. When metabolized, these materials release estrogenic compounds such as nonylphenol or bisphenol-A. World Health Organization and the US Environmental Protection Agency findings indicate that estrogenic compounds released by plastics interfere with human and wildlife endocrine systems leading to development, behaviour and reproductive problems (EPA 2000).

Recommendations

1. Research current legislation to determine how effective it is at preventing marine debris and how it may be improved. For example, should fines be increased? Do waste handling capabilities on shore provide reasonable support for the regulations?
2. Study how other regions or countries are solving the PIMD problem, e.g., placing responsibility on the manufacturer to take back and recycle packaging and items when the consumer is finished with them.
3. Research the effects of PIMD incineration on local air, soil and water and determine the types of toxic chemicals released by the different types of PIMD when incinerated.
4. Research effects of plastic metabolization on the food chain, e.g., determine if it is bioaccumulative and what the effects are to living systems.
5. Improve waste handling infrastructure for coastal debris in each of the four study areas.
6. Educate coastal resource users on the adverse impacts of PIMD and consult with public and industry on solutions to PIMD problems.

Proper waste management requires an understanding of the material composition of tools, equipment and packaging used by industry that are likely to end up as PIMD. It also requires evaluation of current waste resource collection methods and handling operations as well as locating local markets for PIMD. If PIMD take-back, collection and handling facilities are inadequate, then regulations and waste management programs will be ineffective.

Acknowledgements

I would like to thank Eastern Charlotte Waterways, the New Brunswick Salmon Growers Association, Dalhousie University, the Department of Fisheries and Oceans, the St. Andrews Biological Station, Shubenacadie Education, and my thesis committee at SRES, Dalhousie University, for resources and support that made this study possible. To my family and friends for their encouragement and help – thank you. I would also like to express appreciation to the Bay of Fundy Ecosystem Partnership for the opportunity to communicate these findings.

References

British Broadcasting Corporation (BBC). 2002. " Rubbish menaces Antarctic species". 24 April, URL: <http://news.bbc.co.uk/hi/english/sci/tech/newsid1948000/1948714.stm>. Date of Access: April 29, 2002.

Butler, M., A. Guinchard, O. Olojede, R. Parker, J. Ross, K. Soltan, M. Strickland, and S. Sweeny. 1989. A Survey of Shoreline Litter in Halifax Harbour 1989 Joint Project. School for Resource and Environmental Studies, Dalhousie University, Halifax.

Environmental Protection Agency (EPA). 2000. Endocrine Disruptor Screening Program. URL: <http://www.epa.gov/oscpmont/oscpendo/index.htm>. Date of access: 15 August, 2002.

Marine Conservation Society. 2000. "National Aquatic Litter Group", last updated: not indicated. URL: <http://www.adoptabeach.org.uk/NALG/html/nalg_home.htm>. Date of access: March 15, 2001.

Mote Marine Laboratory. 1993. Marine biodegradation time line. Sarasota, FL.

Sea Grant National Media Relations Office. 1994–2001, "Sea Grant National Media Center", last updated: not indicated. URL: <http://seagrantnews.org>. National Sea Grant College Program, Washington D.C. Date of access: March 15, 2001.

Figure 1. Study areas

PIMD Assessment Sites

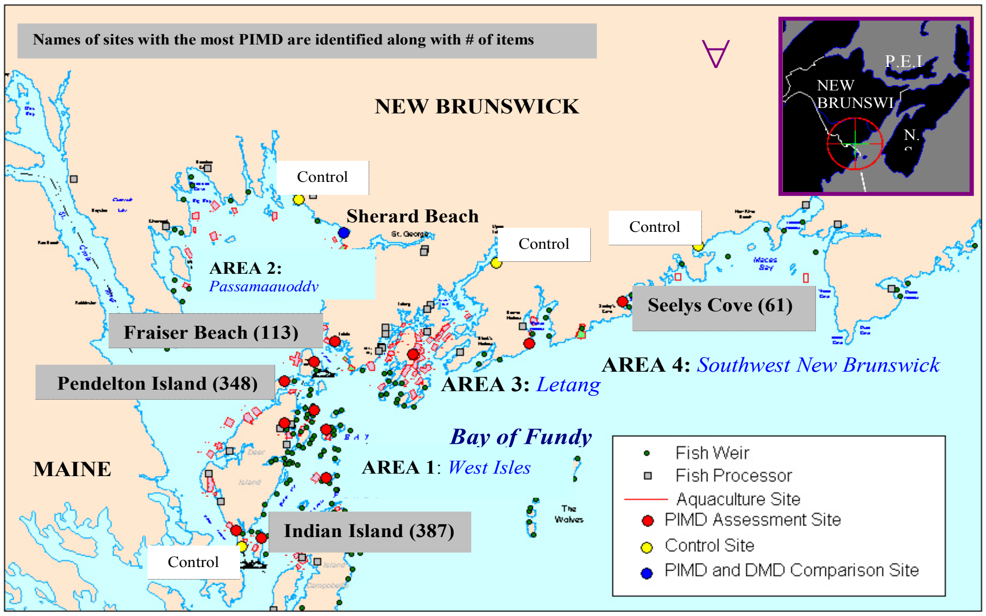


Table 1. Data collection sites: Area use, PIMD, DMD and control amounts

Environmental Region	#	Site Name & Number of PIMD items counted	Area use	Data use
The West Isles (Quoddy)	1	Sandy Island (44)	Weirs, aquaculture	PIMD
	2	Simpsons Island (245)	Weirs, aquaculture	PIMD
	3	Indian Island (387)	Aquaculture site	PIMD
	4	Ship Hbr, MacMasters Island (57)	Aquaculture site	PIMD
	5	Lords Cove, Deer Island (288)	Lobster pound, Fish Processing Plant	PIMD
	6	Hardwood Island (202)	Aquaculture	PIMD
	7	Deer Island Point (3 PIMD & 106 DMD items)	Provincial Park & ferry to Campabello I.	Control
Passamaquoddy Bay	8	Cummings Cove (165)	Fish Processing Plant, aquaculture	PIMD
	9	Pendleton Island Beach (348)	Aquaculture	PIMD
	10	Sherard Beach (120)	Fish Processing Plant, aquaculture and rural - residential	Comparison PIMD and DMD
	11	Timber Cove, Oven Head (0)	Rural - some cottages	Control
L'Etang Harbour	12	Fraiser Beach, Mathew's Cove (113)	Aquaculture	PIMD
	13	Birch Cove, Frye Island, Lime Kiln Bay (62)	Fish Processing Plant, aquaculture	PIMD
	14	Treinors Cove (5 PIMD & 15 DMD items)	Rural - rural - residential	Control
Southwest New Brunswick Coast	15	Lighthouse Pt., Beaver Harbour (51)	Fish Packing Plant, Weirs, aquaculture	PIMD
	16	Seelys Cove (61)	Weirs, aquaculture	PIMD
	17	Pocologan Hbr, Maces Bay (3 PIMD and 105 DMD items)	Rural – residential	Control

Table 2. Amount of PIMD in each study area (percentages of the total)

Study Area	Total Plastics	Total Foam	Total Rubber	Total Metal	Total Wood	Area Total	Average for each site
West Isles (6 sites)	646 (52.8%)	386 (31.6%)	21 (1.7%)	28 (2.3%)	142 (11.6%)	1223	204
Passamaquoddy (3 sites)	332 (55%)	171 (28.3%)	4 (0.66%)	3 (0.49%)	94 (15.6%)	604	201
L'Etang (2 sites)	72 (41.1%)	55 (31.43%)	6 (3.43%)	15 (8.6%)	27 (15.43%)	175	87.5
Southwest NB Coast (2 sites)	64 (57.1%)	22 (19.6%)	8 (7.1%)	2 (1.79%)	16 (14.29%)	112	66
Total for Study Region	1114	634	39	48	279	2114	~ 163

Table 2.1. Plastic items counted at sites as a percentage of total for each study area

Plastic Items Counted at Each Site	West Isles (%)	Passamaquoddy (%)	L'Etang (%)	Southwest N.B. Shore (%)
Cleaner bottles	11.9	6.6	7.0	7.8
Oil bottles	11.5	14.2	4.2	15.6
Pipes	0.5	0.3	41.7	0
Flotation pipes	2.0	0.6	4.2	1.56
Totes	1.9	1.2	1.4	1.56
Feed or salt bags	12.4	11.5	4.2	4.7
Floats	0.5	0.9	2.8	0
Fish boxes	0.6	0	0	0
Drums	0	0.9	0	0
Aquaculture pens (cages)	0.5	1.5	9.70	0
Synthetic fibre: rope / lines>2m	33.1	43.7	16.7	35.9
Fishing nets >1m	2.8	1.5	0	0
Weir nets >1m	0.6	1.2	0	0
Nets >1m	3.7	0.6	5.0	0
Plastic sheeting > 1m	3.7	7.2	4.2	40.6
Melted plastic	1.5	2.4	0	4.7
Buckets	1.24	2.1	0	0
Other plastic or synthetic fibre items	11.6	4.5	1.4	0

Table 2.2. Foam items counted at sites as a percentage of total for each study area

Foam Items Counted at Each Site	West Isles (%)	Passamaquoddy (%)	L'Etang (%)	Southwest N.B. Shore (%)
Foam sheets > 0.25m	10.88	28.7	27.27	4.5
Foam floats	3.88	7.0	1.8	13.63
Foam packing: flotation or insulation	2.33	0	1.8	0
Foam Pieces < 0.25m	78.5	63.74	45.45	81.81
Other foam items	0.26	0.58	0	0

Table 2.3. Metal items counted at sites as a percentage of total for each study area

Metal Items Counted at Each Site	West Isles (%)	Passamaquoddy (%)	L'Etang (%)	Southwest N.B. Shore (%)
Crab or lobster traps	3.57	0	0	0
Aquaculture pens (cages)	0	0	0	0
Motors	0	0	20.0	0
Vessel parts	25.0	66.66	13.33	0
Rusty drums	17.86	0	0	0
New metal drums	0	0	0	0
Other metal items	42.86	33.33	66.66	100.0

Table 2.4. Rubber items counted at sites as a percentage of total for each study area

Rubber Items Counted at Each Site	West Isles (%)	Passamaquoddy (%)	L'Etang (%)	Southwest N.B. Shore (%)
Rubber tires	80.96	25.0	66.66	50.0
Oher rubber items	19.0	75.0	33.33	50.0

Table 2.5. Wood items counted at sites as a percentage of total for each study area

Wood Items Counted at Each Site	West Isles (%)	Passamaquoddy (%)	L'Etang (%)	Southwest N.B. Shore (%)
Weir poles	16.19	9.57	0	6.25
Finfish cages	2.11	1.06	48.15	0
Aquaculture (cage) parts	2.11	3.2	0	0
Crates	4.9	0	0	0
Pallets	6.34	9.57	3.7	0
Beams or planking	67.6	74.5	25.93	93.75
Other wood items	6.34	2.13	22.22	0

Table 3. Highest amounts, largest items and industry presence

Study Area	Sites With Highest Amounts of PIMD	Largest Items and Sites where Located	Concentration Of Industry:
West Isles	Indian Island (387)	Pontoon - Simpsons Island Feed barge - Indian Island	Fishing Weirs: 65 Aquaculture sites: 14 Fish Processing Plants: 5 Total: 84
Passamaquoddy Bay	Pendelton Island (348)	Aquaculture cage - Pendelton Island Floating docks - Cummings Cove	Fishing Weirs: 21 Aquaculture sites: 22 Fish Processing Plants: 10 Total: 53
L'Etang	Fraiser Beach (113)	Fishing vessels - Frye Island	Fishing Weirs: 15 Aquaculture sites: 28 Fish Processing Plants: 8 Total: 51
Southwest NB coast	Seelys Cove (61)	Furnace oil drum - Seelys Cove	Fishing Weirs: 16 Aquaculture sites: 4 Fish Processing Plants: 3 Total: 23

Table 4. Location of incineration sites

Area	Site	Fire Pit Detected?	Melted Plastic or rubber?
West Isles	Simpsons Island	No	Yes
	Indian Island	Yes – 3 pits	Yes - plastic and rubber
	Lords Cove	No	Yes
Passamaquoddy Bay	Cummings Cove	Yes – 1 pit	Yes – plastic
	Pendelton Island Site	No	Yes
L'Etang Harbour	Fraiser Beach	Yes ~ 2-3 pits	Yes – melted rubber
Southwest NB coast	Beaver Harbour	Yes	No
	Seelys Cove	No	Yes

THE COMPARATIVE TOXICITY OF ORIMULSION® AND NO. 6 FUEL OIL TO THE SEDIMENT DWELLING AMPHIPOD, *Corophium volutator*

Isabel C. Johnson[1], Ken Doe[2] and Paula Jackman[2]

[1] Golder Associates Inc., Gainesville, FL. iJohnson@GOLDER.com
[2] Environment Canada, Environmental Science Centre, Moncton, NB.

Abstract

ORIMULSION® is a bitumen-based fuel being transported and used worldwide as an alternative fuel for power plant electric generation. Based on the increased use of ORIMULSION® in electric power production, a significant effort has been devoted to research on the potential fate and effects of accidental marine spills of this fuel.

ORIMULSION® is an emulsion of bitumen particles (70 percent) in water (30 percent); the emulsion of bitumen particles is maintained through the use of a surfactant (alcohol ethoxylate) and an emulsion stabilizer (monoethanolamine). Research carried out at numerous research centers, laboratories, and universities worldwide indicate that should an accidental spill of ORIMULSION® occur in the marine environment, ORIMULSION® will initially dilute in the upper few meters of the water column as a dispersion of bitumen particles, dissolved aromatic hydrocarbons and surfactant. Extensive research has been carried out on the chemical and physical characteristics of ORIMULSION® as well as its potential ecological effects.

Environment Canada's Toxicology Laboratory in Moncton and Golder Associates Inc. evaluated the effects of both ORIMULSION® and Fuel Oil No. 6 on the sediment dwelling amphipod, *Corophium volutator*, an important benthic species in the Bay of Fundy (New Brunswick and Nova Scotia). Acute and long-term sediment toxicity tests were conducted using both fuels. The toxicity tests endpoints were survival and growth. Exposure sediment concentrations of both fuels were confirmed by chemical analysis conducted by Environment Canada, Ottawa. *C. volutator* was found to be relatively insensitive to either fuel, although Fuel Oil No. 6 was 3 times more toxic to *C. volutator* than ORIMULSION®.

Introduction

Sediments from a clean reference site, Walton Beach, located on the Bay of Fundy coast of Nova Scotia, were spiked with a series of concentrations of ORIMULSION® and Fuel Oil No. 6. Spiked sediments were tested for acute toxicity (survival) and long-term effects (growth) to the marine amphipod, *C. volutator*, using the standard Environment Canada 10-day growth test (Environment Canada 1992). The ORIMULSION® test was extended to 20 and 40 days.

Spiked sediment toxicity tests were initiated immediately after spiking with either fuel. Sediment exposure concentrations were confirmed by chemical analysis for polynuclear aromatic hydrocarbons (PAH) and total petroleum hydrocarbons (TPH). These chemical analyses were conducted by Environment Canada, Environmental Technology Centre, Ottawa.

Methods and Materials

Control Sediment Collection, Handling, and Spiking

Control sediment was collected from Walton Beach, Nova Scotia, using new non-toxic containers. A 30-L batch of the sediment was collected on January 19, 2002 and taken to the Toxicology Laboratory of Environment Canada in Moncton, New Brunswick, on January 21, 2002. The sediment was sieved through a 1 mm sieve to remove indigenous organisms and large particles, and thoroughly homogenized. Sediment subsamples were removed for chemical characterization, the parameters tested were: grain size, total organic carbon (TOC), metals, polychlorinated biphenyls (PCBs), and PAHs. The storage containers were filled to eliminate any air space, refrigerated (4 ± 3°C) and kept dark to assure minimal changes between collection and use for spiking sediment for toxicity tests.

Sufficient sediment was spiked through direct addition of weighted fuel at each test concentration for all replicates of the toxicity test and additional samples for chemical confirmation of initial exposure concentrations. Chemical confirmation of exposure concentrations were conducted as: total solvent extractable material (TSEM) and TPH. The Environment Canada Laboratory, Environmental Technology Centre, Ottawa, Ontario (Wang 2002a and 2002b), conducted these analyses.

The control sediment was spiked on a weight: weight basis [weight of test material (Fuel Oil No. 6 or ORIMULSION®) to wet weight of control sediment]. The required amounts of sediment and test material were measured and the weights recorded. The spiked sediment was mixed thoroughly by hand in stainless steel trays with stainless steel spoons for approximately 10 minutes. The spiked sediments were used immediately to set up toxicity tests with *C. volutator* and for test concentration chemical confirmation.

The nominal test concentrations prepared for ORIMULSION® were: control, 108, 429, 1,620, 6,450 and 12,900 mg/g. For the Fuel Oil No. 6 tests, the concentrations were: control, 32.3, 61.7, 434, 1,560 and 6,600 mg/g. These test sediment concentration ranges were selected based on previous unpublished sediment toxicity test data conducted by the authors using these two fuels and freshwater amphipods (Hyalella).

Test Materials

The ORIMULSION® was provided by Bitor America Corporation from a shipment received at NB Power's Dalhousie Generating Station in New Brunswick, Canada. The ORIMULSION® was received in a barrel, which was subsampled at Golder's HydroQual Laboratories in Calgary, Alberta.

Fuel Oil No. 6 was provided by New Brunswick Power, from a Fuel Oil No. 6 shipment received for use at the Coleson Cove Generating Station, near Saint John, NB. The Fuel Oil No. 6 originated from the US Gulf coast. Both the ORIMULSION® and the Fuel Oil No. 6 were chemically characterized by Environment Canada's Environment Technology Center, Ottawa.

Test Protocol

C. volutator were collected by Harris Industrial Testing Services of Mount Uniacke, Nova Scotia on January 19, 2002 and held in the collection site sediment with minimal disturbance at their laboratory until January 21, 2002. The sediment samples (including the test organisms) were at 5 to 10°C upon arrival at Environment Canada's laboratory and were acclimated to and maintained at 15 ± 2°C and 30 ± 2 ppt salinity until used for testing. The tests were started on January 25, 2002.

On the day prior to starting the test, each concentration of test sediment was spiked using the procedure described above. One-litre mason jars were used as test containers and each test container received 175 mL of spiked sediments; five replicates were used for each treatment and control. The test containers were then filled with 800 mL of clean seawater (salinity was 28 ppt), covered, and aerated overnight. The seawater was natural water collected at Pointe-de-Chêne, NB, and filtered through a 5 Fm filter. Tests were conducted according to Environment Canada (1992) standard acute tests for sediments using marine amphipods.

On day 0 of the test, twenty amphipods were added to each of the test containers. Testing was performed with a 24-hour light photoperiod with lighting provided by overhead fluorescent fixtures at an intensity of 500 to 1000 lux. *C. volutator* testing was performed at 15 ± 1°C. Tests were checked daily for observations, aeration and temperature. Three times a week a replicate of each sample was monitored for temperature, pH, salinity and dissolved oxygen.

After 10 days, the contents of each test chamber were sieved through a 0.750 mm sieve. Amphipods were observed under a microscope; death was defined as lack of all movement when observed under a dissecting microscope for 5 to 10 seconds. Any amphipods missing were assumed to be dead. The mean percentage survival of amphipods exposed to each of the test sediments was statistically compared to the mean percent survival of amphipods exposed to the clean lab control sediment using ANOVA statistics in the SigmaStat software (SPSS 1997). The LC50, the concentration that caused a 50% decrease in mortality, was estimated for each fuel using the program Toxstat version 3.5 (West 1996).

In addition to the standard 10-day survival assay, six additional replicates of the control, 108 and 429 mg/g ORIMULSION® were prepared and tested. Testing methods for these additional replicates was the same as the standard test with the following exceptions: tests organisms were fed, 10 organisms were used per vessel instead of 20, test duration was longer, and organism weights were determined at test initiation. Starting on day 11 until test termination, each test vessel was fed 30 milligrams of finely ground dry food three times a week. The food consisted of 50% Tetramin, 25%

Tetramarin and 25% Enteromorpha. Overlying water was occasionally renewed at approximately 90% of the volume. The test duration was 20-days for three of the replicates and 40-days for the remaining three replicates.

On the day the tests were started, five trays of ten organisms each were rinsed with distilled water and transferred to a tared weighing dish. The animals were dried at 60°C for at least 24 hours, cooled in a dessicator for 15 minutes and the dry weight of the test organisms was determined. Animals were dried to constant weight (+ 0.05 mg).

All surviving amphipods at the end of these tests were treated in a similar manner. The survivors from any one replicate of each treatment were pooled and dry weights determined. The average weights of test animals from that replicate were then calculated. The average dry weight of test organisms for all replicates of a treatment was compared to the control sediment using ANOVA statistics in SigmaStat statistical software (SPSS 1997) to determine if exposure to the sediment caused a significant decrease in organism weight.

Results and Discussion

The results of the standard 10-day bioassay with the marine amphipod, *C. volutator*, for ORIMULSION®-spiked sediments are summarized in Table 1. A summary of calculated toxicity endpoints using nominal and measured concentrations is provided in Table 2. The mean survival of the amphipods in control sediment was 98%. These values meet acceptability criteria as defined in the test method (Environment Canada 1992). Significant decreases in survival were observed at 6,450 and 12,900 Fg/g nominal ORIMULSION® test concentrations. The LC50 was estimated at 6,540 Fg/g ORIMULSION®, or 2,840 Fg/g TSEM, or 1,030 Fg/g TPH (Wang 2002a).

The results of the 10-day bioassay with the marine amphipod, *C. volutator*, for Fuel Oil No. 6-spiked sediment are summarized in Table 3. A summary of calculated toxicity endpoints is provided in Table 4. The mean survival of the amphipods in control sediment for this test was 91%. These values meet acceptability criteria as defined in the test method (Environment Canada 1992). Significant decreases in survival were observed at 1,560 Fg/g nominal Fuel Oil No. 6 concentration. The LC50 was estimated at 1,990 Fg/g nominal concentration; or 1,310 Fg/g expressed as measured TSEM; or 575 Fg/g expressed as measured TPH (Wang 2002b). Based on these 10-day acute toxicity tests Fuel Oil No. 6 was found to be more toxic to the amphipod, *C. volutator*, than ORIMULSION®.

The results of the 20-day bioassay using ORIMULSION® with the marine amphipod, *C. volutator*, are provided in Table 5. The mean survival of the amphipods in control sediment after 20 days was 86.7%. The two ORIMULSION® test concentrations had higher survival than the lab controls (93 and 100 % for the 420 and 108 Fg/g, respectively). The average weight of organisms at the start of the test was 0.75 mg. After 20-days the control organisms' average weight was 1.11 mg , the mean weight of the organisms from the 108 and 429 F/g ORIMULSION® were 1.18 and 0.89 mg, respectively. All test organisms had increased in weight. Neither ORIMULSION® test concentration had weights significantly different from the lab control.

The results of the 40-day bioassay with the marine amphipod, *C. volutator* were considered invalid, as all the control animals were dead. Twenty-three percent survival was observed in the 108 Fg/g ORIMULSION® test concentration after 40 days.

Conclusions

The 10-day standard bioassay using ORIMULSION®-spiked sediments conducted with the marine amphipod, *C. volutator* showed a significant decrease in survival at 6,450 Fg/g nominal concentration. The 10-day LC50 was estimated to be 6,540 Fg/g nominal ORIMULSION® in the sediments. The 10-day standard bioassay using Fuel Oil No. 6-spiked sediments with the marine amphipod, *C. volutator*, showed significant decreases in survival at 1,560 Fg/g nominal concentration. The LC50 was estimated to be 1,990 Fg/g nominal Fuel Oil No. 6 in the sediments. Based on nominal concentrations, Fuel Oil No. 6 was 3 times more toxic than ORIMULSION® to the marine amphipod *C. volutator*.

For the 20-day bioassay with the marine amphipod, *C. volutator*, for ORIMULSION® spiked into sediment at 108 and 429 Fg/g, there was no effect on survival and growth. The 40-day test with the marine amphipod, *C. volutator,* was not valid as there was no survival of control animals.

References

Environment Canada. 1992. *Biological Test Method: Acute Test for Sediment Toxicity Using Marine or Estuarine Amphipods*. Report EPS 1/RM/26. Environment Canada, Ottawa, ON.

SPSS Inc. 1997. SigmaStat Version 2.0 Statistical Software. SPSS Inc., Chicago, IL.

Stephan, C. E. 1977. Methods for calculating an LC50. Pages 65–84. In: *Aquatic Toxicology and Hazard Evaluation*. F. L. Mayer and J. L. Hamelink (Eds.). ASTM STP 634. American Society for Testing and Materials, Philadelphia, PA.

Wang, Z. 2002a. Technical Memorandum to K. Doe and I. Johnson. February 19, 2002. Reference # 2002-07. Environment Canada, Environmental Technology Centre, Ottawa, ON.

Wang, Z. 2002b. Technical Memorandum to K. Doe and I. Johnson. February 24, 2002. Reference # 2002-08. Environment Canada, Environmental Technology Centre, Ottawa, ON.

West Inc. 1996. Toxstat Version 3.5. Statistical Software. Western EcoSystems Technology Inc., Cheyenne, WY.

Table 1. Survival results of 10-day sediment test with *Corophium volutator* for ORIMULSION®-spiked sediments

Nominal Concentration µg/g	**Mean % Survival (Std. Dev.)**
Walton Beach Lab Control	98.0 ± 2.7
108	96.0 ± 2.5
429	95.0 ± 6.1
1620	90.0 ± 11.7
6450	68.0 ± 13.0
12900	11.0 ± 11.9

Table 2. Calculated toxicity results for *Corophium volutator* based on nominal and measured concentrations for ORIMULSION®-spiked sediments

	10-Day LC50
Nominal Concentration of Orimulsion (µg/g)	6540 (5330 – 8030)
TSEM Measured (µg TSEM/ g sample)	2840 (2310 –3500)
TPH Measured (µg/g)	1030 (794 – 1340)

Table 3. Survival results of 10-day sediment test with *Corophium volutator* for Fuel Oil No. 6 spiked into sediments

Nominal Concentration µg/g	**Mean % Survival (Std. Dev.)**
Walton Beach Lab Control	91.0 ± 6.5
32.3	91.0 ± 7.5
61.7	96.0 ± 6.5
434	93.0 ± 7.6
1560	57.0 ± 16.8
6600	4.0 ± 4.2

Table 4. Calculated toxicity results for *Corophium volutator* based on nominal and measured concentrations for Fuel Oil No. 6 spiked into sediments

	10-Day LC50
Nominal Concentration of No. 6 Fuel Oil (µg/g)	1990 (1730 – 2290)
TSEM Measured (µg TSEM/ g sample)	1310 (1120 – 1530)
TPH Measured (µg/g)	575 (489 – 676)

Table 5. Survival results of 20-day sediment test with *Corophium volutator* for ORIMULSION® spiked into sediments (t = number of days)

Nominal Concentration µg/g	**Mean % Survival (Std. Dev.)**	**Mean dry weight**
Walton Beach Lab Control t=0		0.75 ± 0.03
Walton Beach Lab Control t=20	86.7 ± 11.6	1.11 ± 0.16
108	100 ± 0	1.18 ± 0.07
429	93.3 ± 5.8	0.89 ± 0.03

Table 6. Survival results of 40-day sediment test with *Corophium volutator* for ORIMULSION® spiked into sediments

Nominal Concentration µg/g	**Mean % Survival (Std. Dev.)**
Walton Beach Lab Control	0 ± 0
108	23.3 ± 23.1
429	3.3 ± 5.8

ASSESSING NUTRIFICATION IN THE BAY OF FUNDY: SEAWEEDS AS EXCELLENT BUT UNDERUTILIZED BIOINDICATORS FOR INTEGRATED COASTAL MANAGEMENT

Thierry Chopin[1,2], Ellen Belyea[1,2], Christopher Pearce[3,1], Tara Daggett[1,3], Gary Saunders[2] and Colin Bates[2]

[1] Centre for Coastal Studies and Aquaculture, University of New Brunswick, Saint John, NB. tchopin@unbsj.ca
[2] Centre for Environmental and Molecular Algal Research, University of New Brunswick, Fredericton, NB. gws@unb.ca and i851z@unb.ca
[3] Ross Island Salmon Ltd., Grand Manan, NB.

One of the most difficult tasks scientists, resource managers and policy advisors face when assessing the health of coastal ecosystems is understanding their assimilative capacity under cumulative pressure as anthropogenic activities increase in the coastal zone (sewage effluents, urban/rural effluents, precipitations, agricultural/industrial runoffs, aquaculture, etc.). The inorganic output of these activities is presently emerging as a pressing issue as nutrification of coastal waters is a worldwide phenomenon which does not spare the Bay of Fundy.

Assessing nutrification through seawater analyses can rapidly become a nightmare in highly dynamic systems, such as the Bay of Fundy, due to sampling logistics. Our results demonstrate that seaweeds can be excellent bioindicators of nutrification because they are integrators of bioavailable nutrients over time. They can also be very useful tools for measuring the zone of influence of an aquaculture site. Our results will also emphasize the need to carefully choose the species selected as biomonitors (benthic, reasonably abundant, easy to identify and sample near the low tide level, large enough for analysis, tolerant of handling stress, resistant to a wide range of environmental conditions, and net accumulators of nutrients of interest without rapid saturation of algal tissues).

Considering seaweeds as renewable biological nutrient scrubbers allows for an understanding of one of their fundamental roles in coastal ecosystems, and validates their sustainable harvesting and their use for bioremediation and diversification in integrated aquaculture systems.

THE HELMINTH COMMUNITIES OF FIVE SHOREBIRD SPECIES IN THE BAY OF FUNDY, NEW BRUNSWICK, CANADA

Andy S. Didyk[1] and Michael B. D. Burt[2]

[1] Faculty of Biology, University of New Brunswick, Moncton, NB. adidyk@unb.ca
[2] Department of Biology, University of New Brunswick, Fredericton, NB. mburt@unb.ca

As part of a larger study examining the helminth communities of five sympatric species of nearctic shorebirds collected at major stops along their entire migratory routes, 61 helminth species, comprising 23,668 individuals, were recovered from Least Sandpipers, *Calidris minutilla* (Vieillot), Semipalmated Sandpipers, *C. pusilla* (L.), Lesser Yellowlegs, *Tringa flavipes* (Gmelin), Short-billed Dowitchers, *Limnodromus griseus* (Gmelin), and Semipalmated Plovers, *Charadrius semipalmatus* Bonaparte, collected in the Bay of Fundy, New Brunswick, Canada. The most common and most abundant helminth species were the digeneans *Maritrema subdolum* and *Spelotrema papillorobustum*; together the two species accounted for over 85% of all helminths recovered. Prevalence of infection was high as 170 of 193 bird hosts (88.1%) were infected with an average of three helminth species. The intensity of infections varied among the different hosts, being highest in Semipalmated Plovers and lowest in Semipalmated Sandpipers. The helminth communities of Least and Semipalmated Sandpipers and Lesser Yellowlegs exhibited high similarity as did the helminth communities of Short-billed Dowitchers and Semipalmated Plovers. These similarities can be explained in terms of the importance of the burrowing amphipod, *Corophium volutator* Pallas, in the diets of the staging shorebirds.

ANNAPOLIS RIVER GUARDIANS: REFLECTIONS ON A DECADE OF VOLUNTEER WATER QUALITY MONITORING

Stephen Hawboldt and Shelley Pittman

Clean Annapolis River Project, Annapolis Royal, NS. c.a.r.p@ns.sympatico.ca

The Clean Annapolis River Project (CARP) is a charitable, non-governmental organization created to work with communities and organizations to foster the conservation, restoration and sustainable use of the freshwater and marine ecosystems of the Annapolis watershed. Since its founding in March 1990 and its subsequent invitation in October 1991 to participate in the Atlantic Coastal Action Program (ACAP), the organization has initiated nearly 100 projects related to volunteer-based water quality monitoring, environmental quality assessment, coastal zone management, fish habitat restoration, sustainable agriculture, environmental education, private stewardship, and conservation planning. The group has been honoured with several regional and international environment awards and used as a model for community-based environmental management at local, regional, national, and international levels.

With scientific support from the Acadia Centre for Estuarine Research and several other partners, CARP launched the Annapolis River Guardians, the first volunteer-based water quality monitoring program in Atlantic Canada, likely one of the first in the nation. In the past decade, approximately 200 volunteers have participated in the collection of over 2,000 water samples and created a very comprehensive picture of water quality issues in the Annapolis River and its tributaries.

The presentation will include a description of the program and how it has evolved over the decade. Based on that background, the focus will be on the lessons learned about water quality in the Annapolis and on the operations of a long-term, volunteer-based, water quality monitoring program. What are the strengths? What are the challenges? What could be done differently? How can volunteer water quality monitoring programs lead to enhanced understanding by the general public of scientific principles and environment issues?

THE CANADIAN COMMUNITY MONITORING NETWORK (CCMN)

Marieka Arnold

Canadian Community Monitoring Network, New Brunswick Federation of Naturalists,
Fredericton, NB. nbfn@nb.aibn.com

Every day, Canadian coastal communities are exposed to many human-induced stresses, including harmful pollutants in our air, land and water. Knowing where and how our ecosystems are being affected by these multiple stresses—and what we can do to minimize their impacts on biodiversity and the sustainability of our resource-based economy— is crucial to our well-being, and the well-being of all other biotic and abiotic components in our ecosystems.

The Canadian Community Monitoring Network (CCMN) was formed as a partnership between the Canadian Nature Federation (CNF) and the Ecological Assessment and Monitoring Network (EMAN) of Environment Canada. As a regional co-ordinator with CCMN, we will involve Bay of Fundy coastal communities in our pilot project. One of our goals is to provide access at the community level to consistent and well-developed tools for monitoring projects.

Within our first year we intend to meet with all interested stakeholders in each of the selected coastal communities and work together with the goal of establishing a new monitoring project in each community. We hope to involve and build the capacity of communities to address ecosystem and human health. There are many monitoring tools currently in place and as a CCMN regional co-ordinator we will strive to share and standardize ecosystem monitoring at the local community level. In addition, CCMN aims to share/provide the tools that relate ecosystem sustainability and change to policy development.

PANEL DISCUSSION

Chair: Larry Hildebrand
Rapporteur: Megan Trites-Tolson
Panellists: Members of audience

Question 1. *What would be an appropriate integrated monitoring and research system for the Bay of Fundy? a) What are the best indicators to assess ecosystem health? b) Who should be involved in this monitoring and research agenda?*

We need to look at the many different regions around the Bay of Fundy because each area may have different priorities or concerns. Communities need to be brought together with other ones facing similar problems to share their concerns and resources.

Monitoring requires end points. What are the most appropriate measurements of change and who should do the monitoring of these? How much can be done and by whom should it be done?

Students could be involved in monitoring projects in inter-tidal areas where sampling is somewhat easier and relatively inexpensive. However, once you move away from the shore into deeper water, there are increasing technical difficulties involved in sampling. In addition, it becomes much more costly because of the need for ship support and more sophisticated sampling gear.

Question 2: *Is what we're doing in the Bay of Fundy good enough? Are we finding the solutions?*

We need to look much further ahead down the road. We should be assessing how current developments will impact the area 20 to 50 years from now. Some ecological effects may be evident now, but others might only emerge sometime in the future.

We have to identify the problem, determine what is causing it and then find the resources to fix it. Physicians know that certain symptoms can indicate a specific health problem. They assess the symptoms, give a diagnosis, and then start treating the problem to restore the patient's health. We need to look at the Bay of Fundy in the same way. What is it that we can measure that would be diagnostic and also make a convincing case to gain support for making progress in resolving the environmental problem?

Possible solutions are not being recognized or accepted by the people who could do something about the problems. We need indicators that are unequivocal and will be widely accepted. A series of measurements is required that will help determine the causes of environmental changes so we can cure the problems instead of simply going round in circles year after year.

The work that is going on at present is relatively small-scale and does not trigger ACTION. Monitoring would help to raise the profile of particular issues and elevate them on the political agenda.
Perhaps as a group, we need to make the bold statement that we already know what many of the problems are. We can still continue to do further research on these issues, but the time has also come to move forward and take action.

“Assimilation capacity” is an important ecological concept pertaining to human impacts on the environment. However, finding the right balance is difficult on a regional scale.

In terms of climate change, we have a general sense of the sorts of ecological effects that may be coming, but we do not yet have definitive indicators of change. There are mechanisms to gauge risk. If you are able to gauge the risk then some relative value can be placed on issues. Without this it is hard to take action on the planning side of Risk Management. Let’s determine how climate change may affect the health of the Bay of Fundy and then take action to protect ourselves from any major future risks that are identified.

There is a long history of environmental stress in the Bay of Fundy. The situation is comparable to a boat with a hole in it – you can continue to bail out the water, but it will keep coming in until you fix the hole. We cannot just continue monitoring; we have to try to fix some of the problems.

Question 3. *What is the purpose of monitoring?*

Some of the reasons to carry out monitoring programs include the protection of human health and to protect the ecological integrity of the ecosystem. Sometimes “comfort monitoring” is engaged in, largely to appease the public by giving the impression that something is being done to solve the problem. This is often just a way to buy time and to justify doing even more research and monitoring before making a decision about the issue. Other types of monitoring are carried out for regulatory purposes, such as restricting effluent discharge.

Question 4. *Can questions 1a and 1b serve as a framework for a monitoring program?*

In any monitoring program there has to be a predetermined trigger point at which action should be taken. When that point is reached then you have to do something about the cause of the problem. The response or action may involve mitigating the impacts, restoring the ecosystem or pushing for appropriate social change.

Question 5. *What do we need to go forward?*

Unfortunately, we are still battling many of the same environmental issues over time without seeming to make any progress. We need to narrow the focus down to a few bioindicators that can be widely used. We also need to define thresholds for these indicators that will specify when we should begin to react to particular environmental changes.

However, do we really have enough regional information to take such a bold step forward? We need an iterative process whereby we make a decision, monitor the indicators and then keep making further decisions, so that we make progress while continually updating the decision-making framework.

The real problem is a lack of adequate funding and the inability to enforce existing regulations. By and large, we already know what some of the major problems are and what needs to be done to resolve them.

Should we continue monitoring, if only to keep particular issues alive and in the public eye, so that people do not simply assume the problem is solved or unimportant and can thus be ignored?

Session Six

COROPHIUM AND MUDFLAT ECOLOGY

Chair: Diana Hamilton, Atlantic Cooperative Wildlife Ecology Research Network and Department of Biology, University of New Brunswick, Fredericton, New Brunswick

SPATIAL AND TEMPORAL VARIATION OF SUSPENDED SEDIMENT CONCENTRATION IN THE CUMBERLAND BASIN, BAY OF FUNDY, CANADA

Jeff Ollerhead[1], Jennifer F. Parry[2] and Robin G.D. Davidson-Arnott[2]

[1] Department of Geography, Mount Allison University, Sackville, NB. jollerhead@mta.ca
[2] Department of Geography, University of Guelph, Guelph, ON.

Abstract

A field investigation of variation in suspended sediment concentration (SSC) was conducted over a three-month period during the summer of 2000 at several salt marshes in the Cumberland Basin, Bay of Fundy, Canada. The purpose of the study was to examine some geomorphic controls affecting spatial and temporal variation in SSC. Five marshes were selected along the west side of the Cumberland Basin, representing a diversity of marsh morphologies. Rising stage bottles were deployed to collect samples of SSC over the duration of individual tidal cycles and wind speed and direction were measured continuously. Mean wave height was predicted for both the marshes and the mouth of the Basin for each deployment. The results indicate that regional wave height is a key control on SSC at marshes throughout the Basin and that tidal amplitude is a less influential control. Variation in local wave height and differences in marsh morphology were found to be minor controls on variation in SSC between marshes.

Introduction

The purpose of this study was to investigate some geomorphic controls influencing the spatial and temporal variation in suspended sediment concentration over a selection of salt marshes in the Cumberland Basin, Bay of Fundy. It was hypothesized that suspended sediment concentration is a function of local and regional wave height and tidal amplitude. The objectives of the study were to: 1) measure the spatial and temporal variation of suspended sediment concentration and temporal variation in wind velocity along the Cumberland Basin at the scale of a tidal cycle; 2) predict wave height and monitor tidal amplitude; and 3) examine the relationships between each geomorphic control and concentrations of suspended sediment in the salt marshes of the Cumberland Basin.

Study Area

The study was conducted in the Cumberland Basin, Bay of Fundy (Figure 1). The Bay is characterized by a high concentration of suspended sediment (approximately 0.3 g/litre), which is subject to seasonal variation (Ollerhead et al. 1999). This sediment is derived from cliff line erosion of Paleozoic mudstone and sandstone and an eroding seabed of laminated silts and clays (Amos 1987). The suspended sediment is composed of 95% coarse silt, 2.5% clay and 1.5% sand, with a mean grain size of 4.8 phi (0.036 mm) (van Proosdij et al. 1999). High sediment supply and large tidal range has allowed for the development of extensive salt marshes, mudflats and sandflats. Presently, the Bay of Fundy is composed of 17% salt marshes, 40% mudflats and 43% sandflats (Amos and Tee 1989).

The Cumberland Basin is an 118 km^2 turbid estuary, with a semi-diurnal tide ranging between 10–13 m. Salt marshes in the Basin are exposed to fetches that range from < 5 km to > 20 km, which may contribute to observed differences in the morphology of the marshes. The dominant wind in the summer is from the southwest with an average wind speed of 15 km/hr.

The five marshes chosen for the study are located at Pecks Cove (PC), West Allen Creek (AC), Westcock (WC), Tantramar (TR) and Fort Beauséjour (FB) (Figure 1). Marshes at Pecks Cove and West Allen Creek are characterized by a gentle slope that is maintained across the marsh surface and extends out onto the mudflats. Located low in the tidal frame, both marshes are inundated with every tide. The dominant vegetation is a low marsh species, *Spartina alterniflora*.

The marshes at Westcock and Fort Beauséjour are similar, however quite different from Pecks Cove and West Allen Creek marshes. Westcock and Fort Beauséjour Marshes are both bounded by an earthen dyke at the back and sides and a two-tier marsh cliff approximately two m high delimits the seaward extent of the marshes. They sit significantly higher in the tidal frame than the marshes at Pecks Cove and West Allen Creek and are only inundated during very high spring tides. The dominant vegetation is *Spartina patens*; *Triglochin maritimum*, *Plantago maritima, Puccinellia maritima, Atriplex patula*, *Juncus gerardii*, and *Distichlis spicata* are also found on these marshes.

Tantramar Marsh is similar to Westcock and Fort Beauséjour Marshes, but with some important differences. Tantramar marsh is located approximately 2.25 km upstream from the mouth of the Tantramar River, which is essentially a very large tidal creek at the head of the Cumberland Basin. Infrequently flooded, this marsh is characteristically composed of high marsh vegetation; however, at the base of the small cliff (approximately 0.3–0.5 m high) bounding the seaward extent of the high marsh is a narrow band of low marsh.

Methods

This study was carried out over an 8-week period between May 31 and July 22, 2000. Over the temporal scale of a tidal cycle, measurements of suspended sediment concentration (SSC) and wind speed and direction were made. Rising stage bottles were used to collect samples of water and suspended sediment. Samples were filtered through 9-cm-diameter qualitative filter paper with a pore size of 1 μm. SSC was then calculated in mg/L.

Wind data collected at Amherst, Nova Scotia by the Atlantic Climate Centre, Environment Canada were the primary source of wind speed and direction data for this study. Supplementary wind data were collected by a Davis Instruments anemometer and wind vane mounted on the rooftop of a two-story house situated along the shore of the Cumberland Basin between West Allen Creek Marsh and Westcock Marsh.

Wind speed, wind direction and fetch are required to predict significant wave height. Wind speed and wind directions were averaged for six hours prior to each high tide. Fetch was determined from a 1:50 000 map of Amherst, New Brunswick/Nova Scotia (21 H/16, Edition 3) and a 1:250 000 map of Amherst (21 H, Edition 3), both published by Natural Resources Canada. Significant wave height was predicted using the averaged wind speed and wind direction, calculated fetch, and the ACES™ (Automatic Coastal Engineering System) software of the U.S. Army Corps of Engineers. Significant wave height was calculated for the 6-hour period prior to high tide for each marsh.

Non-parametric statistical analyses were used to examine relationships between SSC and various geomorphic controls. Spearman's rank-difference correlation was used to determine the degree of association between variables. The Wilcoxon matched-pairs, signed ranks test was used to determine if there were significant differences between data sets. All statistics were calculated at the 90% confidence level.

Results

Variation in Suspended Sediment Concentration (SSC)

Using non-parametric statistical tests, variation in SSC between sites was analyzed. A strong to moderate significant correlation was found between SSC for all sites with the exception of Tantramar Marsh (Table 1). Lack of correlation between Tantramar Marsh and the other four sites suggests that geomorphic controls affecting SSC at Tantramar may be different or at least partially different than those affecting the remaining sites. The significant correlations between the sites (excluding Tantramar) suggest that these sites are collectively influenced to some degree by one or more geomorphic controls.

Of those sites with significantly correlated SSC, however, results indicate significant differences in SSC between all sites, with the exception of Pecks Cove and Fort Beauséjour, and West Allen Creek and Westcock Marshes. It is important to note, however, that just because these sites are not statistically different in terms of SSC, it does not mean that their comparable levels of SSC arise by the same geomorphic controls. Based on these results it may be suggested that, although some controls may influence all sites, other controls are site specific allowing for local variation in SSC to occur.

In the scatterplots developed to illustrate the nature of these relationships, an outlier was discovered for July 5, 2000 (Julian day 186). This day was characterized by low wave height and low to average SSC at Pecks Cove and West Allen Creek Marshes. However, very high SSC was measured at Westcock and Fort Beauséjour Marshes (Figure 2). A thunderstorm with heavy intermittent rain passed over the upper portion of the Cumberland Basin during data collection. Thus, the outlier suggests that rainfall may be an important geomorphic control on SSC. However, with only one observation, this control could not be further explored and the data for day 186 were excluded from the data set for subsequent analyses.

Variation in SSC as a Function of Local and Regional Wave Height

One of the geomorphic controls that may contribute to local variation in SSC is local wave height (i.e., wave height predicted for the marsh margin). In a correlation of predicted significant wave height for the marsh margin and SSC for each marsh, only West Allen Creek exhibited a significant correlation ($r = 0.43$), while the remainder of the sites showed no significant relationship between locally generated significant wave height and SSC. However, when wind speed alone was correlated with SSC for each marsh, all relationships were significant (Table 2). This suggests that waves generated elsewhere, perhaps at the mouth of the basin, are the dominant control on the level of SSC at the marshes.

Predicted significant wave height was calculated for an arbitrary point centred in the mouth of the Cumberland Basin. When predicted significant wave height was correlated with SSC, a significant strong to moderate relationship was found at all sites but Fort Beauséjour (Table 2). The results of these tests reveal the importance of regional waves to the level of SSC observed at the marsh margins; in other words, waves at the mouth of the basin account for a significant amount of the variation in SSC throughout the Basin.

Variation in SSC as a Function of Tidal Amplitude

While regional waves appear to be the primary mechanism influencing SSC, tidal amplitude may also play an important, albeit lesser role, in influencing levels of suspended sediment throughout the Basin. It was expected that higher current velocities, which occur during spring tides, would increase SSC. A correlation of tidal amplitude and SSC suggests that SSC at Westcock and Fort Beauséjour Marshes is moderately influenced by variation in tidal amplitude (Table 2). SSC at Pecks Cove and West Allen Creek Marshes exhibited low to no relationship with tidal amplitude. However, scatter in the data may be attributed to the influence of regional waves and other geomorphic controls, which may mask any relationship between SSC and tidal range. SSC remained relatively constant at Tantramar Marsh regardless of variation in tidal amplitude.

Conclusions

Suspended sediment concentrations in the Cumberland Basin are the result of complex interrelationships between various geomorphic controls. These results suggest that regional waves generated at the mouth of the Cumberland Basin are the dominant factor influencing SSC throughout the Basin. Differences remain, however, in the absolute levels of SSC at each marsh. These differences may be attributed to several other variables. The contribution of locally generated waves to suspending sediment is well recognized in the literature, as is the role of tidal currents (e.g., see van Proosdij et al. 2000). The importance of rainfall in increasing SSC is suggested by the anomalous data for Julian day 186. Furthermore, because the morphology of the chosen marshes differed throughout the Basin, it cannot be ruled out as an influential factor.

Acknowledgements

We thank Michelle Zehr, Jaime Dawson, Danika van Proosdij and Erin Whitley for their assistance in the field. The research was supported by research grants from the Natural Sciences and Engineering Research Council (NSERC) to JO and RD-A, and by a Latornell Graduate travel scholarship and Ontario Graduate Scholarship in Science and Technology to JP.

References

Amos, C. L. 1987. Fine-grained sediment transport in Chignecto Bay, Bay of Fundy, Canada. Continental Shelf Research 7: 1295–1300.

Amos, C. L. and K. T. Tee. 1989. Suspended sediment transport processes in Cumberland Basin, Bay of Fundy. Journal of Geophysical Research 94: 14407–14417.

Ollerhead, J., D. van Proosdij, and R. G. D. Davidson-Arnott. 1999. Ice as a mechanism for contributing sediments to the surface of macro-tidal salt marsh, Bay of Fundy. Pages 345–358. In: *Proceedings of the 1999 Canadian Coastal Conference, 19-22 May 1999, Royal Roads University, Victoria, BC*. Volume I. C. J. Steward, Ed. Canadian Coastal Science and Engineering Association, Ottawa, ON.

van Proosdij, D., J. Ollerhead, R. G. D. Davidson-Arnott, and L. Schostak. 1999. Allen Creek Marsh, Bay of Fundy: A macro-tidal coastal salt marsh. The Canadian Geographer 43: 316–322.

van Proosdij, D., J. Ollerhead, and R. G. D. Davidson-Arnott. 2000. Controls on suspended sediment deposition over single tidal cycles in a macrotidal salt marsh, Bay of Fundy, Canada. Pages 43–57. In: Coastal and Estuarine Environments: Sedimentology, Geomorphology and Geoarchaeology. K. Pye and J. R. L. Allen (Eds). Special Publication 175. Geological Society, London.

Table 1. Correlation between samples of SSC from different marshes. Significant correlations are in bold italics (90% confidence level).

Variable pairs	***Spearman's R***
PC and AC	***0.60***
PC and WC	***0.51***
PC and TR	0.39
PC and FB	***0.43***
AC and WC	***0.70***
AC and TR	0.46
AC and FB	***0.68***
WC and TR	0.43
WC and FB	***0.80***
TR and FB	0.61

Table 2. Correlation between SSC at each marsh and wind speed, predicted local significant wave height, predicted regional significant wave height, and tidal amplitude. Tantramar Marsh (TR) was not included in the correlations for wind speed or local wave height as there were no waves at this site. Significant correlations are in bold italics (90% confidence level).

Marsh	***Wind speed***	***Predicted local significant wave height***	***Predicted regional significant wave height***	***Tidal amplitude***
PC	***0.49***	-0.16	***0.62***	0.34
AC	***0.80***	***0.43***	***0.80***	0.23
WC	***0.45***	0.35	***0.53***	***0.40***
TR	n/a	n/a	***0.64***	0.13
FB	***0.46***	0.36	0.39	***0.67***

Figure 1. Map of the Cumberland Basin, indicating the locations of the study sites. 1) Peck's Cove Marsh, 2) West Allen Creek Marsh, 3) Westcock Marsh, 4) Tantramar Marsh, and 5) Fort Beauséjour Marsh.

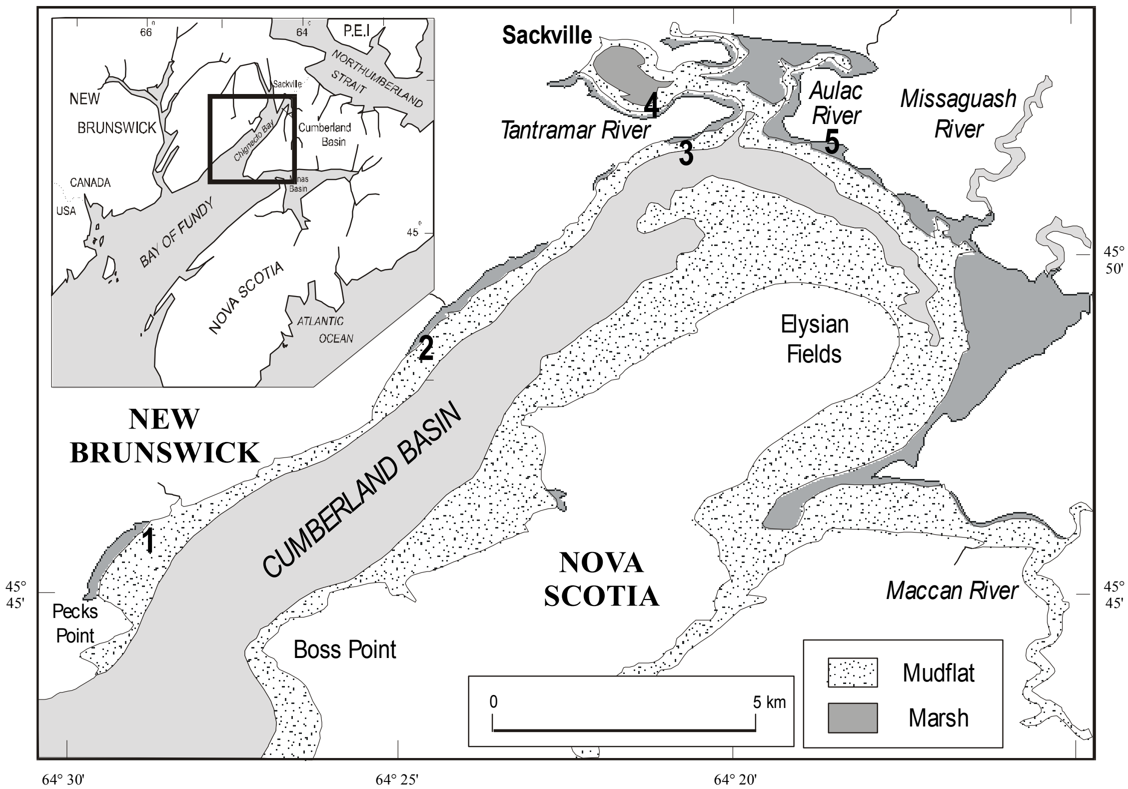
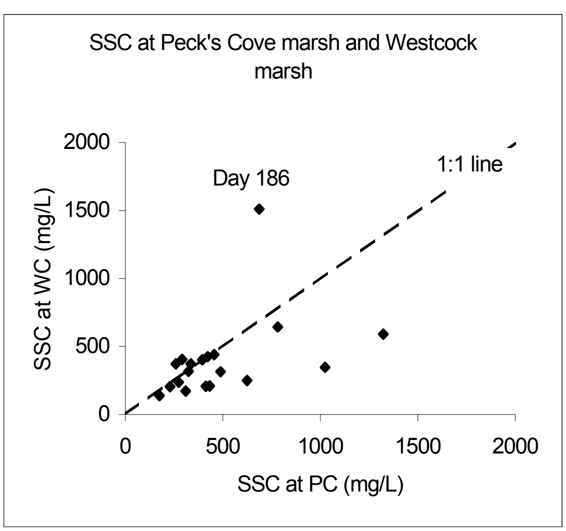
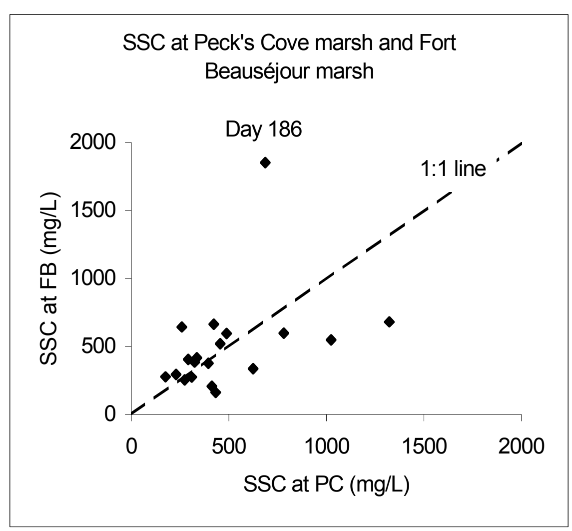


Figure 2. These graphs illustrate the anomalous results for Julian day 186. Note the significantly higher SSC at Westcock Marsh (WC) and Fort Beauséjour Marsh (FB) for day 186 than experienced at Pecks Cove Marsh (PC).





CONCEPTUAL MODEL OF THE SEASONAL AND SPATIAL CONTROLS ON SEDIMENT DEPOSITION AND EROSION IN AN UPPER BAY OF FUNDY SALT MARSH

Danika van Proosdij[1], Robin G.D. Davidson-Arnott[2] and Jeff Ollerhead[3]

[1] Department of Geography, Saint Mary's University, Halifax, NS. dvanproo@stmarys.ca
[2] Department of Geography, University of Guelph, Guelph, ON. rdarnott@uoguelph.ca
[3] Department of Geography, Mount Allison University, Sackville, NB. jollerhead@mta.ca

This paper presents results from a field study on the controls on the sediment budget of Allen Creek Marsh in the upper Cumberland Basin. Temporal and spatial variations in flow, suspended sediment concentration (SSC) and sediment deposition were measured over single tidal cycles across the marsh surface. Data were collected over a range of tidal heights, wave conditions and vegetation characteristics. These data were combined with seasonal measurements of erosion and accretion into a conceptual model illustrating the seasonal and spatial patterns of the major mechanisms of accretion and erosion across the marsh surface at Allen Creek Marsh. Erosion occurs primarily through a cycle of undercutting and block failure at the marsh margin. The dominant controls on sediment deposition vary seasonally: (winter) ice and high SSC; (spring) melting ice blocks, calm water with high SSC; (summer) high SSC, calm water and (fall) high SSC from wave activity, high relative roughness of vegetation to dampen wave energy. The relative significance of these processes will vary above and below the mean high water line.

This empirically derived conceptual model demonstrates that the processes of erosion and deposition on the marsh surface exhibit considerable spatial and temporal variability. As a result, predicting marsh 'survival' in the face of global warming scenarios cannot be achieved using single deterministic functions nor data collected using SET (sediment elevation table or sedimentation table) or marker horizon data alone. Spatial and temporal variations in the processes of erosion and deposition must be incorporated into any predictive numerical models to be developed.

MUDFLAT DIATOMS IN THE BAY OF FUNDY: WHAT IS KNOWN ABOUT THEM?

Irena Kaczmarska and Marsha Trites

Department of Biology, Mount Allison University, Sackville, NB.
iehrman@mta.ca and mjtrts@mta.ca

With lack of visible vegetation, mudflats appear to be barren. Upon closer examination, however, it becomes evident that this impression is untrue. In addition to migratory shorebirds, epi- and infaunal invertebrates, there is also a myriad of microorganisms living in and on the sediments. This attests to mudflats being diverse and productive ecosystems, or "secret gardens of unvegetated, shallow-water marine habitats" (MacIntyre et al. 1996; Underwood and Kromkamp 1999). Mudflats account for one third (or more) of the primary production in some shallow water estuaries (Pickney and Zingmark 1993). In the upper Bay of Fundy, the amphipod *Corophium volutator* is considered a keystone invertebrate species in the intertidal mud-flat community (Hicklin et al. 1980; Daborn et al. 1993). This mud shrimp provides an essential ecological link between migratory shorebirds and the microbial community in the sediments. *Corophium*, as many other tidal flat herbivores, thrive when the sediments are of optimal structure and contain favored psammic and epipelic microbial gardens (Jensen and Siegismund 1980; Créach et al. 1997; Underwood and Smith 1998). In the temperate latitudes, diatoms dominate such biofilms (Admiraal and Peletier 1980; Vos et al. 1988). Although significance of microbial biofilms in a great variety of benthic environments worldwide is well established, very little is known about the structure and composition of these communities in North American mudflats (Table 1). Our data indicate that even closely located mudflats may differ significantly in composition and abundance of diatom assemblages. Several seminal studies in this field were conducted either in the laboratory or on European coasts where quantitative assessments were based on measurements of chlorophyll *a*, polysaccharides or generic affinity of the native flora and fauna (Paterson 1989 and 1990). In fact, little has changed since the 1980s when Admiraal (1984) pointed out the scarcity of knowledge of the physiology and ecology of individual species of benthic diatoms.

Two different microhabitats occur within mudflat sediments, each with its own assemblage of resident microalgae. In the upper Bay of Fundy, diatoms dominate these habitats, although euglenophytes, other colored micro-flagellates and cyanobacteria are also present. Here we will limit dicussion to diatoms. The first microhabitat is the sediment grains to which diatoms attach, e.g., sand grains, and remain sessile throughout their lifetime. This is the epipsammon and in the upper Bay of Fundy *Delphineis surirella* and *Rhaphoneis amphiceros* most often occupy this habitat.

Secondly, capillary spaces between sediment grains provide a three-dimensional network of interspaces. An assemblage of diatoms (called tychoplankton) which are immobile, suspended and/or trapped between sediment particles inhabit this capillary network. These species await resuspension into position close to the sunlight in the sediments or in the water column. A more specialized category of these diatoms is the surfing species, whose life history cycles between benthic and planktonic stages.

For example, a native *Actinoptychus senarius* is found living as a single-cell organism while in the sediments but at times develops organic "skirts" around cells to facilitate formation of plate-like colonies. In this colonial form *A. senarius* exists suspended in the water column as a temporary member of the phytoplankton. When colonies disaggregate, cells return to the benthic environment.

Lastly, through the same microcapillary net, motile (epipelic) diatom species migrate vertically, depending on light and tidal cycle (Palmer and Round 1967; Round 1971). These diatoms may concentrate at the sediment surface at low tide on a sunny day, making a spectacular display of golden-brown patches (Peterson 1986). Raphid diatoms with naviculoid and nitzschioid morphologies dominate this microhabitat. Locally, several species from the genus *Gyrosigma* and *Nitzschia* are the most common members.

Sessile and mobile diatoms produce different types and different quantities of mucilaginous matrices with the different potential to bind and consolidate sediments (Vos et al. 1988). Tychoplankton add to the pool of energy available for herbivores and deposit-feeding invertebrates.

Of the three assemblages, epipsammon, tychoplankton and epipelon, only the last have been rigorously examined (Admiraal et al. 1984; Paterson 1989), although only the most common were identified to the species level. This assemblage of species is widely thought to play a very important role in intertidal mudflat ecology (Vos et al. 1988; Madsen et al. 1993). Sessile and suspended diatoms have received very little research attention worldwide (Zong and Horton 1998), but in our samples they were found to make up as much as 47% of all live diatoms (Trites et al. this volume). The lack of similarly comprehensive examinations of the diatom community, including all three functional groups, does not allow us to conclude whether this higher diversity is a typical or unusual characteristic of the upper Bay of Fundy intertidal mudflat diatoms.

References

Admiraal, W. 1984. The ecology of estuarine sediments inhabiting diatoms. Progress in Phycological Research 3: 269–322.

Admiraal, W. and H. Peletier. 1980. Distribution of diatom species on an estuarine mudflat and experimental analysis of the selective effect of stress. Journal of Experimental Marine Biology and Ecology 46: 157–175.

Admiraal, W., H. Peletier, and T. Brouwer. 1984. The seasonal succession patterns of diatom species on an intertidal mudflat: An experimental analysis. Oikos 42: 30–40.

Agatz, M., R. M. Asmus, and B. Deventer. 1999. Structural changes in the benthic diatom community along a eutrophication gradient on a tidal flat. Helgoland Marine Research 53: 92–101.

Créach, V., M. T. Schricke, G. Bertru, and A. Mariotti. 1997. Stable isotopes and gut analyses to determine feeding relationships in salt marsh macroconsumers. Estuarine, Coastal and Shelf Science 44: 599–611.

Daborn, G., C. Amos, M. Brylinsky, H. Christian, G. Drapeau, R. Faas, J. Grant, B. Long, D. Paterson, G. Perillo, and M. Piccolo. 1993. An ecological cascade effect: Migratory birds affect stability of intertidal sediments. Limnology and Oceanography 38: 225-231.

Hicklin, P., L. Linkletter, and D. Peer. 1980. Distribution and abundance of *Corophium volutator* (Pallas), *Macoma balthica* (L.) and *Heteromastus filiformis* (Clarapede). Canadian Technical Report of Fisheries and Aquatic Sciences 965. Department of Fisheries and Oceans, Ottawa. 56 pp.

Jensen, K. T. and H. R. Siegismund. 1980. The importance of diatoms and bacteria in the diet of *Hydrobia*-species. Ophelia, Supplement 1: 193–199.

Madsen, K. N., P. Nilsson, and K. Sundback. 1993. The influence of benthic microalgae on the stability of a subtidal sediment. Journal of Experimental Marine Biology and Ecology 170: 159–177.

MacIntyre, H. L., R. J. Geider, and D.C. Miller. 1996. Microphytobenthos: The ecological role of the "Secret Garden" of unvegetated, shallow-water marine habitats. I. Distribution, abundance and production. Estuaries 19: 186–201.

Palmer, J. D. and F. E. Round. 1967. Persistent, vertical-migration rhythms in benthic microflora. VI. The tidal and diurnal nature of the rhythm in the diatom *Hantzschia virgata*. Biological Bulletin 132: 44–55.

Paterson, D. 1986. The migratory behaviour of diatom assemblages in the laboratory tidal micro-ecosystem examined by low temperature scanning electron microscopy. Diatom Research 1: 227–239.

Paterson, D. 1989. Short-term changes in the erodibility of intertidal cohesive sediments related to the migratory behaviour of epipelic diatoms. Limnology and Oceanography 34: 223–234.

Paterson, D. 1990. The influence of epipelic diatoms on the erodibility of an artificial sediment. Pages 245–355. In: *Proceedings of the Tenth International Diatom Symposium, Joensuu, Finland, August 28–September 2, 1988*. H. Simola (Ed.). Koeltz Scientific Books, Koenigstein.

Pickney, J. and R. G. Zingmark. 1993. Photophysiological responses of intertidal benthic microalgal communities to in situ light environments: Methodological considerations. Limnology and Oceanography 38: 1373–1383.

Round, F. E. 1971. Benthic marine diatoms. Oceanography and Marine Biology, Annual Review 9: 63–75.

Trites, M., P. Hicklin, J. Ollerhead and I. Kaczmarska. 2003. Benthic diatoms from two intertidal mudflats in the upper Bay of Fundy. This proceedings, pp. 200-207.

Underwood, G. J. C. and D. Smith. 1998. Predicting epipelic diatom exopolymer concentrations in intertidal sediments from sediment chlorophyll *a*. Microbial Ecology 35: 116–125.

Underwood, G. J. C. and J. Kromkamp. 1999. Primary production by phytoplankton and mircophytobenthos. Advances in Ecological Research 29: 93–153.

Vos, P. C., P. L. de Boer, and R. Misdrop. 1988. Sediment stabilization by benthic diatoms in intertidal sandy shoals; qualitative and quantitative observations. Pages 511–526. In: *Tide-Influenced*

Sedimentary Enviroments and Facies. P. L. de Boer, A. van Gelder and S. D. Nio (Eds.). D. Riedel Publishing Company, Dordrecht and Boston.

Watt, D. A. 1998. Estuaries of contrasting trophic status in KwaZulu-Natal, South Africa. Estuarine, Coastal, and Shelf Science 47(2): 209–216.

de Winder, B., N. Staats, L. J. Stal, and D. M. Paterson. 1999. Carbohydrate secretion by phototrophic communities in tidal sediments. Journal of Sea Research 42(2): 131–146.

Wolfstein, K., F. Colijn, and R. Doerffer. 2000. Seasonal dynamics of microphytobenthos biomass and photosynthetic characteristics in the Northern German Wadden Sea, obtained by the photosynthetic light dispensation system. Estuarine, Coastal and Shelf Science 51: 651–662.

Zong, Y. and B. P. Horton. 1998. Diatom zones across intertidal flats and coastal salt marshes in Britain. Diatom Research 13(2): 375-394.

Table 1: List of diatoms reported from intertidal mud and sand flats. Abbreviations: Af = Africa, As = Asia, Eu = Europe, N = North America, S = South America, Ep = epipelic, Att = epipsammic, T = tychoplankton, ThSt = this study (bold). References: 1 = Zong and Horton 1998; 2 = Admiraal and Peltier 1980; 3 = Admiraal et al. 1984; 4 = Palmer and Round 1967; 5 = de Winder et al. 1999; 6 = Round 1971; 7 = Watt 1998; 8 = Underwood and Smith 1998; 9 = Agatz et al. 1999; 10 = Wolfstein et al. 2000.

Diatom Name	Continent	Sediment Size	Reference	Assemblage
Amphora acuta	As	sand	6	Ep
A. coffeaeformis var. acutiuscula	unknown	sand	6	Ep
A. proteus	Eu	sand, silt	10	Ep
Brockmaniella brockmanii	**N**	**mudflat, sand**	**ThSt**	**T**
Caloneis amphisbaena var. subsalina	unknown	sand	6	Ep
C. westii	Eu, S	muddy	1	Ep
Cyclotella meneghiniana	Af	sand	7	T
C. striata	Eu, S	muddy	1	T
Cylindrotheca closterium	Eu, S	sand, silt	5, 8, 9	Ep
C. gracilis	**Eu, N**	**sandflat, mudflat**	**9, ThSt**	**Ep**
Delphineis surirella	**Eu, N**	**sandy, mudflat**	**1, 6, ThSt**	**Att**
Diploneis didyma	Eu	muddy	1, 10	Ep
D. pupula	Af	fine mud	7	Ep
Fallacia pygmaea	Eu	sand	3, 6	Ep
Gyrosigma balticum	**Eu, N**	**muddy**	**1, ThSt**	**Ep**
G. distortum	**N**	**mudflat**	**ThSt**	**Ep**
G. fasciola	Eu, Af	mudflat, sand	2, 3, 7, 9	Ep
G. spencerii	Eu, Af	sand	7	Ep
G. wansbeckii	**Eu, N**	**muddy**	**1, ThSt**	**Ep**
Hantzschia virgata	N	sandflat	4, 6	Ep
Melosira nummuloides	unknown	unknown	6	Ep
Navicula arenaria	Eu	silt and sand mix	6, 10	Ep
N. cincta var. heufleri	Eu	silts	6	Ep
N. cf. cryptocephala	Eu, Af	mud and sand	2, 7	Ep
N. digitoradiata	Eu	silt and sand	10	Ep
N. flanatica	Eu	unknown	2, 3	Ep
N. gregaria	Eu	sand, silt	6, 9	Ep
N. perminuta	Eu	silts	8	Ep
N. phyllepta	Eu, S	muddy	1, 2	Ep
N. saliniarum	Eu	unknown	2, 3	Ep
N. viridula	unknown	sand	6	Ep
Nitzschia compressa var. elongata	Eu	silt and sand	10	Ep
N. frustulum	Eu	silts	8	Ep
N. navicularis	Eu	muddy	1	Ep
N. obtusa	Eu	muddy	1	Ep
N. obtusa var. scalpeliformis	Eu	silts	6	Ep
N. pellucida	**N**	**mudflat**	**ThSt**	**Ep**
N. sigma	**Eu, N, S**	**silt, sand**	**1, 8, ThSt**	**Ep**
N. spathula	Eu	silt and sand	9	Ep
N. tryblionella	Eu	sandy	9	Ep
Planothidium lanceolatum	Af	fine mud	7	Att
Paralia sulcata	**Eu, N**	**muddy**	**1, ThSt**	**T**
Plagiogrammopsis vanheurckii	**N**	**mudflat**	**ThSt**	**T**
Plagiotropis vanheurckii	**N**	**mudflat**	**ThSt**	**Ep**
Pleurosigma aestuarii	Eu	silt and sand	6, 10	Ep
P. angulatum	**N**	**mudflat**	**ThSt**	**Ep**
P. elongatum	S	sand	6	Ep
P. strigosum	As, Eu	sand	6	Ep
Psammodictyon panduriforme	unknown	sand	6	Ep
Rhaphoneis amphiceros	**Eu, N**	**sandy, mudflat**	**1, 6, ThSt**	**Att**
Scoliopleura tumida	Eu	silts, sand	6	Ep
Surirella ovata	Eu	silts	8	Ep
Trachyneis aspera	Eu	muddy	1	Ep

BENTHIC DIATOMS FROM TWO INTERTIDAL MUDFLATS IN THE UPPER BAY OF FUNDY*

Marsha Trites[1], Peter Hicklin[2], Jeff Ollerhead[3] and Irena Kaczmarska[1]

[1] Department of Biology, Mount Allison University, Sackville, NB.
[2] Canadian Wildlife Service, Environment Canada, Sackville, NB.
[3] Department of Geography, Mount Allison University, Sackville, NB.

Abstract

Little is known about benthic diatoms from Upper Bay of Fundy mudflats but they likely play an important role in the support of the mudflat keystone species, *Corophium volutator*. This study examined a tidal flat diatom community from a *Corophium* rich mudflat (Daniel's Flat) and a *Corophium* poor mudflat (Grande Anse Flat) in Chignecto Bay. The mudflat sediments are very different physically. Daniel's Flat has lower water and organic content than Grande Anse Flat and a larger mean grain size of sediments. Diatoms, especially mobile diatoms, were more abundant at Grande Anse Flat, which correlates negatively to *Corophium* density. These differences in diatom abundance and composition could be the result of higher grazing pressure at Daniel's Flat and/or higher water content at Grande Anse Flat.

Introduction

Benthic diatoms, found both in and on sediments, dominate intertidal mudflats in cold temperate climates (Pickney and Zingmark 1993; Underwood and Smith 1998). In the Upper Bay of Fundy, the presence of these diatoms is of importance to the mudflat keystone species *Corophium volutator,* and possibly other animals, for two reasons. Diatoms increase stability of surface sediments through the production of polysaccharide exudates (Daborn et al. 1993; Pickney and Zingmark 1993) and act as a food source for benthic fauna (Créach et al. 1997). It is mobile diatoms that produce copious amounts of sediment binding polysaccharides. They move up through sediments at low tide to form dense aggregations which may discolour the mudflat surface.

The structure and composition of Fundy mudflat diatoms is virtually unknown. Research has been conducted on these communities in the Minas Basin, but even in these seminal studies only a few species of diatoms have been identified beyond the genus level. Furthermore, most intertidal mudflat diatom studies focus on the physical interactions between diatom extracellular exudates and sediments (e.g., Daborn et al. 1993) and were conducted in a laboratory (e.g., Paterson 1989).

* This paper is based on a poster presented at this workshop, replacing the poster abstract.

Materials and Methods

Two different types of mudflats occur in Chignecto Bay in the Upper Bay of Fundy (Table 1). One contains relatively compact sediments and supports high densities of *Corophium* (Daniel's Flat), while the other is more aqueous and supports few *Corophium* (Grand Anse Flat). This study examined both types of flat. Specifically, it explored how mudflat diatom communities may differ between these two very different sites. It also relates differences in diatom communities to selected physical or biological properties of mudflat sediments.

The two mudflats were each sampled prior to the arrival of Semipalmated Sandpipers, while the birds were present in maximal densities, and after they had left. Sediment cores were taken along shore-normal transects following Hicklin et al. (1980). The cores were cut in half vertically, with one half to be used for *Corophium* enumeration and the other for sediment analysis and diatom enumeration. Using EDS (energy dispersive X-ray spectroscopy), mineral composition of sediment grains was analyzed. Sediment grain size distribution was determined by laser diffraction, drying was used to determine water content, and loss on ignition to calculate organic content. *Corophium* were enumerated with a 710 Fm sieve, following Hicklin et al. (1980). Light microscopy and scanning electron microscopy were used to identify and quantify diatoms present. Only live diatom cells were enumerated.

Results and Discussion

Sediment grains at both flats were mostly composed of quartz or one of several feldspars. Some of the rarer minerals were only found at one of the two mudflats (Table 2). An iron and magnesium feldspar, for example, was only observed at Daniel's Flat while sodium feldspar was only observed at Grande Anse Flat. Using the Wentworth scale to classify particle sizes (Bearman 1989), the proportion of clay (0.5–2 Fm) and silt (2–62.5 Fm) was highest at Grande Anse Flat while Daniel's Flat had a larger fraction of sands (62.5–2000 Fm). Also, sediments were more poorly sorted at Grande Anse Flat (Figure 1). Water and organic content were both highest at Grande Anse Flat. Water content ranged from 39–63% at Grande Anse Flat while values ranged from 22–42% at Daniel's Flat. At Grande Anse Flat, organic carbon content ranged from 2.2–3.1% while at Daniel's Flat it ranged from 0.8–2.4%. Clearly the sediment properties of these two mudflats are different in every aspect we examined.

The diatom flora encountered was diverse in terms of species and functional groups. Of 39 counting categories, 13 were identified to the species level, and these comprised nearly 80% of cells enumerated. Of the remaining counting categories, most were identified to genus and nearly all of these represented a single species. Only six categories were broadly defined, e.g., centric, pennate, or naviculoid diatoms, and these represented 13% of cells. Naviculoid diatoms represented several genera similar in size and shape, making them unidentifiable while alive. This broad naviculoid category did not prevent accurate classification into functional categories. Diatom abundance was greatest at Grande Anse Flat, where densities often exceeded 200,000 cells per gram of wet sediment, while sediments from Daniel's

Flat rarely contained more than 150,000 cells per gram (Figure 2). Three functional groups of diatoms were present: epipelon, epipsammon, and tychoplankton. Epipelic diatoms are mobile and move by secreting strands of mucilage through their raphe systems while epipsammic diatoms attach to surfaces; most often to sand grains. Tychoplankton are a group of free-living diatoms that are usually associated with the benthic and nearshore community but may be transported into the water column to live as plankton. The most common diatoms at both mudflats were the tychoplanktonic *Paralia sulcata* and *Brockmaniella brockmanni*, together making up 47% of cells enumerated. The most common epipsammic diatom, *Delphineis surirella*, accounted for approximately 11% of cells. The most common epipelic species were *Gyrosigma wansbeckii* and *Nitzschia sigma*.

As expected, *Corophium* densities at Daniel's Flat were high, up to 22,600 individuals/m^2, while *Corophium* were undetectable by our methods from all but one core at Grande Anse Flat (Figure 2). The density there was below 1000 individuals/m^2. *Corophium* densities at Daniel's Flat seem to have increased when compared to Hicklin et al. (1980), who reported a mean density of 2,567 individuals/m^2 during July 1978. In contrast, the *Corophium* density at Grande Anse Flat decreased precipitously when compared to Hicklin et al. (1980). They reported a mean density of 5,162 individuals/m^2 during July of 1978. The virtual absence of *Corophium* from Grande Anse Flat observed in our study was also reported by Shepherd et al. (1995).

Similar to sediment data, the two mudflats are distinctly different in diatom and *Corophium* abundances. The high abundance of diatoms at Grande Anse does not support a high abundance of *Corophium*. Some functional groups show a relationship to *Corophium* density. At Daniel's Flat, epipelic diatoms were least abundant while *Corophium* were present in maximal densities and most abundant in late August, after *Corophium* had suffered grazing from shorebirds, suggesting a causal relationship (Figure 3).

We thus speculate that *Corophium* grazing pressure reduces abundance of some benthic diatoms, specifically the mobile species (e.g., large *Gyrosigma* and *Nitzschia* species) which aggregate in surface sediments during low tide. Alternatively, it could be that the physical characteristics of sediments at Grande Anse Flat render it more suitable for diatom growth. A Pearson correlation with Bonferonni's adjustment showed that diatom density was most strongly positively correlated with water content of sediments (0.744), which was highest at Grande Anse Flat. In a laboratory setting, Paterson (1990) found that diatom density was higher in wetter sediments, as would be expected for all aquatic plants. Because Grande Anse Flat supported the greatest abundance of diatoms, the low densities of *Corophium* observed at this mudflat cannot be attributed to a shortage of food in the form of diatoms.

References

Bearman, G. (Ed.). 1989. *Waves, Tides, and Shallow-water Processes*. Pergamon Press, Toronto. 187 pp.

Créach, V., M. T. Schricke, G. Bertru, and A. Mariotti. 1997. Stable isotopes and gut analyses to determine feeding relationships in saltmarsh macroconsumers. Estuarine, Coastal and Shelf Science 44: 566–11.

Daborn, G., C. Amos, M. Brylinsky, H. Christian, G. Drapeau, R. Faas, J. Grant, B. Long, D. Paterson, G. Perillo, and M. Piccolo. 1993. An ecological cascade effect: migratory birds affect stability of intertidal sediments. Limnology and Oceanography 38: 225–231.

Hicklin, P., L. Linkletter, and D. Peer. 1980. Distribution and abundance of *Corophium volutator* (Pallas), *Macoma balthica* (L.) and *Heteromastus filiformis* (Clarapede). Canadian Technical Report of Fisheries and Aquatic Sciences 965. Department of Fisheries and Oceans, Ottawa.

Paterson, D. 1989. Short-term changes in the erodibility of intertidal cohesive sediments related to the migratory behaviour of epipelic diatoms. Limnology and Oceanography 34: 223–234.

Paterson, D. 1990. The influence of epipelic diatoms on the erodibility of an artificial sediment. Pages 345–355 In: *Proceedings of the Tenth International Diatom Symposium, Joensuu, Finland, August 28-September 2, 1988*. Simola, H. (Ed.). Koeltz Scientific Books, Koenigstein.

Pickney, J. and R. G. Zingmark. 1993. Photophysiological responses of intertidal benthic microalgal communities to in situ light environments: Methodological considerations. Limnology and Oceanography 38: 1373–1383.

Shepherd, P., V. Partridge, and P. Hicklin. 1995. Changes in sediment types and invertebrate fauna in the intertidal mudflats of the Bay of Fundy between 1977 and 1994. Technical Report Series No. 237. Canadian Wildlife Service.

Underwood, G. J. C. and D. Smith. 1998. Predicting epipelic diatom exopolymer concentrations in intertidal sediments from sediment chlorophyll *a*. Microbial Ecology 35: 116–125.

Table 1. Co-ordinates and metric distances of sampling stations at Daniel's Flat and Grande Anse Flat

	station	distance from shore (m)	latitude (North)	longitude (West)
Daniel's Flat	1	100	45°47'09.1"	64°37'04.7"
	2	300	45°47'03.9"	64°36'59.2"
	3	500	45°46'58.7"	64°36'53.6"
	4	700	45°46'53.4"	64°36'48.1"
	5	900	45°46'48.1"	64°36'42.5"
	6	1200	45°46'43.0"	64°36'36.8"
	7	1300	45°46'37.8"	64°36'30.9"
	8	1500	45°46'32.5"	64°36'25.7"
Grande Anse Flat	1	100	45°50'0.8"	64°30'50.0"
	2	300	45°49'56.2"	64°30'56.5"
	3	500	45°49'51.5"	64°31'03.1"
	4	700	45°49'47.0"	64°31'09.7"
	5	900	45°49'42.2"	64°31'16.6"
	6	1100	45°49'39.0"	64°31'21.2"

Table 2. Mineral composition found by EDS of 20 observed sediment grains from selected stations at Daniel's Flat and Grand Anse Flat. Mineral presence denoted by '+' and absence by '-'

				Feldspar							
	Station	Date	Quartz	Na	K	Ca	Fe	K-Fe	Mg-Fe	Chlorite	Rutile
Daniel's Flat	1	June 21	+	-	+	+	-	+	-	+	-
	4	July 20	+	-	+	-	+	+	+	-	+
	7	Aug 24	+	-	+	+	+	-	-	-	+
Grand Anse Flat	2	Aug 23	+	-	+	-	+	+	-	-	+
	4	July 25	+	+	+	-	+	+	-	-	-
	6	July 10	+	-	+	-	+	-	-	+	-

Figure 1. Grain size distribution of sediments from the surface layer of sediments at Daniel's Flat and Grande Anse Flat, 2001, found by laser diffraction

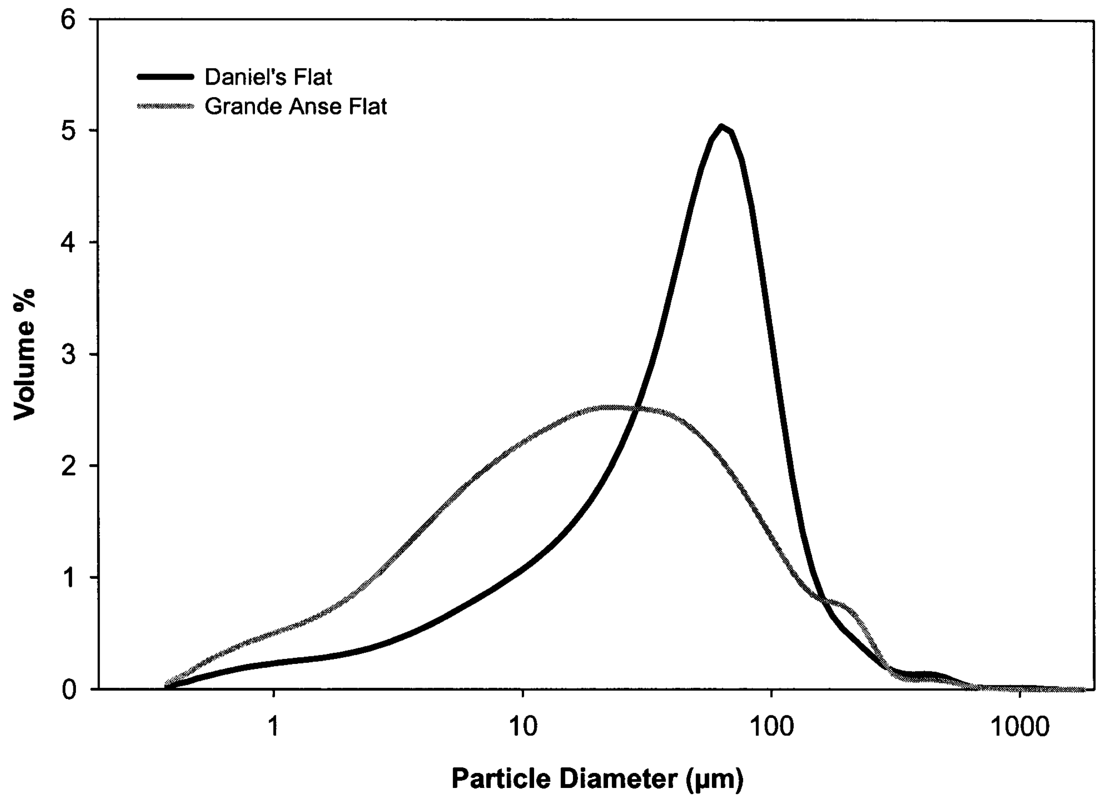


Figure 2. Densities of *Corophium volutator* and diatoms from Daniel's Flat and Grand Anse Flat, 2001. *Corophium* density is represented by black bars and diatom density by white bars. Diatom density is expressed as cells/g of wet sediment. Stations were numbered starting at the shore side of mudflats.

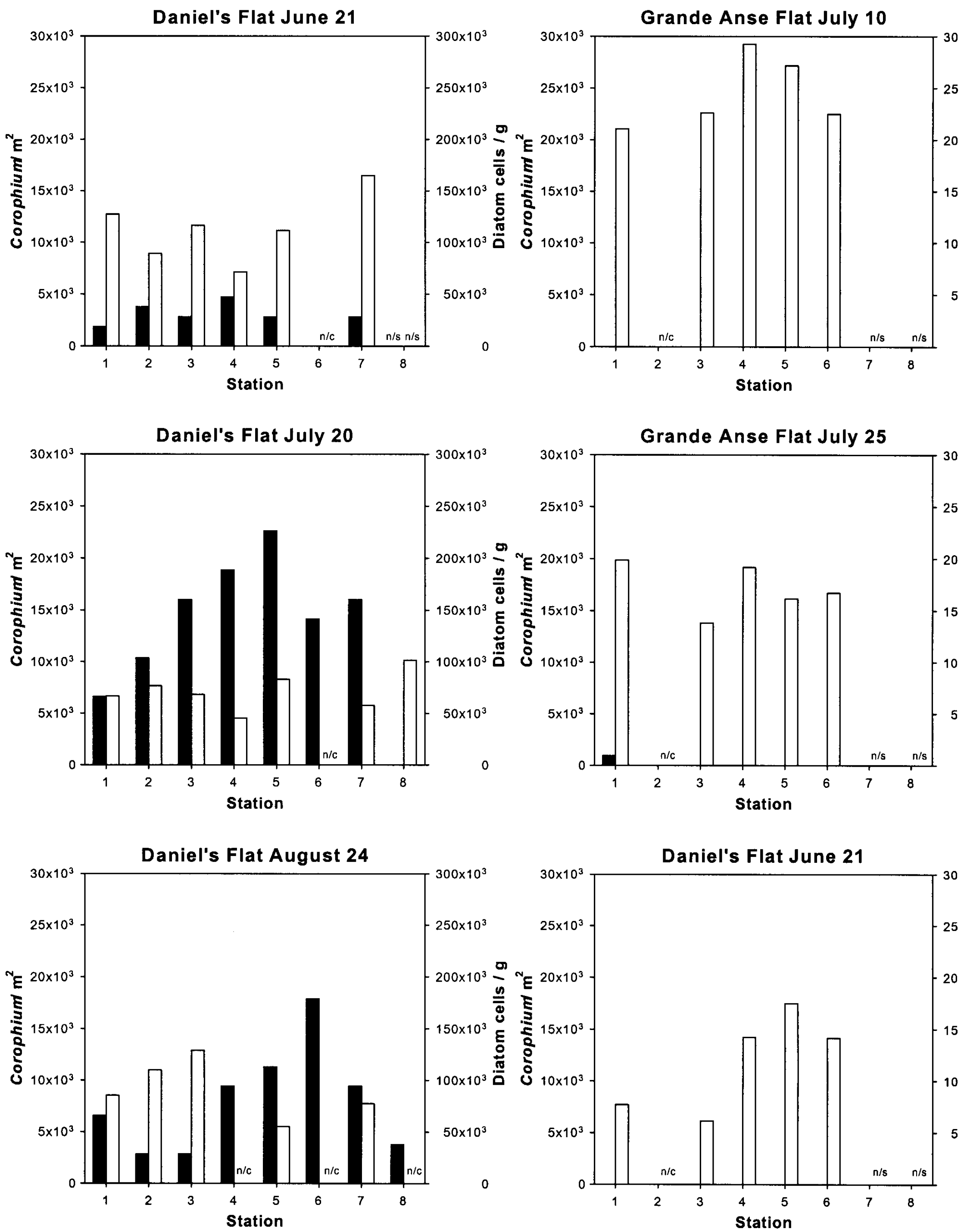
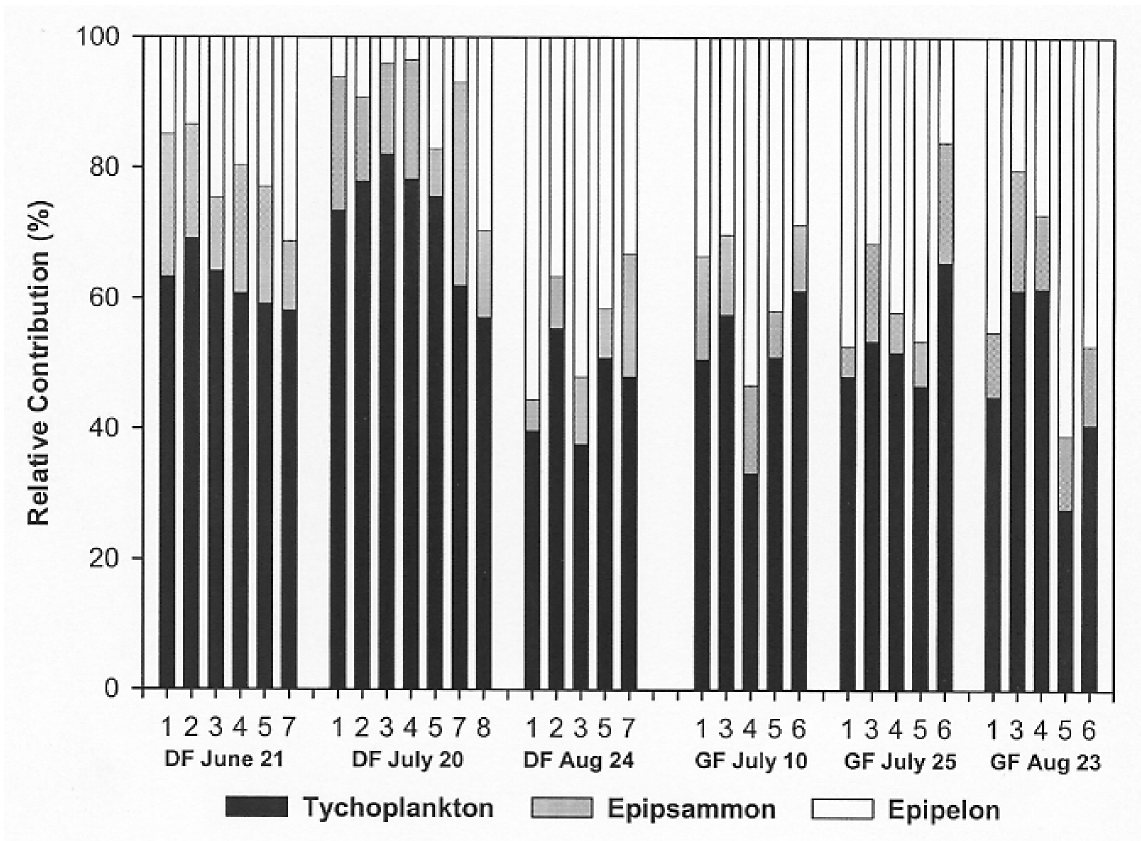


Figure 3. Relative contribution of the three functional groups of diatoms (tychoplankton, epipsammon and epipelon) to the diatom flora of Daniel's Flat and Grand Anse Flat, 2001



POPULATION DYNAMICS OF *Corophium volutator* IN THE UPPER BAY OF FUNDY: PAST AND PRESENT RESEARCH

Myriam A. Barbeau and Diana J. Hamilton

Department of Biology, University of New Brunswick, Fredericton, NB.
mbarbeau@unb.ca and dhamilt2@unb.ca

Mudflats in the upper Bay of Fundy are densely colonized by the amphipod *Corophium volutator*. These amphipods are major prey for fish and migratory shorebirds. Because *C. volutator* is so important in the estuarine food chain, its population dynamics provide a simple and informative index of the ecological state of the Bay of Fundy. Various mudflats have been studied intensively at different times since the1970s. The latest study of population abundance and structure of *C. volutator* was undertaken April 1999–May 2001 at 2–4 sites (Daniel's Flat, Grande Anse, Minudie, Avonport Beach). Densities of *C. volutator* ranged from ~ 1,000 to 70,000/m^2, depending on site and season. The densities observed in 1999-2001 were much lower at Grande Anse than other sites. Furthermore, the densities at Grande Anse were much lower than observed 20 years earlier. Two generations of *C. volutator* are produced per year; generations are more discrete in some populations than in others. Juveniles overwinter and dominate the population size structure, except in May when adults are more abundant. Between May and August, ~30% (range 5-60%) of adult females are gravid (a few can be found in September and October). Brood size is ~35 eggs/female (range 4–127). Adults experience high mortality from bird predation in late summer. Year-round, sex ratios are skewed towards females. A few adults (2%) are intersex individuals (displaying male and female characteristics). These data will be used to quantify vital rates (survival, growth, fecundity) of different *C. volutator* populations, and to develop models of population dynamics.

QUANTIFYING RELATIONSHIPS AMONG SPECIES ON INTERTIDAL MUDFLATS IN THE UPPER BAY OF FUNDY: COMMUNITY-LEVEL INTERACTIONS AND THE INFLUENCE OF ABIOTIC FACTORS

Diana J. Hamilton[1,2], Myriam A. Barbeau[2], and Antony W. Diamond[1]

[1] Atlantic Cooperative Wildlife Ecology Research Network, University of New Brunswick, Fredericton, NB. diamond@unb.ca
[2] Department of Biology, University of New Brunswick, Fredericton, NB. mbarbeau@unb.ca and dhamilt2@unb.ca

Intertidal mudflats in the upper Bay of Fundy are home to dense populations of *Corophium volutator*. These amphipods are the main food for migrating Semipalmated Sandpipers (*Calidris pusilla*) which are present in the region annually during late summer. In an effort to understand *Corophium* population changes and movements of birds around the Bay, we undertook a sampling program at four mudflats. During visits to each mudflat from June to September 2000, we collected samples to assess *Corophium* abundance, chlorophyll *a* concentration, and sediment characteristics (particle size, water content, nutrient availability). We also quantified mud whelk (*Ilyanassa obsoleta*) density and shorebird abundance. We found that *Corophium* abundance correlated negatively with whelk density, and that small *Corophium* were especially adversely affected by whelks. Whelks, which rapidly respond to high quality food sources, correlated positively with chlorophyll *a* concentration. Shorebird abundance could be predicted by the density of adult, but not juvenile, *Corophium*. This suggests that movements of birds around the Bay could be explained by small year-to-year changes in population dynamics of *Corophium* at the various sites. There was also a strong indirect relationship between whelks and shorebirds; abundance of birds in an area could be predicted several weeks before they arrived by abundance of whelks. Finally, sediment water content and particle size varied among mudflats, and helped to explain variation in *Corophium* abundance and outliers in the above-mentioned relationships.

LABORATORY INVESTIGATIONS OF ECOSYSTEM HEALTH USING *Corophium volutator*: CHEMICAL AND BIOLOGICAL ENDPOINTS

Jocelyne Hellou[1], Kerry Cheeseman[3], Elaine Desnoyers[2], Anette Gronlund[3], Dawn Johnston[2], Jim Leonard[1], Sarah Robertson[3] and Sean Steller[1]

[1] Marine Environmental Sciences Division, Bedford Institute of Oceanography, Dartmouth, NS.
hellouj@mar.dfo-mpo.gc.ca
[2] Chemistry Department, Dalhousie University, Halifax, NS.
[3] Biology Department, Dalhousie University, Halifax, NS.

To determine marine environmental quality and ecosystem health, it is important to investigate the type, level and fingerprint of contaminants and the proportion available for uptake that could be linked to potential biological effects. The level of contaminants in different marine environmental compartments is determined by the presence of sources of contamination, their transport, and type or physical-chemical properties of the chemicals that determine their partitioning and reactivity. The risk associated with exposure is linked to the importance of different uptake routes and will depend on the characteristics of the species under consideration. Small organisms like amphipods would be exposed through the carapace, feeding and respiration of water (Hellou 1996). The binding of chemicals to sediments will depend on the properties of the compounds, the grain size and total organic carbon (OC) content of sediments at one location (Law and Hellou 1999).

Polycyclic aromatic compounds (PACs) are ubiquitous contaminants found in air, soil, sediments, water and living organisms (Neff 1979). The sub-group of polycyclic aromatic hydrocarbons (PAHs) has been linked with a wide range of toxic effects, including behavioural, narcotic, immunologic, neurologic, physiologic, reproductive, carcinogenic and teratogenic effects. PAHs are recognized priority pollutants worldwide, including in Canada, because of the potential toxic effects associated with environmental exposure.

In general terms, hydrocarbons are derived from biogenic, diagenetic and anthropogenic sources (Steinhauer and Boehm 1992). Biogenic sources include various plant waxes and animal lipids. The decomposition of natural products over geological time scales leads to the formation of hydrocarbons. Combustion and petroleum sources can be of natural or anthropogenic origin. The more common natural combustion sources are forest fires and volcanic eruptions, while in the marine environment, hydrocarbons are also naturally introduced by underwater petroleum seeps. The main sources of concern in the environment, however, are due to the use of petroleum products or combustion processes. The latter include automobile exhausts, coking plants, asphalt production and domestic or industrial incineration. Petroleum products include crude and refined oils, lubricating oils, creosote and coal. In the offshore, hydrocarbons are also found in produced water, oil-based muds and would be discharged if a spill or blow-out occurs, while spills of various origin can occur inshore or on land.

The fate of PACs, the most abundant organic priority pollutants in coastal sediments, was investigated using a local marine amphipod, *Corophium volutator*, collected inter-tidally from the Minas Basin, Nova Scotia and exposed in the laboratory to contaminated sediments. The bioaccumulation of PACs was examined with exposure time, different groups of animals and post-depuration. It took an increasing length of time for the higher molecular weight PACs to reach equilibrium compared to lower molecular weight compounds, but equilibrium was reached within the ten-day experiment performed at 15^0C. A first study performed with a particularly abundant and reactive PAC added to pristine sediments determined that the amphipods do not metabolize PACs even after ten days of exposure, since no phase I or phase II, oxidation or conjugation products, respectively, were detected under the experimental conditions. Other experiments compared the availability of PACs present in sediments that received an older combustion source of contamination and mixed sources of PACs. Biota-sediment accumulation factors (BSAF) representing the concentration in amphipods divided by the concentration in sediments, both in dry weights, differed with contamination sources and by specific structure/size of PAC. Using laboratory spiked or field collected sediments demonstrated a lower availability of pyrene from field relative to spiked sediments.

A subset of results obtained for one of the more abundant PAHs examined in our studies, i.e. pyrene, a tetracyclic molecule that tends to partition into sediments is presented in Figure 1. Our observations point to the importance of performing laboratory experiments that would represent worst case scenarios in terms of possible chemical-biological interactions, since availability was lower in field relative to lab exposures. Laboratory experiments provide valuable data in the interpretation of field studies.

Biological effects, i.e. amphipod survival, reproduction of females and behavioural response were also examined and interpreted relative to the source of contamination assigned according to the chemical profile. In all our studies, narcotic effects were observed only once and analytical results correlated with the expected body burden leading to narcosis discussed in the literature (McCarthy and Mackay 1991). In all tests, >80% of females survived and reproduced. This is somewhat similar to the reference site (>90%), however the health of the progeny should be further investigated. Avoidance and preference of contaminated vs pristine sediments was observed for our most contaminated site and needs further experiments to link cause to effects. The presence of PCBs was also assessed in some sediment samples and exposed animals. The lower abundance of PCBs, i.e. 100 times lower than PACs, and similarity to background and reference sites points to their minor role in toxicity. However, the unknown role of other contaminants discharged in harbours receiving raw sewage effluents could contribute to specific and cumulative biological effects. Investigations are ongoing.

Acknowledgements

Funding from the Environmental Sciences Strategic Research Fund (1997–2000 and 2000–2003) of the Department of Fisheries and Oceans is acknowledged.

References

Hellou, J. 1996. Polycyclic aromatic hydrocarbons in marine mammals, finfish and mammals. Pages 229–250. In: *Interpreting Concentrations of Environmental Contaminants in Wildlife Tissues* N. Beyer and G. Heinz (Eds.). SETAC Special Publication, Pergamon Press.

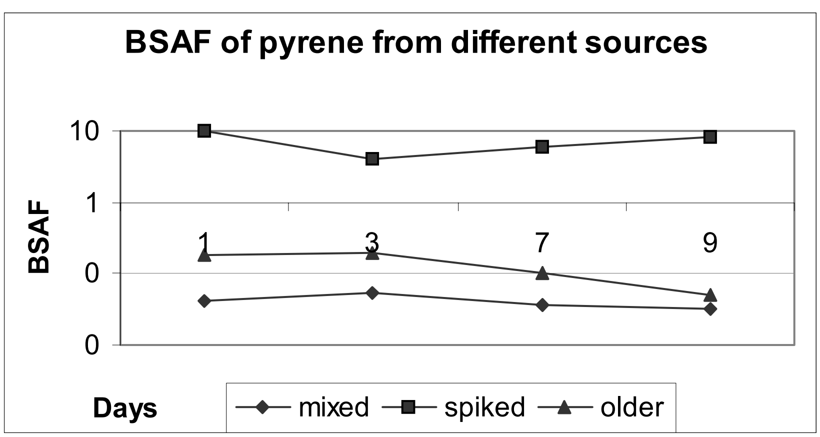
Law, R. J. and J. Hellou. 1999. Contamination of fish and shellfish following oil spill incidents. Environmental Geosciences 6: 90–98.

McCarthy, L. S. and D. Mackay. 1991. Interpreting aquatic toxicity QSARs. The significance of toxicant body residues at the pharmacologic endpoint. The Science of the Total Environment 109–110: 515–525.

Neff, J. M. 1979. *Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Sources, Fates and Biological Effects*. Applied Sciences Publisher, London. 262 pp.

Steinhauer, M. S. and P. D. Boehm. 1992. The composition and distribution of saturated and aromatic hydrocarbons in nearshore sediments, river sediments, and coastal peat of the Alaskan Beaufort Sea. Implications for detecting anthropogenic hydrocarbon inputs. Marine Environmental Research 33: 223–253.

Figure 1. BSAF: biota-sediments accumulation factors. Mixed refers to sediments containing pyrene and numerous other compounds from mixed sources. ‘Spiked’ refers to adding pyrene to pristine sediments, in the laboratory. ‘Older’ refers to aged sediments containing a combustion source of many PAHs.



DOES PARASITISM CONTRIBUTE TO SEGREGATION IN MIGRATING SHOREBIRDS?

Andy S. Didyk

Department of Biology, University of New Brunswick, Moncton, NB. adidyk@unb.ca

In many species of nearctic shorebirds there is a marked tendency for one of the parents, usually the female, to desert the family within days of hatch. A number of hypotheses have been put forward; some argue a benefit for the young while others suggest early departure increases the survival of the departing parent. None of the currently held hypotheses, however, adequately explain the phenomenon. The parasite-factor hypothesis proposes that selection should favour early departure from breeding grounds to take advantage of optimal feeding conditions that would include a low prevalence of parasite-infected prey. It predicts differential infections according to the age and sex of the birds, differential infectivity of the intermediate hosts, short parasite life cycles, and a benefit, in terms of condition, to individuals that leave the staging areas before others. The hypothesis considers the role of the burrowing amphipod *Corophium volutator* Pallas, a major prey item for staging shorebirds in the Bay of Fundy, as an important factor in shaping the migratory behaviour of the birds.

PANEL DISCUSSION

Chair: Diana Hamilton
Rapporteur: Jennifer Whitney
Panellists: Myriam Barbeau, Jocelyne Hellou, Peter Hicklin, Irene Kaczmarska, Peter Wells

The panel discussion opened with each panellist describing his or her current research interests in the Bay of Fundy.

Peter Wells discussed the formation of the *Corophium* Working Group of BoFEP in 1997. Its principal goals are to synthesize the available information about *Corophium* as a keystone species in the Bay of Fundy mudflats, identify key research questions, and plan and encourage relevant research projects. The group has developed an extensive, up-to-date bibliography on *Corophium* in support of its activities. This bibliography and review underway by the working group is providing insight into new research questions and directions relevant to the Bay of Fundy.

Myriam Barbeau's research interests include assessment of the factors that influence *Corophium* population dynamics, using models developed to integrate population-related data. She is also currently studying the spatial dynamics of *Corophium* distribution.

Peter Hicklin's research examines the dependence of shorebird populations on *Corophium*. He has proposed a periodic resampling of *Corophium* densities and sediment characteristics at mudflat sites that he first examined in a study in the late 1970s. In his view, such continued monitoring may be helpful in determining if recent changes in sediment water content at the Grande Anse site are an exception to the less dramatic changes observed in some other areas of the Bay.

Jocelyne Hellou's key interests are chemistry and ecotoxicology, particularly in relation to the possible presence of contaminants in *Corophium's* mudflat habitat. She is studying the amphipod's ability to survive under different environmental conditions, in order to develop the basic knowledge needed to predict or explain changes in *Corophium* populations that may occur as a result of habitat contamination.

Irena Kaczmarska is studying the ecological relationships between herbivores and diatoms, including the relationship between diatom abundance and *Corophium* abundance. She is also interested in the relationships between microorganisms and sediment characteristics, such as water chemistry, mineral composition and grain type, as well as how these factors affect the construction and composition of diatom mats.

The panel chair invited suggestions from the panellists and the audience for the development of research projects pertaining to *Corophium.*

The threshold *Corophium* population size needed to maintain a healthy shorebird population was discussed. The question was raised as to whether shorebird overfeeding on the second *Corophium* generation of the year might have a negative effect on the subsequent year's population. Peter Hicklin felt that winter mortality is probably harder on *Corophium* populations than predation by shorebirds. Discussion turned to the question of what the *Corophium* are eating and how abundant the benthic diatoms are on the mudflats. Irena Kaczmarska explained that her study contains little information about the consumption of diatoms by *Corophium.*

Although it may not be obvious from the numbers of Semipalmated Sandpipers that annually visit the Bay of Fundy, Peter Hicklin reported that the eastern population is definitely declining. The recent reintroduction of Peregrine Falcons to the area may be having an effect on the congregation of shorebirds. Peter Wells noted that the investigation of the population decline requires trend information for both *Corophium* and shorebirds, which is only available from the late 1970s to the present. Peter Hicklin suggested that information about habitat change is also required; for example, changes to the Grande Anse mudflats that may have been triggered by the opening of the Petitcodiac causeway.

There was a lengthy discussion about the observed changes in the composition of the mudflat at Grande Anse. It was noted that there is a need to study the factors that influence the health of *Corophium*. The physical nature of the Grande Anse mudflat system has changed, and the proposed removal of dykes and dams to restore salt marshes may have a large impact on the abundance of *Corophium* and diatoms. While the observed changes at Grande Anse may have been sudden, this does not necessarily imply that the opening of the Petitcodiac Causeway was the primary cause. Irena Kaczmarska commented on the need for data on the sediments to aid in understanding changes at Grande Anse. The feasibility of attempting to define the fundamental state of such an ecosystem was questioned. Perhaps, individually predictable factors are impossible to combine to predict ecosystem equilibrium. It was suggested that perhaps the habitat changes at Grande Anse have more to do with an incomplete understanding of mudflat ecology, rather than to changes resulting from the opening of the causeway. Jeff Ollerhead felt that, while there may be some truth in this, the opening of gates or the removal of dams are major perturbations that would likely have some effect on surrounding ecosystems.

Myriam Barbeau asked how long *Corophium* have existed in the Bay of Fundy influencing mudflat ecology. Peter Wells stated that there is no conclusive evidence as to whether *Corophium* is a native or introduced species. However, as *Corophium* species are distributed almost worldwide it is commonly assumed to be native to the Bay of Fundy. The question of shorebird feeding in the absence of *Corophium* was discussed. Peter Hicklin reported that there is evidence that shorebirds on their wintering grounds in French Guyana eat horseshoe crabs. Andy Didyk asked if an historical absence of *Corophium* in the Bay of Fundy region might have prevented the shorebirds from migrating as far as they do now, if their main prey at that time had less food energy. Peter Hicklin suggested that the shorebird migration path probably followed the coast, resulting in the discovery of the *Corophium* concentrations as a good food source of which the shorebirds have since taken full advantage.

The discussion returned to a consideration of the changes observed at Grande Anse. It was asked whether water height and depth measurements have been taken at the site. Peter Hicklin responded that these had been measured as part of tidal power related study carried out in the 1980s. The possibility that Grande Anse has eroded and filled back in was proposed. Diana Hamilton noted that the unconsolidated layer at Grande Anse is much deeper and that the depth to the anoxic layer has increased. Peter Hicklin reported the existence of anecdotal evidence from the 1930s and 1940s, which supports the notion that erosion has caused significant changes at the site. However, there is no anecdotal evidence for the time period surrounding the opening of the Petitcodiac Causeway. Mike Brylinsky asked whether rocks carried onto the mudflat by ice floes might have changed the hydrology of the area. Peter Hicklin replied that the rocks on the mudflat are too uniformly distributed to have been carried there by ice floes; it is more likely that they were uncovered by erosion.

Mike Brylinsky asked about the abundance of diatoms at Grande Anse. Irena Kaczmarska replied that they are consistently abundant early in the season. She also noted that sediment in the area appears to be subjected to very high turbidity (not through bioturbation), with the appearance of anoxic sediment on the surface of the mudflat noticeable even over the short period of a three-month study. The question was again raised as to whether the high level of unconsolidated mud observed at Grande Anse could be explained by erosion. Jeff Ollerhead responded that, in his opinion, the rocks in the area were likely ice-rafted onto the mudflat, as erosion would have exposed a harder substrate, rather than the soupy sediment currently found there. He noted that the relationship between the sedimentary and biological systems is crucial – if the sediment system has not recovered, it may be because the biological system has yet to recover in some fundamental manner. He feels that it is possible that the biological systems at Grande Anse have yet to regain their equilibrium state, if the observed changes are indeed due to the opening of the Petitcodiac Causeway ten years previously. He and several others agreed that ten years is a relatively short period of time in this context.

Peter Wells reported on the existence of European literature on *Corophium* that demonstrates its adaptability to different sediment conditions. For example, in sandier areas, *Corophium* builds tubes, rather than burrows. Such behavioural changes may occur in response to changes in sediment conditions. He suggested that the patchiness of the *Corophium* may change, and although animals may occur in decreased numbers, they will still be present. In his opinion, it is difficult not to find *Corophium* in the Bay of Fundy. Peter Wells asked Myriam Barbeau about her *Corophium* research, which found two generations occurring in the inner Bay, while the literature suggests that only a single generation occurs in the outer Bay. She replied that the number of generations is quite variable and that there may even be three in some places. It is influenced by such environmental factors as temperature. Diana Hamilton cited literature suggesting that heavy predation might also result in a second generation.

Diana Hamilton asked if there were any ideas for new research directions for the *Corophium* Working Group. Jocelyne Hellou suggested the possibility of doing some laboratory studies on the effect of factors such as temperature, sediment composition, etc. on the number of generations each year in *Corophium.* Although Grande Anse still has *Corophium*, the numbers are greatly reduced. Jocelyne Hellou suggested that the group might investigate the factors contributing to such fluctuations in their populations. Peter Wells commented that *Corophium* is a dominant, keystone species worthy of such study. However, there are gaps in the Working Group's current understanding of the dynamics of mudflats and about how environmental factors, such as chemical changes in the water and sediments or the erection and removal of barriers, affects *Corophium* populations. This highlights the importance of more intensive studies on the ecology of mudflats. Jeff Ollerhead agreed that *Corophium* is a keystone species and that changes in mudflat ecology are very important. He also wondered why the Grande Anse mudflats have not yet regained their equilibrium and are in fact worsening. He stressed the need to understand why these changes are taking place.

Mike Brylinsky wondered whether or not the amount of phytoplankton production in Fundy's upper basins is high enough to support the observed populations of *Corophium*. He also noted that ultraviolet radiation affects the production of diatom communities. Irena Kaczmarska responded that the diatoms are able to migrate up or down in the sediment in order to be exposed to the most favourable illumination. Thus any factors that affect their vertical migration necessarily affect the production of the diatom communities.

Andy Didyk asked whether too much emphasis is being placed on the events at Grande Anse. Is it possible that natural changes in the sediment composition or water content are taking place? He wondered if perhaps the Working Group should be examining other sites where *Corophium* are thriving in order to determine why they are so successful there. Someone also asked whether there are other sites where changes have been observed similar to those at Grande Anse. Mike Brylinsky responded that Starr's Point has large numbers of *Corophium*, whereas Porter's Cove has very few. And yet, these two sites are very similar, particularly their diatom communities. Jamie Gibson asked whether the relative abundance of *Heteromastus* (Capitellid Thread Worms) might account for the observed differences. Diana Hamilton and Mike Brylinsky responded that this is unlikely since *Heteromastus* is present in every sample and the sites are very similar.

Jeff Ollerhead asked about the population densities of *Corophium* along riverbanks. Diana Hamilton responded that the population densities have generally been found to be lower along riverbanks. Jeff Ollerhead wondered whether, since the sediment is most soupy at the bottom of a river channel, the Grande Anse site might not be becoming part of the river system. He suggested that a comparison be made of *Corophium* densities at Grande Anse with those in river channels. In response, Mike Brylinsky suggested that sediment soupiness is less crucial to *Corophium* since they are abundant at Starr's Point. Jeff Ollerhead then proposed that the many sites around the Bay be studied for *Corophium* density and sediment characteristics such as weight loss on ignition (organic content), water content and grain size. Such data might be used to examine the relationship between site characteristics and population densities. Diana Hamilton pointed out that much of this work has already been done; the necessary samples and data have been collected and are simply awaiting analysis.

Peter Hicklin restated the importance of understanding the changes observed at the Grande Anse site. Andy Didyk asked about the effect of the declining *Corophium* populations on shorebirds. What will happen to shorebirds if their primary food supply in the Bay of Fundy diminishes? Peter

Hicklin replied that the reason for the decline in shorebird populations is not evident within the Bay itself, but is more likely a result of changes in the northern breeding grounds or southern wintering grounds. He is uncertain as to what these changes might be, but may possibly involve climate changes or habitat changes.

Peter Wells closed the panel discussion by inviting anyone interested to participate in the *Corophium* Working Group. The Group is presently forming a network to facilitate the exchange of ideas and encourage co-operation in research activities. It is also drafting a review paper to consolidate the available knowledge about *Corophium* and to serve as a guide in identifying new research directions. Diana Hamilton concluded with a request for more contributions to the *Corophium* review paper.

Session Seven

MINAS BASIN

Chair: David Duggan, Oceans and Coastal Management Division, Bedford Institute of Oceanography, Halifax, Nova Scotia

MOVING TOWARD INTEGRATED MANAGEMENT OF THE MINAS BASIN: A CAPSULE SUMMARY OF PROGRESS

Pat Hinch

Nova Scotia Department of Environment and Labour, Halifax, NS. hinchpr@gov.ns.ca

Abstract

The Minas Basin is a highly productive and dynamic ecosystem which is blessed with many natural resources that have been used for generations for the benefit of its surrounding communities. Some species, habitats, and ecological processes are now threatened by current and anticipated activities in the Basin and its watershed. To sustain or rejuvenate this ecosystem requires co-operation among scientists, researchers, resource users, residents of communities, the private sector, and government. The Minas Basin Working Group of the Bay of Fundy Ecosystem Partnership was established to facilitate co-operative effort and partnerships to protect and sustain environmental quality in the region and to promote sustainable use of natural resources. The Working Group hopes to do this by working with communities and other interested groups to develop a broadly supported integrated management plan for the region. This presentation will provide an overview of the mission, goals and objectives of the Working Group, its current activities, and future plans to engage multistakeholder groups in an integrated management approach to address issues of concern to communities.

Introduction

The Minas Basin, which is the southern branch of the upper Bay of Fundy, is a semi-enclosed silted remnant of a 200 million-year old rift valley, once located near the Equator. Minas Basin is comprised of four distinct regions: Minas Channel at the mouth, the central Minas Basin, a southward bulge called the Southern Bight, and Cobequid Bay which forms the inner extremity. At its westernmost end, with Cape Chignecto to the north and Harbourville to the south, the Channel is 24 kilometres wide. Between Partridge Island (near Parrsboro) and Cape Blomidon, the Channel is only five kilometres wide. The water depth over much of the Minas Basin is less than 25 metres at low tide (average 14.5 metres), although a deeper trench which runs through the Minas Channel from the west is up to 115 metres deep (Percy 2001).

The tides of the Basin exceed those of any other place in the world. Tides rise and fall an average of 13 metres and to more than 16 metres during spring tides. (The world record tidal amplitude of 16.27 metres occurs at Burntcoat Head on the southern shore of the Basin.) This amplitude causes more than 10 cubic kilometres of seawater, weighing 10 billion tonnes, to flow into and out of the Basin twice daily, more than forty times the flow of the St. Lawrence River. Inrushing water reaches speeds of four metres per second (8 knots) past Cape Split. As the tide ebbs, the waterline may recede as much as five kilometres seaward, exposing an intertidal zone of almost 40,00 hectares, more than a third of the Basin's total area.

The combined area of the Minas Basin and Channel is about 190,000 hectares. The watershed of the Minas Basin, which drains into and influences the marine ecosystem, is nearly five times larger, almost 900,000 hectares, over 20% of mainland Nova Scotia.

The Ecosystem

The Minas Basin is a highly productive and dynamic ecosystem with natural resources that for generations have sustained surrounding coastal communities (Thurston 1990). Characterized by extreme tides, turbulent currents, a soft substrate, and silt-laden waters, Minas Basin is also a highly stressful environment for marine species. Biodiversity in the Minas Basin is low by comparison to marine areas, but for those species that can thrive, there is little competition and their populations are large and stable. Plant production (notably seaweeds) is lower than in most estuaries because of turbulence and turbidity.

Tidal mudflats and sandflats dominate over half of the Upper Bay of Fundy intertidal zone. Minas Basin has about 1,330 hectares of low salt marsh which fringe the mudflats. Almost 80% of salt marshes lie in the Southern Bight. The large stretches of intertidal mudflat exposed to the sun at low tide, provide a surface for benthic diatom populations, substrate for burrowing polychaetes such as the commercial baitworm species, and burrowing amphipods including *Corophium volutator*. The mudflats also provide critical feeding grounds for shorebirds, particularly the plovers and the migratory Semipalmated Sandpiper. The Southern Bight mudflat is in fact so important to these migratory species that 26,800 hectares of coast have been designates a Ramsar site—a wetland of international importance. This area has also been designated as a Western Hemisphere Shore Bird Reserve to protect a series of habitats for migrating shorebirds extending from the Arctic to southern South America.

The Minas Basin supports over 50 species of fish including commercial fisheries for American shad, Atlantic salmon, winter flounder, and soft-shelled clam, *Mya arenaria*, which have since declined. Minas Basin offers a range of ecotourism activities including camping, coastal hiking, sea kayaking, angling (trout, bass), rock and fossil hunting, and whale and birdwatching.

Change and Stress

Some species, habitats, and ecological processes are now threatened by current and anticipated activities in the Basin and its watershed. The 3rd BOFEP Science workshop held in 1999, focused on understanding change in the Bay of Fundy ecosystem. As indicated by Peter Wells (1999) during his opening presentation during that workshop, there are a number of indicators of change from a natural standpoint in the Bay. These include: climate and local weather patterns (e.g., warming and extreme events occurring more frequently); increases in coastal erosion and sedimentation in local areas; sea level rise throughout the Bay; destruction of dykes by storm surges; occasional/potential flooding of coastal communities; sea surface temperature change; a possibly wider distribution and longer feeding period of migrating shorebirds on some of the mudflats of the upper Bay.

There are many examples of human induced changes, some are well documented in the literature, some observational and anecdotal. These changes include: loss of critical habitat, e.g., diminished total areas of salt marsh spawning, and feeding areas for fish, notably salmon; construction of barriers on rivers, estuaries, shorelines and their related effects; the widespread presence of trace contaminants; increased numbers and types of industrial discharges causing a reduction in water quality; occasional oil spills, increased numbers of shellfish closures due to high bacterial levels, increased paralytic shellfish poison outbreaks; diminished fisheries, e.g., shad, winter flounder, salmon, alewives, and soft-shelled clam. Commercial and recreational salmon fisheries are now banned. There is also a reduction in wildlife populations, e.g., reduced numbers of shore birds and sea ducks, puffins, terns, and Northern Right Whales. In addition, unregulated harvesting, the presence of many tidal barriers or restrictions, nutrification, potential mining activity (for hydrocarbons beneath Cobequid Bay, titanium and other rare metals in the sediments along the southern shore and the lower areas of the Shubenacadie River), may also add stress to the natural environment. Several of these changes can be both natural and human induced, e.g., temperature change can be natural, as well as being caused by carbon dioxide input; shoreline erosion can be the result of climate change and also due to coastal development.

The Minas Basin Committee

For the past 400 years, European settlers to the Minas Basin area have utilized and depended upon natural resources of the Bay of Fundy for their livelihood and well-being. The changes we are witnessing are constant. Over some of these changes we have little or no control, others we have more power to influence. Clearly if we are to continue to rely on the natural resource base indefinitely, we must deal with several issues. People living in communities surrounding the Basin have come to realize:

1. The biodiversity, environmental quality, of the Basin are showing signs of deterioration.
2. Habitats, biodiversity, environmental quality and a way of life based on natural resource use are being compromised.
3. The issues are highly complex.
4. To understand the issues fully and to sustain or rejuvenate ecosystems requires the involvement and co-operation of scientists, researchers, resource users, residents of communities, the private sector, and government.

The Minas Basin Committee was established to facilitate co-operative effort and partnerships to protect and to sustain environmental quality in the region, and to promote sustainable use of natural resources.

History and Purpose of the Minas Basin Project Working Group

The Minas Basin Working Group was established in 1998 as a committee affiliated with the Gulf of Maine (GOM) Council. As a Nova Scotia representative on the GOM Working Group, I was asked to explore the possibility of a community group assuming responsibility for one of the projects under the Gulf of Maine Council Action Plan. This project involved the identification of significant habitats and species in the Nova Scotia portion of the GOM watershed and the development of management recommendations to protect, conserve and sustain each species. This project was to continue the work of two pilot projects that had been conducted in Great Bay, New Hampshire and Passamaquoddy Bay, New Brunswick.

An initial Minas Basin workshop was held in the summer of 1998 in Wolfville, at Acadia University, to gauge the level of interest in the GOM project in Nova Scotia, and needless to say there was strong interest in the project. Those who attended the workshop chose the Minas Basin as the most appropriate site to extend the project to Nova Scotia. (This decision was based on the value placed on the resource base, current conservation programs in the area, the level of local expertise in species and habitat management, research activity, the volume of existing information, and the availability of partners currently engaged in sustainable management.)

A steering committee and focus group were established to guide the development of the Minas Basin project. Project goals were:

- to promote the development of a more integrated systematic approach to management of the Bay of Fundy as an ecosystem
- to increase accessibility and utility of resource data to decision makers, researchers, and the public

The objective was to engage stakeholders (government, non-government organizations, universities, the private sector, and individuals) in a co-ordinated effort to identify critical habitats and develop management plans. Tangible products and outcomes of this project included:

- a demonstration of the use of existing knowledge (community, scientific) to identify significant habitats in the Minas Basin area;
- publication of a series of resource (species/habitat) maps and species/habitat profiles;
- a report of important habitats identifying issues, gaps in habitat/species information, management priorities and options, and issues for future scientific investigation and research
- a model for public participation and involvement in coastal zone management; and
- an action plan for sustainable management of the Minas Basin as an ecosystem which would subsequently be implemented over the long term through co-operative initiatives in habitat conservation involving government agencies, conservation groups and the scientific community.

Between 1998 and 2000, the focus group developed the project outline, study approach, prepared a budget, identified potential partners and sources of funding, formed partnerships, determined information and resource needs, identified priority actions, and developed a project work plan and schedule. The group submitted applications for funding, but applications to the Canada Millennium Fund, the Pew Foundation, and GOM Implementation Grants program were unsuccessful.

Minas Basin Working Group (A Working Group of BOFEP)

In 2000, the Minas Basin Committee requested to become a Working Group of the Bay of Fundy Ecosystem Partnership and began to establish its own identity and to expand its purpose, mission, and objectives. The Working Group adopted the mission statement of the Gulf of Maine Council which is to maintain and enhance environmental quality in the Minas Basin and its watershed, and to allow for sustainable resource use by existing and future generations. Our objectives, are:

- to engage the public in identifying issues and actions pertaining to the sustainability of the Basin's resources and its coastal communities (i.e., to encourage active community participation in all aspects of the working group's activities);
- to facilitate partnerships, collaboration and new funding opportunities among researchers, policy makers, resource managers and community groups pertaining to any aspect of the sustainable use and management of the Minas Basin.
- to work towards a multistakeholder-supported, integrated management plan for the Minas Basin, taking into account its natural resources (living and non-living), the needs for conservation and protection, and Canada's long-term commitment to sustainable development;
- to facilitate co-ordination of efforts to identify critical habitats and living resources of the Minas Basin (i.e. to encourage conservation of the Basin's biodiversity);
- to identify habitats and species issues for future scientific investigation and research; and
- to enhance access to and interpretation of information on Minas Basin and its natural resources.

Definition of Integrated Coastal Management

A definition of integrated coastal management (ICM) which closely matches the intent or purpose of the Minas Basin Working Group is "a continuous and dynamic process by which decisions are made for the sustainable use, development and protection of coastal and marine areas and resources". The goals of integrated coastal management are "to achieve sustainable development of coastal and marine areas, to reduce vulnerability of coastal areas and their inhabitants to natural hazards, and to maintain essential ecological processes, life support systems, and biological diversity in coastal and marine areas" (Cicin-Sain and Knecht 1998).

ICM acknowledges the interrelationships that exist among coastal and ocean use and the environments they potentially affect, is designed to overcome the fragmentation inherent in the sectoral management approach and is multipurpose oriented. It analyzes implications of development, conflicting uses, and interrelationships between physical processes and human activities. It also promotes linkages and harmonization among sectoral coastal and ocean activities.

Working Group Activities

During Phase I of activity (2000–2002), the Working Group was involved in gathering information about the Minas Basin and its watershed. The Working Group received funding from Environment Canada and Department of Fisheries and Oceans to fund a research/co-ordinator position to:

- conduct an inventory of non-government organizations concerned with natural resource issues, the environment, and sustainable development of the Minas Basin and its watershed and their current activities;
- produce a bibliography of existing literature and information on the Minas Basin;
- identify and categorize issues of concern to communities; and
- produce a Minas Basin watershed profile—a compendium of socio-economic information including population, demographics and labour force statistics, and land use in the Minas Basin watershed.

During Phase II, the Group held three community forums in Wolfville (January 24, 2002), Truro (February 27, 2002), and Parrsboro (April 18, 2002). At the request of the community, a fourth is being planned for the Noel shore in the near future.

The overall goal of these forums* was to initiate action toward sustainable management of the natural and human resources of the Minas Basin and its watershed. Specific objectives were to:

- introduce the Minas Basin Working Group and this project;
- increase awareness in the community of existing interest groups;
- enhance co-operation and networking;
- verify identified issues of concern with communities; and
- establish the basis for an action plan development for the Minas Basin watershed.

In terms of future plans (Phase III) the Working Group will be involved in two major projects over the next few years. The Working Group has re-initiated the original GOM Action Plan habitat and species project mentioned earlier to develop action plans for sustainable management of living resources. As a pilot, the initial project will map the resources of the Salmon River watershed near Truro. In terms of outcomes, this project will

- demonstrate the use of existing knowledge to identify significant habitats;
- publish a series of resource (species/habitat) maps and profiles;

* *Editors' Note* (3/03): Proceedings of the forums have now been published and are available from the BoFEP Secretariat, ACER, Acadia University, Wolfville, NS.

- develop a model for public participation and involvement in coastal and watershed management;
- design an action plan for sustainable management of the Salmon River watershed area;
- implement the plan through long-term through co-operative initiatives that involve all stakeholders; and
- evaluate the model and consider the value and feasibility of its application to other watershed areas.

The second project, which follows from the community forums, will involve a meeting of those who volunteered during the community forums as leaders of community action groups. Each leader will be asked to review issues of concern to the community and to call on community members to form an action group. Each group will be encouraged to establish priorities, goals, objectives, and very importantly, develop a project-oriented action plan. Members of the Minas Basin Working Group and others will serve as a resource to assist the groups to identify, develop work plans, provide information and/or identify appropriate contacts/experts to share information or advice on specific issues.

Over the next year, we hope to see the formation of several action groups that will join/work in partnership with the Minas Basin Working Group to address community issues identified in community forums. The Working Group will continue to evaluate progress and to identify emerging issues and trends in the Minas Basin as they arise to help define future initiatives.

References

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated Coastal and Ocean Management: Concepts and Practices*. Island Press, Washington, DC. 517 p.

Percy, J. A. 2001. *Fundy's Minas Basin: Multiplying the Pluses of Minas*. Fundy Issue #19, Spring 2001. Bay of Fundy Ecosystem Partnership, 12 pp. URL: <http://www.auracom/~bofep/publications/fundy%20issues/minas1.htm>. Accessed 26 August 2002.

Thurston, H. 1990. *Tidal Life: A Natural History of the Bay of Fundy*. Camden House Publishing, Camden East, ON. 167 pp.

Wells, P. G. 1999. Understanding change in the Bay of Fundy ecosystem. In: *Understanding Changes in the Bay of Fundy Ecosystem. Proceedings of the 3rd Bay of Fundy Science Workshop, Mount Allison University, Sackville, New Brunswick, April 22-24, 2000*. J. Ollerhead, P. W. Hicklin, P. G. Wells and K. Ramsey (Eds.). Environment Canada, Atlantic Region, Occasional Report No. 12. Environment Canada, Sackville, NB.

PLANNING FOR ACTION IN THE MINAS BASIN WATERSHED: A SUMMARY OF THE BOFEP MINAS BASIN COMMUNITY FORUMS

Robin Willcocks-Musselman

Minas Basin Working Group, BoFEP, Halifax, NS. r.musselman@ns.sympatico.ca

Introduction

The Integrated Management Project for the Minas Basin watershed was initiated by the Minas Basin Working Group of the Bay of Fundy Ecosystem Partnership with the goal of working towards sustainable management of the natural and human resources of the Minas Basin and its watershed. Initial concerns were primarily with the marine environmental quality of the Minas Basin, but since it is often land-based activities that affect marine quality, it was recognized the entire watershed needed to be included. The study area therefore is the watershed of the Minas Basin (Figure 1).

The Integrated Management Project is more aptly described as a "process" rather than a project. It is meant to be fluid and evolve as the process moves forward. The only requirement is that the communities throughout the watershed drive the process, as it is important that people see themselves involved in the process and have a sense of ownership over it. Therefore, securing community involvement was an important first step and would be a requirement of the project's success.

Community Involvement

The Minas Basin Working Group chose to have several community forums throughout the watershed as a method of securing community involvement and support for the Integrated Management Project. Initially, it was thought that the forums would focus on gaining a better understanding of issues of concern with an attempt to prioritize these issues. After talking with many community members, the Minas Basin Working Group became aware that many other public consultations had taken place over the years. A brief inventory of projects/workshops held in Minas Basin was undertaken to ensure that the community forums would not repeat previous work. The inventory revealed that many workshops had been undertaken to identify issues of concern, and there was a sense that the public was frustrated with repeatedly talking about issues with little action being taken. The Minas Basin Working Group decided not to repeat previous efforts but rather build on them. Therefore, the goal of the community forums was not only issue identification and prioritization but, more importantly, development of action plans with the communities to address the issues of concern.

Community Forums

The primary goal of the community forums was to initiate actions toward sustainable management of the natural and human resources of the Minas Basin and its watershed. They were meant to build on past initiatives by government and non-government organizations, which focussed on identifying issues of concern to residents living in the Minas Basin watershed.

The community forums had several objectives:

1. Introduce the Minas Basin Working Group of BoFEP and the Integrated Management Process and foster community involvement in the integrated management process
2. Obtain more input on issues of concern from watershed residents
3. Increase awareness in the community of existing interest groups and their activities
4. Enhance co-operation and networking among interest groups, government, etc.
5. Develop action plans for communities in the Minas Basin watershed

Community Forum Planning

Planning of the community forums began in the fall of 2001 with the intent that the community forums take place in late fall or early winter of 2002 (Table 1). The first step was to identify forum locations and local co-hosts. Because of budget and time limitations, three initial community forums were planned for Wolfville, Truro, and Parrsboro. If more were needed or desired by communities, they could occur at a later date. The three initial community forums were chosen primarily because of their geographic location in the Minas Basin watershed.

From the database of groups/individuals working in the resource area, environmental management, or sustainable development around the Minas Basin watershed, several potential local co-hosts were identified for each of the community forums. Local co-hosts helped primarily in the forum planning process and with logistics. It was felt local co-hosts would be extremely valuable in providing local knowledge about appropriate dates, locations, structure, etc.

The structure of each individual forum was worked out with the aid of local co-hosts. In order to achieve all the objectives, it was decided that the community forums should consist of two distinct parts: an open house with displays from local groups, and small group discussions on priority issues.

1. The Open House portion would provide a chance for participants to network and to increase public awareness of community groups and activities in the watershed. All groups, organizations, and even individuals were encouraged to have displays at the Open House. This event was typically 1.5–2.0 hours in length.
2. The Focus Group Discussions would allow detailed discussion and action planning. By having several small discussion groups, this would also not allow for one issue to take over the meeting. Discussions were allotted 2.5–3 hours.

Focus Group Discussions

Focus groups were decided by using coloured dots to prioritize issues. Each coloured dot represented a priority – 1, 2 or 3. Participants were asked to place their dots on issues sheets, which were developed from information obtained in the preliminary issue gathering study completed in the winter of 2001. Participants were also encouraged to add other issues of concern to the sheets.

This exercise allowed the Minas Basin Working Group to establish four or five focus group discussions at each forum. The total number of dots and the quantity of priority 1 dots were the strongest determinants for the development of focus groups. Figures 2–4 show the results of priority setting for each forum and Charts 1–3 further illustrate the results. It is important to note that these results are reflective only of the people present at the forum, and they may not be indicative of the concerns of the community as a whole.

A member of the Minas Basin Working Group and a local facilitator led each focus group discussion. The structure of the discussion groups was developed in conjunction with the local co-hosts with the intention of identifying issues and problems and working towards developing actions for each group. After each community forum, the Minas Basin Working Group reviewed and adjusted the structure accordingly. For example, in Wolfville participant feedback indicated that the discussions stalled at identifying issues and discussing what others needed to do, not what the group could do. At the Truro forum, emphasis was therefore placed on having the groups focus on one or two issues that the group would like to deal with. Emphasis was put on developing specific actions they could do as a group, not what others needed to do. Unfortunately the Truro community forum was not as successful in this regard because there were so few stakeholders from the area in attendance, and discussion groups felt they could not make decisions for the stakeholders who were not in attendance. Feedback from this forum indicated there is a need to go back to the area and repeat this process in smaller meetings with interested stakeholders in specific areas of interest (i.e. agriculture, forestry, etc.). In Parrsboro, the focus group discussions were less structured and consisted of comments, concerns and then actions. This was the most successful forum for developing specific actions. Table 2 outlines the focus group structures for each community forum.

Community Forum Results

Table 3 summarizes the main characteristics of each community forum. Attendance was highest in Parrsboro and Wolfville but a similar number of displays were found at all three forums. Attendance in Parrsboro was greatly affected by many participants thinking the forum was meant to discuss only the Fundy Biosphere Initiative. In all three community forums, however, fisheries management and water quality/sewage were priority concerns and hence became discussion groups. In Wolfville and Truro, development, forestry practices, and agricultural practices were also priority concerns. The community forum in Parrsboro differed somewhat with focus group discussions being held on recreation/tourism and the Fundy Biosphere Initiative.

From these results the issues of most concern around the Minas Basin watershed are: agricultural practices, development, fisheries management, forestry practices, sewage treatment/water quality, tourism, and recreation. Consistently, sewage treatment/water quality and fisheries management were of concern throughout the watershed, but geographic variations occurred with many of the other issues. For example, agricultural practices and development seem to be of greater concern in Colchester, Hants and Kings Counties, where tourism and recreation are of more interest in Cumberland and Colchester Counties. Specific to the north shore of the Minas Basin, was concern over the Fundy Biosphere Initiative. Chart 4 compares the priority issues for each of the community forums and illustrates their intensity of concern at each community forum.

Actions Developed

In the focus group discussions at each of the community forums, several actions were recorded. Tables 4 through 6 summarize these actions for each focus group discussion. A summary and comparison of the actions developed at each community forum is displayed in Table 7. Table 8 outlines some of the common actions raised in all three community forums.

Common themes identified at the Wolfville Community Forum were:

1. More information about current conditions is needed, i.e. the “state of resources and quality of environment” in Minas Basin Watershed.
2. Better communication between stakeholders and easier access to information for the public is needed.
3. Coalitions or “united fronts” need to be created to tackle issues and take leadership roles.
4. Strategic/management plans need to be developed for issues.
5. The lack of resources (funding, volunteers, etc.) needs to be addressed.
6. Education of resource users and the public on the impacts of practices and sustainable practices needs to be undertaken and or increased.

Common themes identified from the Truro Community Forum were:

1. There needs to be more cooperation and communication between those impacting the environment and those being impacted.
2. Education and awareness raising campaigns need to be undertaken for the public and resource users (on sources of problems, impacts of practices, best management practices, training mechanisms etc.).
3. More research (before education) is needed on the impacts of practices. Community groups are willing to do this, but they need assistance be it financial, logistical, expertise etc.

4. There need to be changes to policies and legislation, and the introduction of positive incentives for resource users
5. Local groups need guidance and assistance rather than larger management approaches.

Common themes identified from the Parrsboro Community Forum include:

1. There needs to be more cooperation, communication and networking amongst various stakeholders.
2. Coalitions or “united fronts” need to be created to tackle issues and take leadership roles.
3. The community wants to gather more information and educate themselves on the issues, more sustainable practices and how other communities are dealing with these issues.
4. More research (before education) is needed on the impacts of practices.

Next Steps

As previously mentioned, the Minas Basin Working Group is approaching the Integrated Management Project as a fluid process, and this approach will also apply to the next phase of the project. The intention of the Working Group is to revisit the focus groups from each of the community forums and bring together individuals who identified themselves as potential leaders or expressed interest in participating in action groups. From the 14 focus groups, six individuals identified themselves as potential leaders and many more expressed interest in being involved in action groups. With the aid of the Minas Basin Working Group, these action groups will be encouraged to develop detailed action plans that will establish goals, objectives, priorities, and specific work plan actions to undertake over the next year. Members of the Minas Basin Working Group and others will serve as resources to assist in the development of work plans. It is the desire of the Working Group to eventually have a network of actions groups around the Minas Basin watershed.

Summary

The community forums that have taken place to date have achieved several of their objectives. They have also provided the Minas Basin Working Group of BoFEP with an initial step towards integrated management of the Minas Basin watershed.

Accomplishments of the community forums:

- The Working Group has become more aware of groups, organizations, and key individuals in the communities working in resource areas or that are interested in sustainable management of the Minas Basin watershed.
- Groups throughout the Minas Basin watershed were able to network with each other, and the public has become more aware of groups and activities in the watershed which they were previously unaware of.

- The public and many community organizations were introduced to the Minas Basin Integrated Management Project.
- The Working Group was able to get a better understanding of the major issues of concern within communities and a sense of their relative priority. As well, other issues of concern that were previously unknown were identified.
- Several leaders and interested individuals were identified to form action groups throughout the watershed.
- Many actions were identified that the Working Group can work with action groups to implement.
- The Working Group has a clearer idea of the potential roles they can play in the integrated management process.

Editors' Note: Please also see the two reports on this project, published by BoFEP as BoFEP Technical Reports Nos. 1 and 2, 2003. See: www. auracom.com/~bofep.

Table 1. Community Forum planning timeline

Fall 2001	Winter/ Spring 2002	Summer/ Fall 2002
• Review past and present public consultation projects – decide to move beyond issue identification and focus on ACTIONS! • Community Forum planning begins: contact local co- hosts	• Community Forums held in Wolfville, Truro and Parrsboro • 4th Forum added for Noel shore area (Fall 2002)	• Go back to focus groups and work on developing actions/specific projects identified through forums

Table 2. Focus Group discussion structure for each Community Forum

Wolfville	Truro	Parrsboro
Discuss/answer the following questions: What is the issue of concern? How do we address this issue? Who wants to be involved? (Check box on sign up sheet) Identify lead for group? (Put name on sign up sheet) Identify who else needs to be involved? What are the next steps to be taken? What do we need (resources, etc.)?	*Turn discussion over to Facilitator to follow the next steps*: BRAINSTORM What are the specific issues of concern in this broader issue – What are your concerns and why? FOCUS Focus the group by trying to pull together issues into “major issues” and identify the one(s) this group wants to address. SOLUTIONS How could we attempt to solve the problem? ACTIONS What are the specific actions we can undertake? WHO Who do we need to help us? RESOURCES What resources do we need (funding, maps, reports, technical data, access to government, etc)?	*Turn discussion over to Facilitator to follow the next steps*: COMMENTS AND CONCERNS What are your concerns and why? FOCUS Identify the major issue(s) from the brainstorming session above or those this group would like to focus on ACTIONS What are the specific actions we can undertake?

Table 3. Community Forum characteristics

	Wolfville (January 24th)	**Truro (February 27th)**	**Parrsboro (April 18th)**
Number in attendance	112	58	161
Number of Open House displays	23	24	20
Focus Groups	• Fisheries Management • Water quality/ Sewage • Agricultural Practices • Development • Forestry Practices	• Fisheries Management • Water quality/ Sewage • Agricultural Practices • Development • Forestry Practices	• Fisheries Management • Water quality/Sewage • Recreation/ Tourism • Fundy Biosphere Initiative

Table 4. Actions identified at Wolfville Community Forum

Agricultural Practices:

- Unite like-minded groups/individuals and strengthen networking to provide leadership role
- Research effects of practices on the environment and then review best management practices
- Educate farmers and public on effects of practices, land ethics, best management practices, etc.
- Work with government to create incentives and enforcement of best management practices
- Create a strategy to collect information, clarify problems, and identify steps to make things happen (involve community, farmers, government, etc.)!

Development:

- Devote more effort to assessment and measurement of the impacts of development
- Educate selves and public on the scope of the problem – need a communications and education strategy to do this (pamphlets, fact sheets, newsletters, web page, etc.)
- Create a development plan for Annapolis Valley area (identify areas of value in community; areas to be protected (non-development) to ensure conservation of biodiversity/ecological integrity and function of critical ecosystem process; low impact recreation use (especially ensure coastal access maintained), etc.)

Fisheries Management:

- Inventory historical and present status of fishery resources in Minas Basin (so appropriate targets can be developed)
- Inventory status of fish habitat (data could then be used to prioritize habitat for conservation/ protection/ restoration)
- Identify all stakeholders (fishers, government, community groups, NGO's, and non-fishing industries that affect fish, fish habitat, and water quality)
- Identify an organization or group to take the lead role as well as specific leaders
- Explore links between fisheries and communities and include this information when assessing importance fisheries
- Identify sources of funding
- Facilitate information exchange between DFO and user groups (stock status, water and habitat quality, etc
- Develop integrated management for fisheries in Minas Basin (build on BoFEP Integrated Fisheries Management Proposal)

Forestry Practices:

- Inventory current forestry groups and activities
- Identify and create incentive programs for foresters (money, publicity, taxes, etc.)
- Review and recommend improvements to legislation
- Have conference/meeting with all key players identified

Water Quality/Sewage:

- Create State of Water Report for surface and groundwater (including quality/quantity; sources of contamination and other threats; effects threats could/do have on aquatic resources, etc.)
- Have more in-depth discussion and some priority given to issues and the ensuing actions
- Work towards utilizing legislation more effectively, and developing standards rather than relying on CCME guidelines
- Establish a coalition with community water boards (include representative stakeholders and citizens)
- Enhance communication between government and communities on water issues (ensure public has access to water information and government is aware of publics concerns)
- Educate and raise awareness about water issues with the wider public
- Lobby government for more funding for water issues
- Work toward jurisdictions clarifying their authority and responsibilities (federal-provincial-municipal)
- Work on having formal environmental assessments of all projects affecting water resources (including some already established projects)
- Investigate local capacity (our capability) for water management
- Develop a Water Strategy for the region (review existing models from elsewhere in Canada that could be applied to area; use of report cards to see how well we are doing, etc.)

Table 5. Actions identified at Truro Community Forum

Agricultural Practices

- Promote more research on the effects of pesticides
- Educate farmers on their potential impacts to the environment, and on best management practices
- Work with government to guide and create incentives for farmers to act responsibly (i.e. demonstration projects)
- Improve communication between farmers and recreation users (ATV, trail groups, snowmobiles, etc.) – bring them together to discuss the recreational use of farmland to help reduce conflicts
- Increase education and licensing for ATV riders

Development

- Review and amend Municipal Act and Provincial EIA process by lobbying interest groups at all levels
- Review and amend current legislation for stronger environmental protection
- Educate and increase awareness on the issues and the need for change
- Bring together stakeholders in this area again

Fisheries Management

- Increase research on why stocks have declined (what is causing the problems?)
- Educate community and corporations on effects of their practices on waterways and on best management practices
- Create a fisheries management plan
- Establish a coalition to take a lead in education of community groups and getting their support
- Find technical and scientific assistance (research, funding, education etc.)
- Improve enforcement of existing legislations

Forestry Practices

- Focus on helping small wood lot owners; educate them on the effects of their practices and help them develop sustainable management plans
- Promote government requiring best management practices on crown land
- Investigate providing incentives to small wood lot owners with good forestry practices

Water Quality/Sewage

- Create an education program for the public (alternatives, hazards, conservation, renewable resources, water cycle, etc.)
- Determine the “state of water” (including sources of contamination/impacts of practices on watershed, state of groundwater, riparian condition?) – create a State of Water Report.

Table 6. Actions identified at Parrsboro Community Forum

Fisheries Management

- Promote better communication between all fishermen (locally and all around Minas Basin) and between fishermen and DFO (i.e. newsletters or columns in local papers, one DFO contact person, fisheries officers more involved, etc.)
- Promote recognition of the Upper Bay of Fundy as a unique region which should be managed separately from the entire Bay of Fundy
- Become involved in BoFEP Fisheries Management proposal for the Upper Bay of Fundy

Fundy Biosphere Initiative

- Promote better communication between proponents of biosphere and residents to address concerns regarding what a Biosphere actually entails, and to provide more community input into the decision making process

Recreation/Tourism

- Help ATV trail organizations to develop a trail pass system and implement trail wardens and trail maintenance activities
- Create a well developed trail system to encourage more ATV tourism in the area (similar to snowmobile focus in NB)
- Organize a meeting between ATV user groups, relevant government departments and environmental groups to discuss guidelines for ATV use (i.e. discuss sensitive areas to be off limits, potential amendments of Wilderness Areas to allow motorized vehicle access to some areas, etc.)
- Improve education on how ATV users can patrol and educate themselves on better practices (perhaps a conference?)

Water Quality/Sewage

- Create a united front on water issues – create an action group to coordinate activities and link with BoFEP
- Obtain information on the use/regulations/effects of chemicals used on blueberries
- Create a communication network (i.e. internet) to circulate information
- Conduct a survey of groundwater quality and quantity (including predictions for the future)
- Review examples of existing groups and the issues they are working on (CARP, ACAP, etc.)

Table 7. Summary of actions raised at Community Forums

Focus Group Discussion	Forum Location		
	Wolfville	**Truro**	**Parrsboro**
Agricultural Practices	• Create a coalition • Research effects of practices • Educate the public & farmers • Create incentive programs • Create a strategy!	• Research effects of pesticides • Educate farmers • Create incentives for BMPs • Increase communication between farmers & recreation users • Hold discussions between farmers and recreation users • Increase education for ATV users	
Development	• Create a development plan • Assess & measure impacts of development • Educate on the scope of problem	• Review legislation • Educate & increase awareness of public • Bring stakeholders from that area together	
Fisheries Management	• Inventory status of resources and habitats • ID stakeholders & funding • ID organization to take lead • Increase communication between DFO and fishermen • Create management plan	• More research (why stocks in decline?) • Increase education, communication, and cooperation • Create a coalition • Find technical and scientific assistance • Better enforcement of legislation • Create a management plan	• Increase communication amongst selves and with DFO • Increase recognition of the Upper Bay as distinct area • Get involved in – BoFEP Fisheries Management proposal
Forestry Practices	• Inventory current activities • Create incentives • Review legislation • Bring stakeholders together for discussions	• Educate and help small woodlot owners develop management plans • Create incentives • Lobby for best management practices on Crown land	

Table 7. Cont'd Summary of actions raised at Community Forums

Forestry Practices	• Inventory current activities • Create incentives • Review legislation • Bring stakeholders together for discussions	• Educate and help small woodlot owners develop management plans • Create incentives • Lobby for best management practices on Crown land	
Water Quality/ Sewage	• Develop State of Water Report • Increase communication between government and communities • Create a coalition • Have more discussion on issues • Develop standards • Educate the public • Investigate local capacity for water management • Clarify jurisdictions • Require an EIA for all projects affecting water resources • Create a water strategy	• Develop a State of Water Report • Educate the public (alternatives, conservation, resources etc.)	• Develop a State of Water Report • Educate selves and form a coalition • Create a communication network • Review existing groups and process
Recreation/ Tourism			• Develop a trail system for ATV tourism • Increase communication between users and environmentalists • Educate ATV users • Help ATV groups organize and monitor themselves
Fundy Biosphere Initiative			• Increase communication between proponents of biosphere reserve and residents

Table 8. Common actions raised at Community Forums

1. Create a "united front" or coalition within the communities/ create networks
2. Inventory state of resources/current activities
3. Research effects of practices
4. Increase education for public and resource users (effects of practices/best management practices etc.)
5. Research and promote use of incentives for resource users
6. Increase communication and cooperation between various stakeholders
7. Review relevant legislation
8. Create strategies and plans

Chart 1. Summary of Wolfville Community Forum – Prioritizing Issues

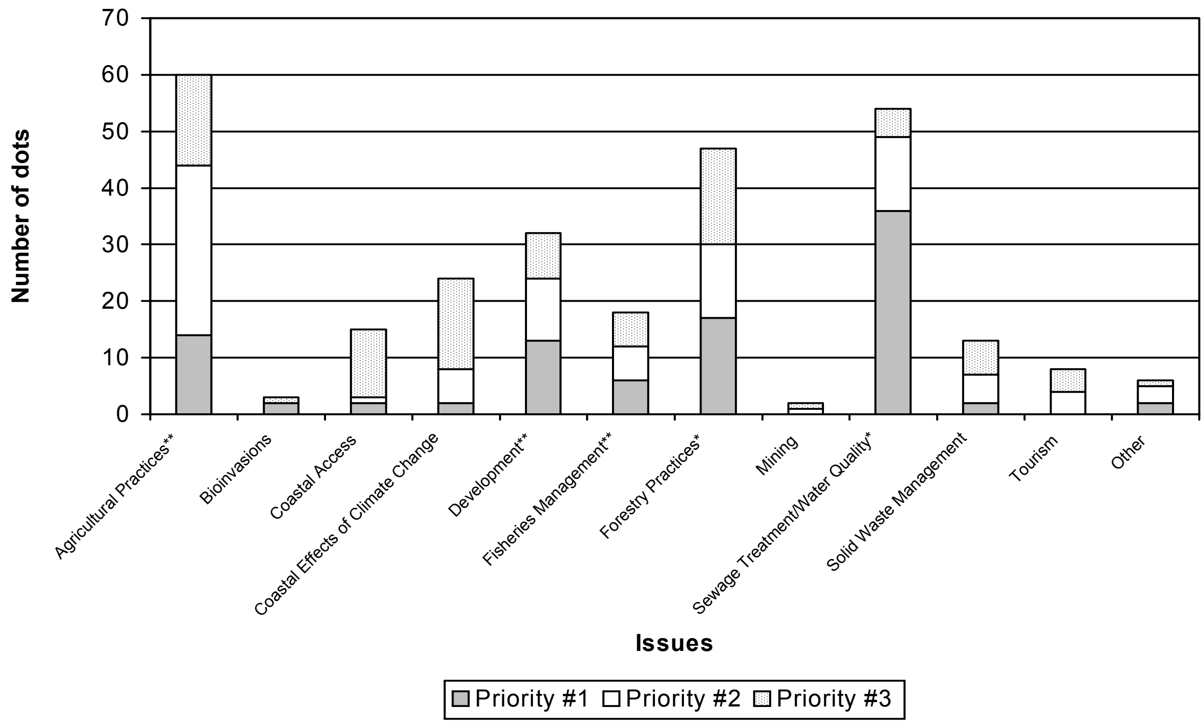
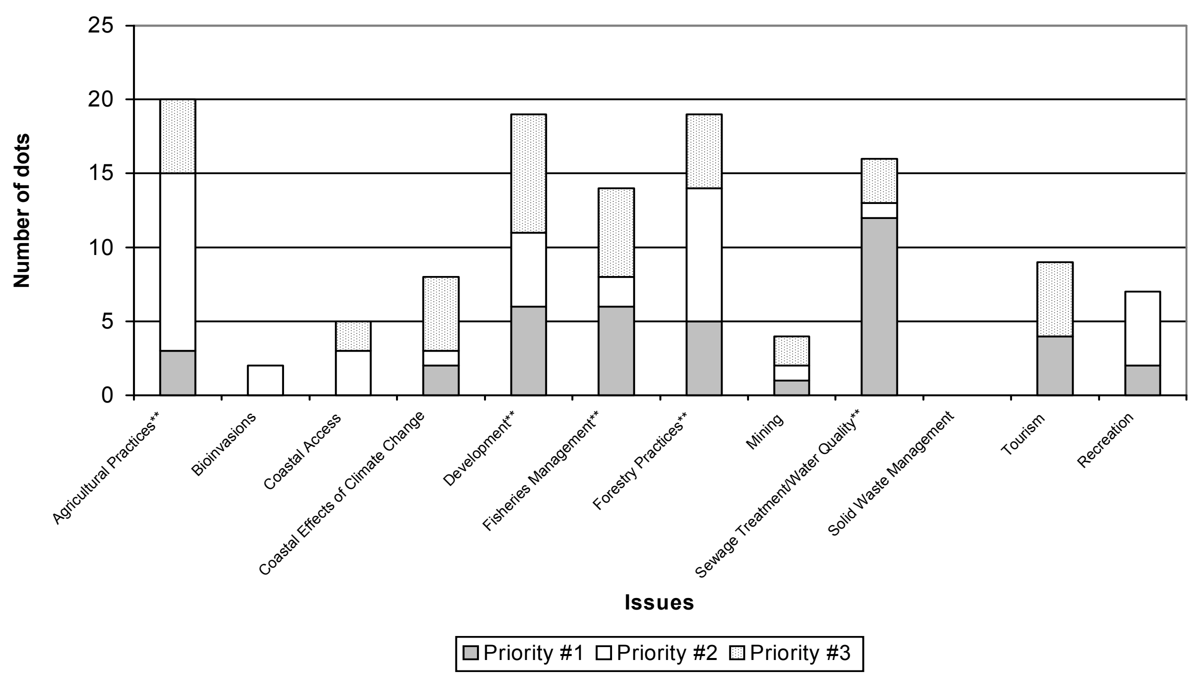
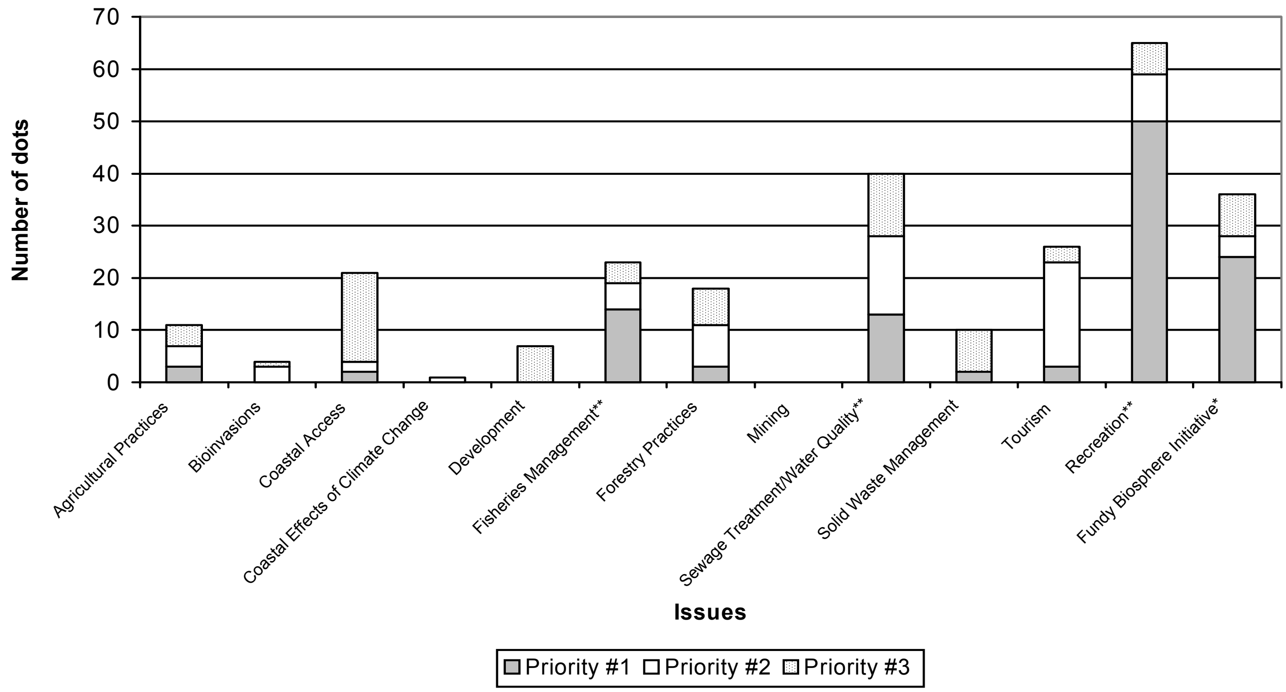


Chart 2. Summary of Truro Community Forum – Prioritizing Issues



** Indicates the issues that became focus group discussions

Chart 3. Summary of Parrsboro Community Forum – Prioritizing Issues



** Indicates the issues that became focus group discussions

Note: Recreation and Fundy Biosphere Initiative results may be misleading since the issue "Fundy Biosphere Initiative" was not added to the list until part way through the prioritizing exercise. Until that point some people concerned about the Biosphere Initiative may have put their dots on the Recreation category.

Chart 4. Priority issues in Minas Basin Community Forums

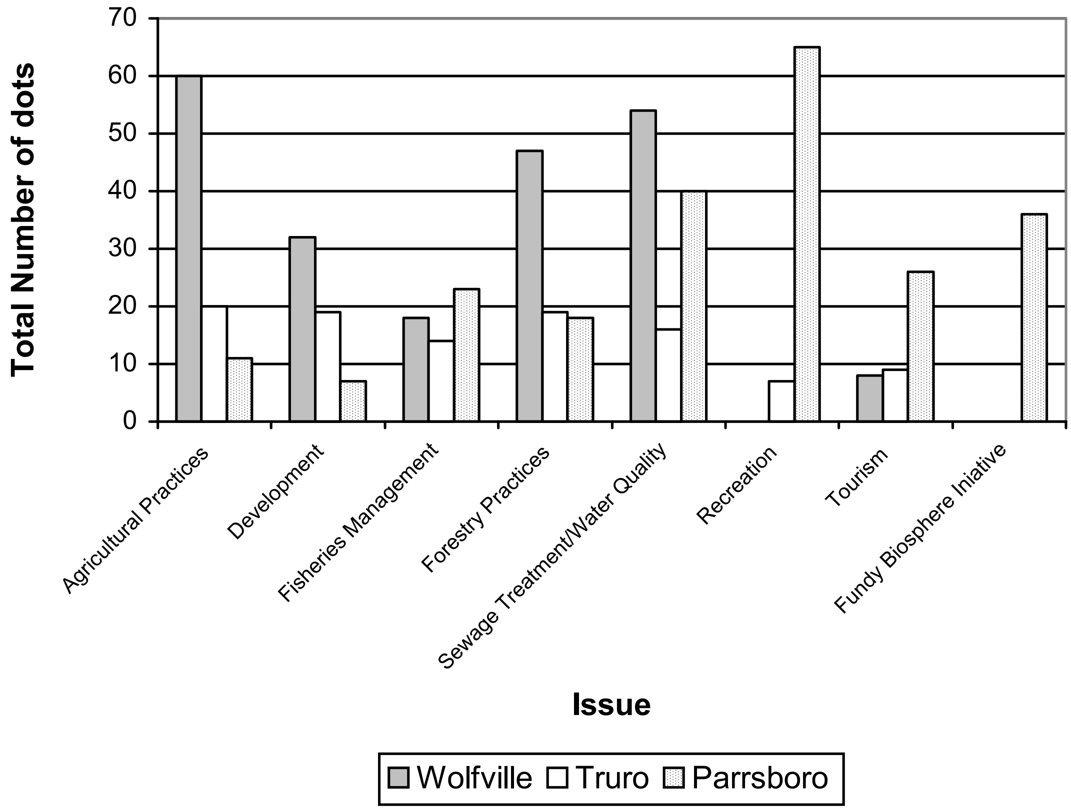


Figure 1. Map of Minas Basin Watershed (Source: Minas Basin Working Group, BoFEP)

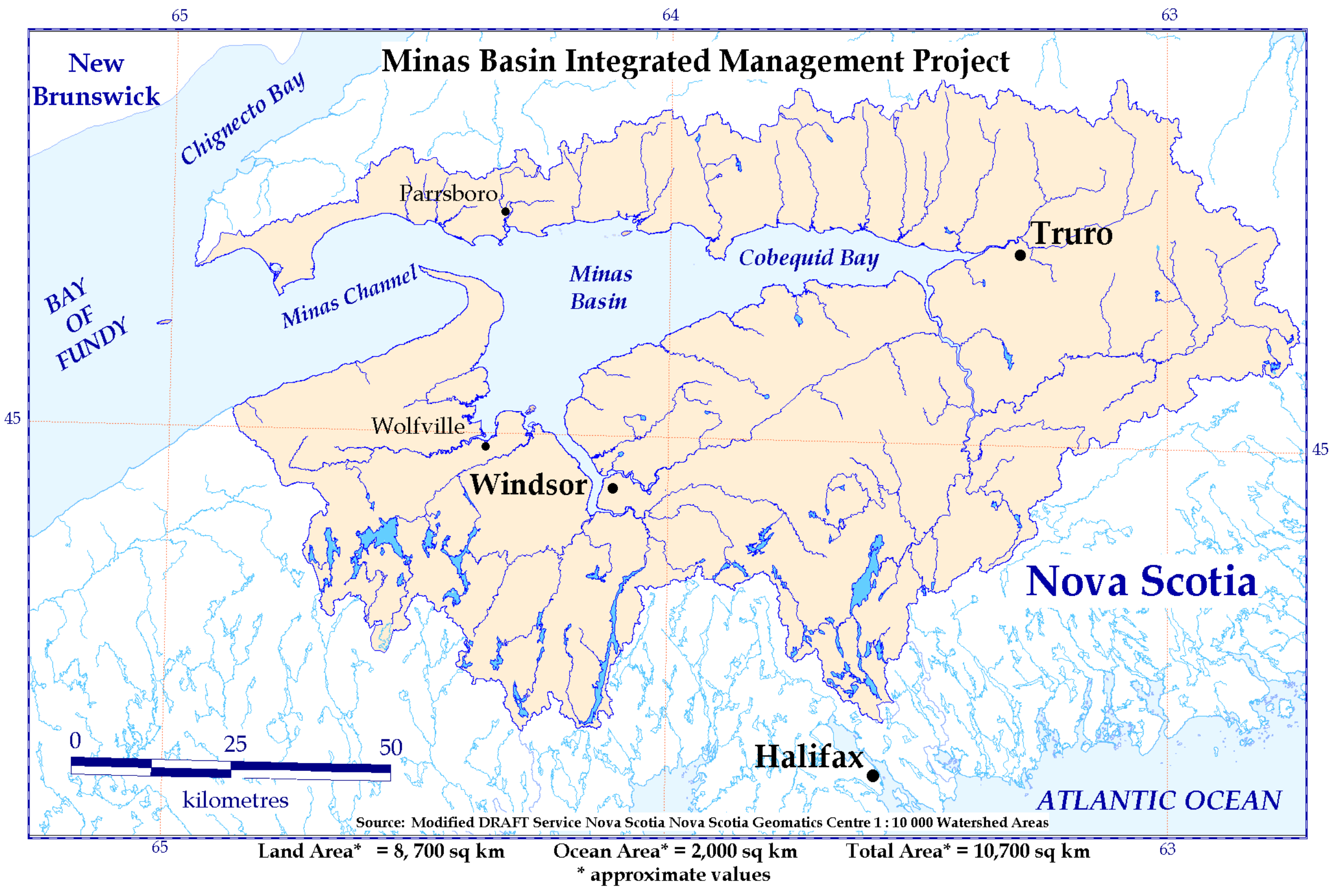


Figure 2. Issues Sheets Summary – Wolfville

Issue	Number of Dots			
	Priority #1	Priority #2	Priority #3	Total
Agricultural Practices	14	30	16	60
Bioinvasions	2	0	1	3
Coastal Access	2	1	12	15
Coastal Effects of Climate Change	2	6	16	24
Development	13	11	8	32
Fisheries Management	6	6	6	18
Forestry Practices	17	13	17	47
Mining	0	1	1	2
Sewage Treatment/Water Quality	36	13	5	54
Solid Waste Management	2	5	6	13
Tourism	0	4	4	8
Issues Added by Participants:				
Biodiversity and Health	1	2	0	3
Detrimental Soil Changes (from Agricultural Sprays and Fertilizers)	1	0	0	1
Toxins from Anti-fouling Paint Products	0	1	0	1
Ship/Watercraft Sewage and Waste	0	0	1	1

Figure 3. Issues Sheets Summary – Truro

Issue	Number of Dots			
	Priority #1	Priority #2	Priority #3	Total
Agricultural Practices	3	12	5	20
Bioinvasions	0	2	0	2
Coastal Access	0	3	2	5
Coastal Effects of Climate Change	2	1	5	8
Development	6	5	8	19
Fisheries Management	6	2	6	14
Forestry Practices	5	9	5	19
Mining	1	1	2	4
Sewage Treatment/Water Quality	12	1	3	16
Solid Waste Management	0	0	0	0
Tourism	4	0	5	9
Issues Added by Participants:				
Recreation	2	5	0	7

Figure 4. Issues Sheets Summary – Parrsboro

Issue	**Number of Dots Posted**			
	Priority #1	**Priority #2**	**Priority #3**	**Total**
Agricultural Practices	3	4	4	11
Bioinvasions	0	3	1	4
Coastal Access	2	2	17	21
Coastal Effects of Climate Change	0	1	0	1
Development	0	0	7	7
Fisheries Management	14	5	4	23
Forestry Practices	3	8	7	18
Mining	0	0	0	0
Sewage Treatment/Water Quality	13	15	12	40
Solid Waste Management	2	0	8	10
Tourism	3	20	3	26
Recreation	50	9	6	65
Issues Added by Participants:				
Fundy Biosphere Initiative	*24*	*4*	*8*	*36*

"… THROUGH A GLASS, DARKLY": WATER AND CLIMATE CHANGE IN THE BAY OF FUNDY WATERSHED

Graham Daborn

Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS. graham.daborn@acadiau.ca

Abstract

Water contamination and supply problems, coupled with large-scale land use and climate changes, are increasing anxiety among Fundy residents about their future water supplies. Proposals to mine groundwater, a resource that has not been adequately quantified, have implications for maintenance of water quality, and of habitat for fish and other wildlife. Research initiatives through the Canadian Water Network, and local groundwater interests, are aimed at developing a more comprehensive assessment of the sustainability of water use plans in the watershed of the Bay of Fundy.

Introduction

At first sight, the Atlantic region is blessed with an abundance of water: annual precipitation exceeds 1 m, and its arrival is distributed throughout the year; the landscape contains thousands of large and small lakes, and numerous rivers; and water-based recreation is a growing interest throughout the region. In spite of this, concerns over water quality and quantity have become commonplace, as more members of the public are forced to recognize that supplies are finite and the high quality of our surface waters more often is an illusion than a reality.

Water quality issues are not new. For more than a century, the region's rivers have been dammed for power generation, used to transport human waste away from its site of origin, and affected by a variety of land use practices. Maritime rivers are among the most modified rivers in the country. They have been blocked, straightened, drained and contaminated. The rise of shellfish aquaculture in the 1980s also focussed attention on the steady decline in water quality in the region's estuaries, resulting from both local input and practices upstream. By the 1980s, the ineffectiveness of central government policies for protection of water had led to discussions of the potential for multi-stakeholder, community-based approaches to environmental management (Daborn and Hawboldt 1994; Daborn 1995, 1996; Daborn and Dickie 1997; Ellsworth et al. 1999).

Increasing uncertainty, fostered recently by successive years of lower than normal precipitation during the growing season, has reinforced apprehensions over the regional effects of global warming. The agriculture sector, a major economic force in the Bay of Fundy watershed, sees its survival in increasing access to fresh water; in many areas, surface supplies are already heavily overused and/or contaminated beyond use, and hence new supplies must be extracted from the ground. Lost in the midst of such increasing demands, is the need for water to maintain ecosystem functions.

Towards Watershed-based Planning and Management

Attempts to establish comprehensive, watershed scale management of water require several vital pieces of information:

a) the present and future water availability;
b) the existing suite of water uses and their trends;
c) the impacts that existing uses have on water quantity, quality, and potential for reuse;
d) the interactions and conflicts between different uses; and
e) the capacity of local authorities and organizations to assess these stresses and manage them into the future.

One might expect that information on existing water uses and trends is readily available, but case studies have shown that is rarely the case. Similarly, the impacts of various activities are known in general, but often the absence of effective monitoring means that little direct information is available to assess the state of the environment in any given catchment basin. Conflicts between alternative uses have been avoided in many areas by assigning water rights in a given watershed to one sector, and thereby precluding development of alternatives. These conflicts become evident when supplies are seen to be inadequate. Finally, almost nothing is clear about the factors influencing the capacity of local communities and governments to establish comprehensive and integrated watershed management.

These difficulties have led to a series of experiments in watershed management in the Bay of Fundy region. An enabling philosophy is found in several places: the Gulf of Maine Council on the Marine Environment (1989) adopted a whole watershed approach to addressing the threats to the Gulf of Maine-Bay of Fundy system; Canada's 'Green Plan' provided the support for the Atlantic Coastal Action Program in 1991; Nova Scotia announced a 'Coastal 2000' policy in 1994, declaring that all provincial land was functionally part of the coastal zone, and indicating a new partnership would be established between local communities and government agencies; and Canada's Oceans Act (1997) explicitly requires an integrated ecosystem approach and a consideration of cumulative and interactive effects.

All of these policies tend to reflect the traditional assumption that ecosystems exist in some steady-state condition that rarely changes except through human influence. It is a critical illusion: ecosystems, particularly coastal ecosystems, are constantly changing. Although many of the changes in the Bay of Fundy watershed can be attributed to human interference and mismanagement (Lotze and Milewski 2002), some changes are undoubtedly independent of human influence. The spectre of global climate change, which will continue far into the future regardless of remedial measures, requires recognition of the dynamic nature of natural systems. Communities involved in integrated management have to understand and act upon that recognition.

Annapolis Valley – A Case Study

The Annapolis Valley has been identified as a good case study area for more than a decade. It was chosen for the first experiment in watershed management initiated under the Atlantic Estuaries Cooperative Venture (1988) which eventually developed into the Atlantic Coastal Action Plan (ACAP) in 1991. The Clean Annapolis River Project (1990) became the first ACAP site. Among the reasons for its choice is that the Annapolis Valley is relatively small, covering about 1,300 km^2. The Annapolis River catchment area covers 1,020 km^2, and drains westward through the Annapolis River, entering the Bay of Fundy near Digby, Nova Scotia. A group of smaller catchments draining about 360 km^2 flows eastward into the Minas Basin (Table 1, AGRA 2000).

Land and water use are notably different in these separate catchment areas. The Annapolis and Cornwallis catchments are dominated by agricultural use, with some degree of domestic-residential development, particularly at the eastern end of the Valley. In contrast, almost all of the Gaspereau-Black River system is committed for power production (AGRA 2000). Thus, the issues vary from watershed to watershed: water contamination from agricultural production predominates in the Annapolis and Cornwallis, whereas barriers to fish migration and cottage development are the principal issues in the Gaspereau-Black River.

Even the form of agriculture varies between the catchments, and consequently the water quality issue is somewhat different. For most of the Annapolis and Cornwallis catchments, the focus is on stock rearing, grains, orchard fruit and, more recently, soft fruits. In the Pereaux and Habitant catchments, major products are soft fruits and vegetables for export. These require irrigation with high quality water. Contamination of surface and ground waters by stock rearing and domestic waste, which has led to extremely high nitrate levels in near-surface ground water (Blair 2001), renders both sources of dubious quality for irrigation (Brylinsky 2001).

For the last decade, water quality of the Annapolis River has been regularly monitored by a volunteer group, the Annapolis River Guardians of the Clean Annapolis River Project Society (CARP). Despite major improvements in the functioning of waste treatment systems that each town operates, fecal coliform counts have consistently exceeded the maximum value for use in cattle watering and irrigation (100 coliforms/100ml), and usually exceeded the level permitting contact recreation (200 coliforms/100ml).

Continued contamination of the Annapolis Valley rivers, is attributable to land use practices, the absence of riparian protection in agricultural lands, and the failure of on-site sewage treatment systems. Several community-based initiatives, organized under CARP and the Friends of the Cornwallis Society (FOCS), are aimed at rehabilitating the rivers through re-establishment of riparian zones and changes in agricultural practice.

The poor condition of these surface waters has significant implications for the future of agriculture in the Annapolis Valley. Market forces are inducing shifts in local products from past focus on orchard fruits and cattle, to vegetables and soft fruits, that require irrigation with high quality water. The failure to maintain sufficiently high water quality places many of these products at risk.

For four of the last five years (1996–2001), annual rainfall has been significantly lower than average, especially during the growing season. Water demand in Kings County has been rising at >1% p.a. (AGRA 2000), and during the recent droughts, shortages have become a serious problem for agriculture. New crops, such as vegetables, soft fruits, and new apple varieties have high water demand. A recent survey of water demand has shown that licenses approved for surface water withdrawal exceed the average annual flow volumes of the five eastward-flowing rivers by 13% (AGRA 2000).

The only remaining source to meet increased demand, is groundwater. Proposals for major irrigation projects in the Annapolis Valley are predicated upon the assumption that a large aquifer underlies the Valley. Although more than 5,000 wells have been drilled into the aquifer in Kings County alone, few of these are monitored, and the total extraction of groundwater is currently unknown (AGRA 2000). Contamination of groundwater by agricultural and domestic waste is known for several areas of the eastern end of the Valley (Blair 2001), and poses a potential threat to human health as well as limiting legal use for irrigation. Assessment of the areas of groundwater recharge and capacity of the Annapolis Valley aquifer is a critical need that has not yet been met.

Climate Change and Adaptation

Although it is still proving difficult to forecast future conditions for the Atlantic Region as a consequence of global climate changes, there is strong belief that droughts will become commonplace. Climate change scenarios being developed by Environment Canada, will form the foundation of local initiatives to adapt agricultural practices and domestic uses to meet growing water shortages. The Atlantic Environmental Science Network (AESN) is a multi-institutional initiative of Environment Canada, aimed at linking regional university, industry, and government research capacity to address environmental issues, particularly those associated with climate change and watershed management.

Adapting water demand and use requires a major increase in knowledge about water sources, supply and replenishment rates. It also requires an unprecedented degree of cooperation between users, governments and residents, and a planning process that does much more to integrate demands and efficient use of water into a strategy for sustainable living. With devolution of responsibility from federal to provincial, and thence to municipal governments, a major challenge is placed on local authorities to develop effective strategies for protecting and using fresh water.

The capacity of local communities to meet this responsibility is essentially unknown. The capacity needed is of two kinds: a scientific capacity to assess water supply and quality, and the planning and decision-making capacity to allocate, reuse and protect water supplies. Because of past non-government initiatives to deal with environmental aspects of water quantity and quality, the Annapolis Valley has become part of a comparative study of capacity issues in watersheds in Canada, funded under the Canadian Water Network (CWN) (de Loë et al. 2002). The CWN is a Network of Centres of

Excellence developed to address the Environmental Implications of Clean Water; it involves researchers at more than 30 universities, together with numerous industries and government agencies.

A significant part of capacity-building is the presence of legislation that enables local authorities and local users to plan and manage water supplies and uses. The long-anticipated Nova Scotia Water Strategy, due to be released in October 2002, was originally designed to provide a locally-based, watershed-scale authority that would manage water issues. Intragovernmental conflicts, and the anxieties over liability issues in the post-Walkerton era, have both delayed and apparently diluted the strategy, especially by reducing the authority of local interests to manage their water supplies. What was intended to be a community-based strategy that would permit an integrated and flexible approach to water management in the Fundy Watershed, now threatens to continue the toothless, top-down approaches of the past. In the absence of significant capacity at the provincial level, and limited authority at local levels, the future of water management in the region remains as opaque as the title suggests. But one aspect of the future is clear:

"The value of water is known when the wells run dry."

Benjamin Franklin

References

AGRA Earth & Environmental Limited. 2000. Water Resources Needs of the Agricultural Industry in the Annapolis Valley, Nova Scotia. Final Report. 134 pp.

Blair, K. 2001. Temporal and Spatial Profiles of Groundwater Nitrate Concentration in Kings County, Nova Scotia. Unpublished MES Thesis, Dalhousie University, Halifax, Nova Scotia.

Brylinsky, M. and N. Pindham. 2001. Eastern Rivers Baseline Water Quality Survey. Unpublished manuscript. Acadia Centre for Estuarine Research, Wolfville, NS. 34 pp.

Daborn, G. R. and S. Hawboldt. 1994. Incorporating volunteers in support of monitoring and research on coastal zone problems. Pages 730–739. In: *Coastal Zone Canada '94: Cooperation in the Coastal Zone*. Volume 2. P. G. Wells, P. Ricketts, S. M. Heming, J. Dale and G. R. MacMichael (Eds.). Coastal Zone Canada Association, Dartmouth, NS.

Daborn, G. R. 1995. Bridging the gap between science and people. Pages 73–82. In: *Proceedings of the National Habitat Workshop, 1995*.

Daborn, G. R. 1996. Experiments in community involvement: volunteer-based monitoring programmes. In: *Proceedings, 15th Eastern Regional Organisation for Planning and Housing (EAROPH) World Planning Congress, Auckland, New Zealand*.

Daborn, G. R. and B. Dickie. 1997. The Whaingaroa (Raglan) Harbour Catchment Project. Pages 485–490. In: *Proceedings Pacific Coasts and Ports Conference, Christchurch, New Zealand*.

De Loë, R., R. Kreutzwiser and G. R. Daborn. 2002. *Building Local Capacity to Provide Clean Water*. Project No. P&Ga. Canadian Water Network.

Ellsworth, J. P., L. P. Hildebrand and A. E. Glover. 1999. Canada's Atlantic Coastal Action Program: A community-based approach to collective governance. Oceans and Coastal Management 36:121–142.

Gulf of Maine Council on the Marine Environment. 1991. *Annual Report 1990-91*. 15 pp.

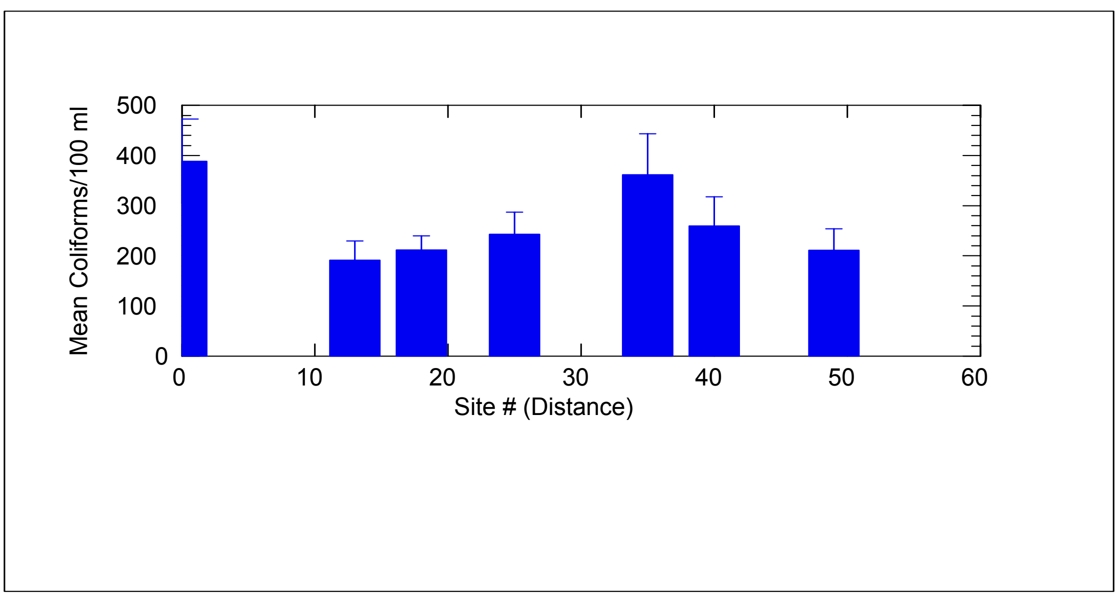
Lotze, H. and I. Milewski. 2002. *Two Hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy*. Conservation Council of New Brunswick. 188 pp.

Government of Canada, 1996. Bill C 26. An Act respecting the Oceans of Canada.

Table 1. Catchments draining into the Minas Basin

	Mean River Flow ($m^3.sec^{-1}$)
Annapolis River (at Lawrencetown)	23.8
Cornwallis River	8.58
Gaspereau & Black River	11.03
Pereaux, Habitant & Canard Rivers	2.99
Total	**46.40**

Figure 1. Mean fecal coliform concentrations of the Annapolis River, 1992–1998 (Brylinsky 2001) (Data for stations with at least six years of record; site # refers to the distance in km downstream from Aylesford, NS.)



EAST-FLOWING RIVERS BASELINE WATER QUALITY SURVEY

Michael Brylinsky[1] and N. Pindham[2]

[1] Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS.
mike.brylinsky@acadiau.ca
[2] Environmental Science Program, Acadia University, Wolfville, NS.

The recent series of unusually hot, dry summers in Nova Scotia has resulted in the growing use of many rivers and their tributaries for irrigation of agricultural crops. This is especially true within the Annapolis Valley where soils are relatively sandy and have limited capacity for retaining moisture over long periods. In the case of the Canard, Habitant and Pereaux Rivers, all of which are currently being used for crop irrigation, there have been no significant studies of water quality and no data exist that allow an assessment of the water quality of these Rivers. The objective of this study was to carry out a basic water quality survey that would provide information useful to resource managers concerned with the water quality of these three Rivers, not only with respect to crop irrigation, but also other activities such as livestock watering, fisheries, and recreational uses.

Each of the three Rivers was sampled at bi-weekly intervals between 16 May and 28 August 2001. The Habitant and Canard Rivers, each of which has a main stem of about 12 km, were sampled at six and five sites respectively. The Pereaux, which has a main stem less than 4 km in length, was sampled at three sites for most parameters, but was sampled at four sites for coliform numbers.

The water quality parameters measured were those typically used in general water quality assessments. These included: total suspended particulate matter (both inorganic and organic); water temperature; conductivity; total, calcium and magnesium hardness; alkalinity; pH; dissolved oxygen; percent dissolved oxygen saturation; total phosphorus; nitrate; chlorophyll *a*; and total and fecal coliform numbers.

In general, there was little difference among the Rivers in the mean level of total suspended particulate matter over the entire survey period. Values were low most of the time, seldom exceeding 10 mg/l. The generally low values observed, however, may be more a result of the lack of precipitation, and therefore surface run-off, during the survey period than evidence of the absence of sediment erosion.

There was considerable variation in temperature among the three Rivers. The mean water temperature at all stations for each River was 12.4, 15.8 and 17.7ºC for the Pereaux, Habitant and Canard respectively, and the maximum summer temperature recorded at each River was 13.8, 21.1 and 19.1ºC for the Pereaux, Habitant and Canard respectively. Water temperatures in the Pereaux River were surprisingly low and varied little, either spatially or seasonally. The Pereaux is a short river and appears to be largely spring fed. In addition, it appears to be relatively more shaded by streamside vegetation than the other two Rivers. Water temperatures in the Canard and Habitant showed more spatial variation with significant increases in temperature from headwater to downstream stations. Increases of 10-12ºC were typical for the Habitant. The Canard had increases in the range of 8-10ºC.

There is considerable variation in the mean levels of total hardness among the three Rivers. Total hardness for the Canard River is in the range of 50-60 mg/l, which is indicative of relatively soft water. The Pereaux River has the highest hardness values with a mean of about 170 mg/l, and the Habitant River is intermediate with a mean of about 150 mg/l. Calcium is the major salt in all of the Rivers.

Alkalinity is reasonably high in all of the Rivers indicating they all have substantial buffering capacity and the ability to offset the negative affects of acid precipitation. This is also reflected in the relatively high pH levels, which were always above the neutral value of 7.

Dissolved oxygen levels and percent saturation values were high at all sample stations in the Pereaux River, but varied considerably in the Canard and Habitant Rivers. The lowest values were observed in the upper part of the Canard, many of which were near and sometimes below the 50 percent saturation level. A few instances of low dissolved oxygen values were also observed in the Habitant, but these never fell below the 50 percent saturation level. In some cases dissolved oxygen levels in the Canard and Habitant Rivers were well above the 100 percent saturation level. This typically occurred in the lower portions of the Rivers and is probably a result of either heating of the water or production of oxygen by photosynthesis of aquatic plants.

The levels of phosphorus and nitrogen were high in all of the Rivers, but varied greatly among the three Rivers. The Canard River had very high phosphorus levels, but the lowest nitrate levels. The opposite was true for the Pereaux River where nitrate was much higher than phosphorus. In the Pereaux and Habitant Rivers, nitrate levels generally increased both downstream and over the study period. In the Canard River, nitrate levels varied little either spatially or temporally.

Total coliform bacteria numbers for all samples were always above the level that could be accurately counted (2,419/100 ml). The numbers of fecal coliform bacteria measured at each sample station ranged from a low of 5 to a high of greater than 2,400. The percentage of times fecal coliform numbers exceeded 100, the level permissible for irrigation of crops for human consumption, was 67, 52 and 58 for the Pereaux, Habitant and Canard Rivers respectively.

In summary, although there was considerable variation among the rivers in many of the parameters monitored, all of the rivers exhibited evidence of impaired water quality.

TIDAL RESTRICTIONS: OPPORTUNITIES FOR SALT MARSH AND TIDAL RIVER RESTORATION IN NOVA SCOTIA

Tony M. Bowron

Ecology Action Centre, Halifax, NS. tbowron@dal.ca

The reclamation of large areas of coastal salt marsh from the sea and conversion of it to agricultural land through the construction of dykes equipped with aboiteau, is a process that has important cultural and historical significance throughout the Bay of Fundy. It is a practice that has resulted in the trading of marine productivity for terrestrial productivity and contributed substantially to the loss of upwards of 85% of salt marsh habitat in the upper Bay. The more recent construction of tidal crossings, such as causeways and roadways with poorly sized and improperly placed culverts and bridges, has also contributed significantly to the amount of tidal river and salt marsh habitat lost around the Bay. This is something that is both preventable and repairable.

In this project, carried out by the Ecology Action Centre with funding from the North American Fund for Environmental Co-operation, a focus was placed on the identification of the adverse effects that tidal crossings such as bridges, culverts and aboiteaux have had on salt marshes and river systems along Highway 215 in Hants County, Nova Scotia. The methodology used for the project was adapted from the Parker River Clean Water Association's *Tidal Crossing Handbook* (Purinton and Mountain 1998) with adjustments made to compensate for the large tides in the Bay of Fundy.

Along Highway 215, twenty-one crossings were identified as influencing tide flow, four of which were selected out for further study. Through collaboration with a number of groups, organizations and government departments, notably the Nova Scotia Department of Transportation and Public Works, one of these crossings has been selected as the site for a pilot restoration project. Pre-restoration habitat monitoring and baseline data collection are currently being carried out at this site. The next phase of the project will include preparing a report detailing the results of the summer's fieldwork and talking further with property owners, the local community, and our other project partners about the future of the project.

During the summer of 2002, through a partnership between the Ecology Action Centre and the Municipality of Colchester, two students were hired to conduct an inventory of tidal crossings along the coast of Colchester County. To summarize, 52 crossings were assessed to determine if a restriction in tidal flow due to the crossing was present. Of these 52 sites, 11 were determined to be complete restrictions, 13 were considered partial restrictions, 23 were considered not to be restrictive, and the remaining 5 were not restrictive due to downstream obstructions such as dykes. The final results of this audit will be detailed in a report titled "Marshes Tides & Crossings: Colchester County Tidal Barriers Audit 2002" which will be available in the fall of 2002.

Looking forward, it is hoped that 2003 will see further on-the-ground work at the restoration site, a reference site (further monitoring and actual culvert replacement) and around the province (expansion of the tidal barriers audit into one or more counties). For more information contact Tony M. Bowron at the Ecology Action Centre 1568 Argyle St. Suite 31 Halifax NS B3J 2B3 902.429.2202(ph); 902.422.6410(fax); tbowron@dal.ca.

Reference

Purinton, T. A. and D. C. Mountain. 1998. *Tidal Crossing Handbook: A Volunteer Guide to Assessing Tidal Restrictions*. Parker River Clean Water Association, Byfield, MA.

A STEWARDSHIP APPROACH TO PROTECT SHOREBIRDS AND THEIR HABITAT IN THE MINAS BASIN

Donald Sam

Nova Scotia Nature Trust/Fundy Shorebird Project (NS), Halifax, NS. nature@nsnt.ca

Introduction

I am here to speak about something that is a bit of a throwback in time. And like my mode of presentation—which includes some good old Kodachrome slides—its basis is time-tested and uncomplicated. It is called stewardship, it has been around for hundreds of years and recently it has been making a resurgence on conservation's top ten charts.

In the case of Nova Scotia, private land stewardship is a must. Over 70% of the province is held by small private and corporate owners, and many of these lands contain significant natural areas.

I wish to set the stage by giving you some background ecology on the fall migration of shorebirds. I will then describe the social and physical context of one of our working sites. Finally, I will tell you what we are doing to foster a stewardship ethic within our target areas.

The Fall Migration

A very quick primer on the migration of shorebirds. Each year, from June through September, millions of shorebirds migrate from Arctic nesting areas to wintering areas in South America. Semipalmated Sandpipers and Semipalmated Plovers comprise the bulk of the migration. The Bay of Fundy is a major stopover for migrating shorebirds during the fall. It is the last major stopover for shorebirds before they cross the Atlantic Ocean to reach the northern coast of South America. While in the Bay of Fundy, shorebirds replenish their energy stores—body fat—and rest up for their pending marathon flight.

But if you had to pick one reason why shorebirds elect to stopover in the Bay of Fundy, it would have to be *Corophium volutator*, the mud shrimp. This tiny shrimp (3–5 mm) by and large fuels the final leg of the shorebird migration. Perhaps by chance, but likely by design, shorebirds pass through this area just about when *Corophium* are most abundant and most available as forage. While in the Bay of Fundy, shorebirds dedicate their time to feeding on the mudflats whenever the tide allows, night or day, and conserving energy by gathering in communal resting areas, called roosts, on shore when the tide is high.

The availability of safe, undisturbed shoreline areas for shorebirds to roost is important to the success of this migration. Remember, migratory shorebirds need a full tank of fuel to complete their migration; when not feeding, they cannot afford to waste energy. They need resting areas.

The Fundy Shorebird Project (Nova Scotia)

The Fundy Shorebird Project is a joint effort of nine organizations (Eastern Habitat Joint Venture, Wildlife Habitat Canada, US Fish and Wildlife Service, Canadian Wildlife Service, Ducks Unlimited Canada, Nature Conservancy of Canada, Nova Scotia Nature Trust, Nova Scotia Department of Natural Resources, and New Brunswick Department of Natural Resources and Energy) working to conserve migratory shorebirds and their habitat in the upper Bay of Fundy in both New Brunswick and Nova Scotia. I will describe the project's efforts in Nova Scotia, and more particularly, the work in the Minas Basin. Our stewardship efforts attempt to preserve high quality roosting habitat for shorebirds and, to a lesser degree, foraging habitat. The two sites in Nova Scotia we currently are targeting are Blue Beach, located north of Hantsport, and Evangeline Beach which is near Grand Pre. Both areas support major roosts, at times exceeding 300,000 shorebirds a day, during the peak of migration.

Evangeline Beach

I am going to discuss our activities at Evangeline Beach to illustrate how we are protecting shorebird habitat through private land stewardship. The landscape of Evangeline Beach is a mixture of intensive summer residential and agricultural farmland, including dykelands. In addition to these land uses, there are several commercial enterprises, including a motel, camp ground and canteen/community hall that draw summer visitors to the area. As you might imagine, during the summer months when shorebirds are moving through the area, Evangeline Beach experiences its highest level of human activity for the year. And often this poses serious challenges to the well-being of migratory shorebirds.

As I mentioned earlier, shorebirds require safe, undisturbed areas to rest when their feeding flats are inaccessible. Ideally, roosting sites are close to feeding areas. Present levels of human activity along the coast—residential, recreational, and commercial—make it difficult for shorebirds to find suitable roosting areas.

The pattern of land ownership along the coast of Evangeline Beach shows that much of the coastline is divided into many small parcels. Today, there are a handful of coastal properties along Evangeline Beach that are large enough to merit protection via outright purchase. The Nature Conservancy of Canada is working on acquiring suitable properties in the area. However, about half of the waterfront area is currently occupied by residential lots, most of which are small lots. Habitat protection through fee simple purchase would be expensive, but more importantly, it would be ineffective in securing habitat, unless many contiguous parcels could be acquired—this is not practical at all.

A Stewardship Approach

The alternative? Private land stewardship. We are taking advantage of the fact that Evangeline Beach is a closely-knit community to foster a community-wide stewardship ethic.

How are we doing this? Our approach is multi-pronged and based on the approach use by the Nova Scotia Nature Trust in its other programs. We arrange to meet individually with landowners, usually in their home, to discuss shorebird conservation. Face-to-face meetings are essential. We want to change human activity on the mudflats as well as along the shoreline. Therefore, we meet with owners of land along the coast, as well as owners of inland properties in the community, since local residents—whether they live on the actual coast or not—are likely to be long-term users of the beach.

During our meeting, we discuss much of the background information that I have shared with you today. More importantly, we advise local residents of things they can do (or not do) to reduce disturbance to shorebirds. The meeting is as much about building trust and co-operation as it is about exchanging technical information—we are trying to initiate a working relationship.

We strive to reach a land use agreement with landowners and enlist them as 'Shorebird Stewards.' This is an informal agreement based on good faith as opposed to legal enforcement. (The terms of our Shorebird Stewardship Agreement appear in Appendix 1.) To 'formalize' a stewardship agreement with a participating landowner, we present them with a Shorebird Stewardship Award. The certificate recognizes their commitment to shorebird conservation, and outlines the stewardship practices they have agreed to observe and the rationale for doing so. We purposely included the stewardship information on the certificate to ensure that the suggested practices remained clear and visible at all times.

We also produced a distinctive garden flag to be displayed on the property of participating landowners. The flag publicly acknowledges the involvement of Shorebird Stewards within their community. We also hope that the flags generate broad community awareness for the program, and perhaps even become ethical status symbols!

Finally, we are further promoting our stewardship initiatives within the greater community by sponsoring a variety of public walks and talks. We have forged links with many groups, including local naturalists, community members, Grand Pre National Park, and Acadia University, to make these events happen. And the list grows.

Ultimately, at the end of the day, we want people and shorebirds to share resources and be able to co-exist side by side.

Lessons Learned to Date

- **Be patient**. The successful negotiation of stewardship agreements is very much built on mutual trust; building trust may take quite some time.
- **Follow-up is important.** You must remain in contact with people you have contacted in the past, e.g., annual newsletters, phone calls, etc.
- **Do not eat the food offered.** You might like it; you might not. In the interest of not offending, politely say no thank you, 'you just has a big meal before you came'.

Appendix 1. Fundy Shorebird Project (NS)—Terms of Stewardship Agreement

Stewardship Practices for the Migration Period

At high tide, shorebirds seek suitable sections of shoreline to rest (roost). Land-based disturbances can interfere with the ability of shorebirds to roost properly during their migratory period (July through October, peaking in August). By observing the following land use practices when migratory shorebirds are present in the Minas Basin, one can minimize disturbance to roosting birds.

- Schedule shoreline activities for months outside of the migration period whenever possible.
- Complete shoreline improvements and maintenance activities, such as lawn cutting and construction, during the periods of low tide, when feeding shorebirds tend to be in offshore mudflats.
- At sites that birds are known to frequent, avoid the beach area during periods of high tide, the time when shorebirds are most likely to be present.
- Direct recreational activities, such as hiking, swimming and boating, away from areas known to be used by shorebirds.
- Leash (or restrain) dogs and other pets at all times while they are on or near the beachfront if shorebirds are present.
- Notify visitors and other beach users of the presence of shorebirds and encourage them to observe appropriate practices.

Stewardship Practices for Year Round

All plans for beach and near shore development should consider any potential long-term effects to the habitat of shorebirds and other wildlife. The following practices support shorebird conservation throughout the year.

- Maintain a natural section of shrubs, unmowed grass and other vegetation by the shoreline.
- Consult the Nature Trust before adding reinforcing structures/rock along the shoreline.
- Consult the Nature Trust when planning construction of boat launches, walkways, or other permanent beachfront structures.

All Shorebird Stewards shall alert the Nature Trust if they note persistent activities/uses that appear to disrupt shorebirds or their habitat.

Shorebird Stewards who own property along the upper Bay of Fundy shall notify the Nature Trust when they transfer ownership of their property so that a representative can meet with new owners to discuss shorebird conservation.

THE REFERENCE CONDITION APPROACH: ON TRIAL IN THE MINAS BASIN

Maxine C. Westhead[1] and Trefor B. Reynoldson[2]

[1] Oceans and Coastal Management Division, Bedford Institute of Oceanography, Dartmouth, NS. westheadm@mar.dfo-mpo.gc.ca
[2] Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS. trefor.reynoldson@acadiau.ca

Context: Marine Environmental Quality and the Oceans Act

The Oceans Act was proclaimed in January of 1997, and provides a legislative framework for the management of Canada's oceans and marine resources. Part II calls for integrated management plans, the development of a national system of marine protected areas, and the establishment of marine environmental quality guidelines, objectives and criteria. In this context, three interconnected Oceans Act programs are presently being undertaken by the Department of Fisheries and Oceans (DFO): Integrated Management (IM), Marine Protected Areas (MPA), and Marine Environmental Quality (MEQ).

What *is* Marine Environmental Quality?

The definition of Marine Environmental Quality (also known as Marine Ecosystem Health) has been a subject of debate for many years. For the purposes of the MEQ Program, DFO has adopted the definition from Skjoldal (1999) stating that Marine Environmental Quality:

> ... is an overall expression of the structure and function of the marine ecosystem taking into account the biological community and natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities.

Figure 1 conceptualizes the overall goals of the DFO Marine Environment Quality Program.

Components of Marine Environmental Quality

MEQ can be broken down into progressively smaller, nested components (Figure 2). Dale and Beyeler (2001) suggest that ecological indicators should be:

1. easily measured
2. sensitive to stresses
3. predictably responsive to stress

To paint a true picture of ecosystem health over time, our selection of indicators should meet Dale and Beyeler's criteria, yet still be manageable—in terms of time, money, and ease of measurement. The indicators must also cover a wide range of ecosystem components, from broad ecosystem measurements to specific site measurements.

DFO is currently developing a broad MEQ framework for the entire Minas Basin, which will include other species and other factors such as contaminants, sediment dynamics, nutrient inputs, etc. This polychaete study is only a small portion of that framework.

Overall Goal of the Study

This study will test the use of the intertidal polychaete community as a Marine Environmental Quality indicator in the Minas Basin mudflats. Specifically, polychaete community structure in mudflats that have been harvested for baitworms will be compared to unharvested areas. Habitat attributes will also be evaluated to determine which have the largest influence on community structure.

Study Area—The Minas Basin Intertidal Mudflats

Low tide exposes approximately 400 km^2 of intertidal area (Thomas 1977), which represents approximately 30–40% of the Minas Basin (Yeo 1977). The intertidal benthic community is mainly comprised of a few dominant species, mostly bivalves, deposit feeding crustaceans and burrowing polychaetes (Percy et al. 1997).

Why Worms?

Polychaetes are soft-bodied bristle worms that cover a wide size range, as both free-moving burrowers and sedentary tube dwellers, and exhibit a wide range of feeding behaviour. Polychaetes are prey for bass, skates, dogfish, tomcod, eel, rockling, and hake (Yeo 1977), making them an intermediate link between primary production and higher trophic levels.

There are four main advantages of using polychaetes for marine environmental monitoring:

1. They are easy to sample and typically abundant
2. They include both sedentary and mobile species
3. Their life histories cover a variety of trophic levels (Pocklington and Wells 1992; Mallin et al. 1997)
4. They are relatively long-lived (years rather than months) (Brown 1993)

Polychaetes have already proven to be useful indicators of chemical pollution (Pocklington and Wells 1992). This study will be exploring another use of polychaetes—community structure as an indicator of sediment disturbance. It will also look at what habitat attributes play the biggest role in determining community structure.

The Reference Condition Approach

The Reference Condition Approach is a method based on establishing the natural diversity in normal, or reference, conditions of community assemblages in an area and linking this to habitat attributes (grain size, slope, salinity, etc.). Models are then developed from these reference databases that allow us to predict the expected community assemblage at any specific site based on its habitat attributes.

This approach has been used successfully in freshwater streams and lakes (see Reynoldson et al. 1997 and Reynoldson et al. 2001), but has yet to be applied in a marine environment. This study will be the first test of this approach in a coastal marine environment. This is accomplished by sampling a wide range of environmental variability in the Minas Basin; 40–50 sites that are 'undisturbed' or 'least impacted' areas will be chosen to be reference sites. Test sites, or areas that have been harvested for baitworms, will be compared to the reference sites to determine the degree of disturbance, if any exists.

Methods

Overlays of environmental variables in the Minas Basin will be mapped, and 40–50 reference sampling sites will be identified with the goal of covering as much environmental variability as possible (e.g., sampling high and low intertidal areas, sandy and muddy areas, etc.). Areas harvested for baitworms, and areas with other types of disturbance, will serve as test sites. The test sites are then compared to the reference sites, and degree of impairment (if any) is determined.

As a management tool, this approach offers potential to be used for building predictive models, thereby allowing us to set marine environmental quality guidelines for the area.

References

Dale, V. H. and Beyeler, S. C. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1: 3–10.

Mallin, M. A., L. B. Cahoon, M. R. McIver, D. C. Parsons and G. C. Shank. 1997. *Nutrient Limitation and Eutrophication Potential in the Cape Fear and New River Estuaries*. Report No. 313. Water Resources Research Institute, University of North Carolina, Raleigh, NC.

Percy, J. A., P. G. Wells and A. J. Evans (Eds). 1997. *Bay of Fundy Issues: A Scientific Overview. Workshop Proceedings, Wolfville, NS, January 29 to February 1, 1996*. Environment Canada - Atlantic Region Occasional Report #8, Environment Canada, Sackville, NB. 191 pp.

Pocklington, P. and P. G. Wells. 1992. Polychaetes: Key taxa for marine environmental quality monitoring. Marine Pollution Bulletin 24: 593–598.

Rapport, D., R. Costanza, P. R. Epstein, C. Gaudet and R. Levins (Eds). 1998. *Ecosystem Health*. Blackwell Science, Inc. Malden, MA.

Reynoldson, T. B., R. H. Norris, V. H. Resh, K. E. Day and D. M. Rosenberg. 1997. The reference condition: A comparison of multimetric and multivariate approaches to assess water-quality impairment using benthic macroinvertebrates. Journal of the North American Benthological Society 16: 833–852.

Reynoldson, T. B., D. M. Rosenberg and V. H. Resh. 2001. Comparison of models predicting invertebrate assemblages for biomonitoring in the Fraser River catchment, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 58: 1395–1410.

Skjoldal, H. R. 1999. Overview report on ecological quality (EcoQ) and ecological quality objectives (EcoQOs). Havforskningsinstituttet Rapport. Bergen, Norway.

Thomas, M. L. H. 1977. Intertidal resources of the Bay of Fundy. Pages 148–159. In: *Fundy Tidal Power and the Environment, Proceedings of a Workshop on the Environmental Implications of Fundy Tidal Power, held at Wolfville, Nova Scotia, November 4–5, 1976*. G. Daborn (Ed.). Acadia University Institute Series No. 28. Acadia University Institute, Wolfville, NS.

Yeo, R. K. 1977. Animal-Sediment Relationships and the Ecology of the Intertidal Mudflat Environment. Minas Basin, Bay of Fundy, Canada. M.Sc. Thesis, McMaster University. 396 pp.

Figure 1. A conceptual framework for marine environmental quality

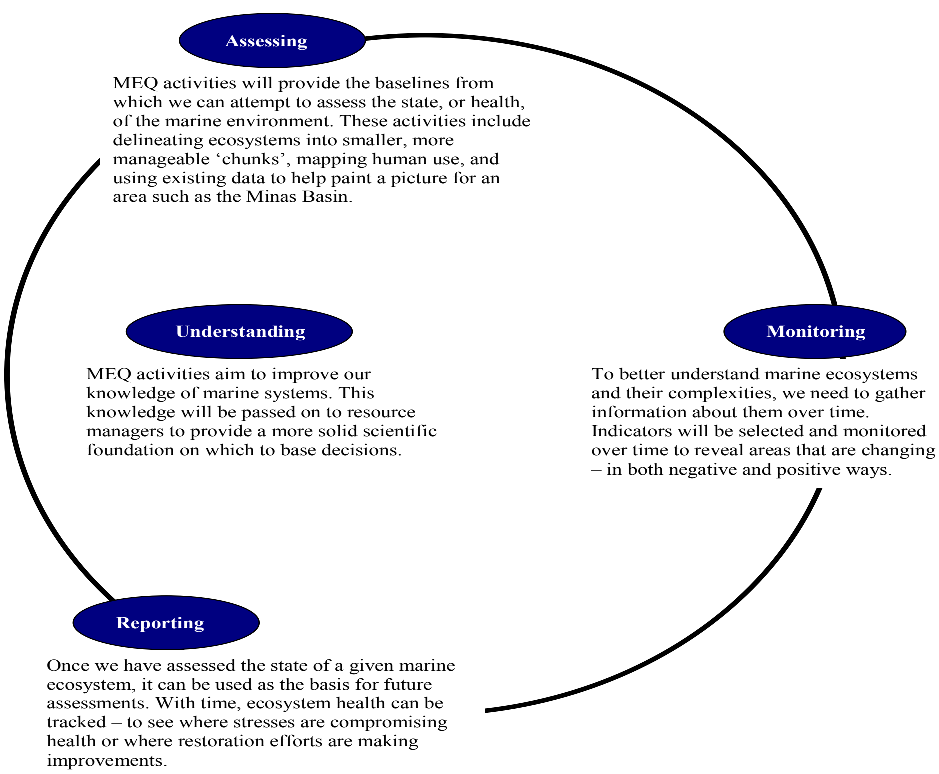
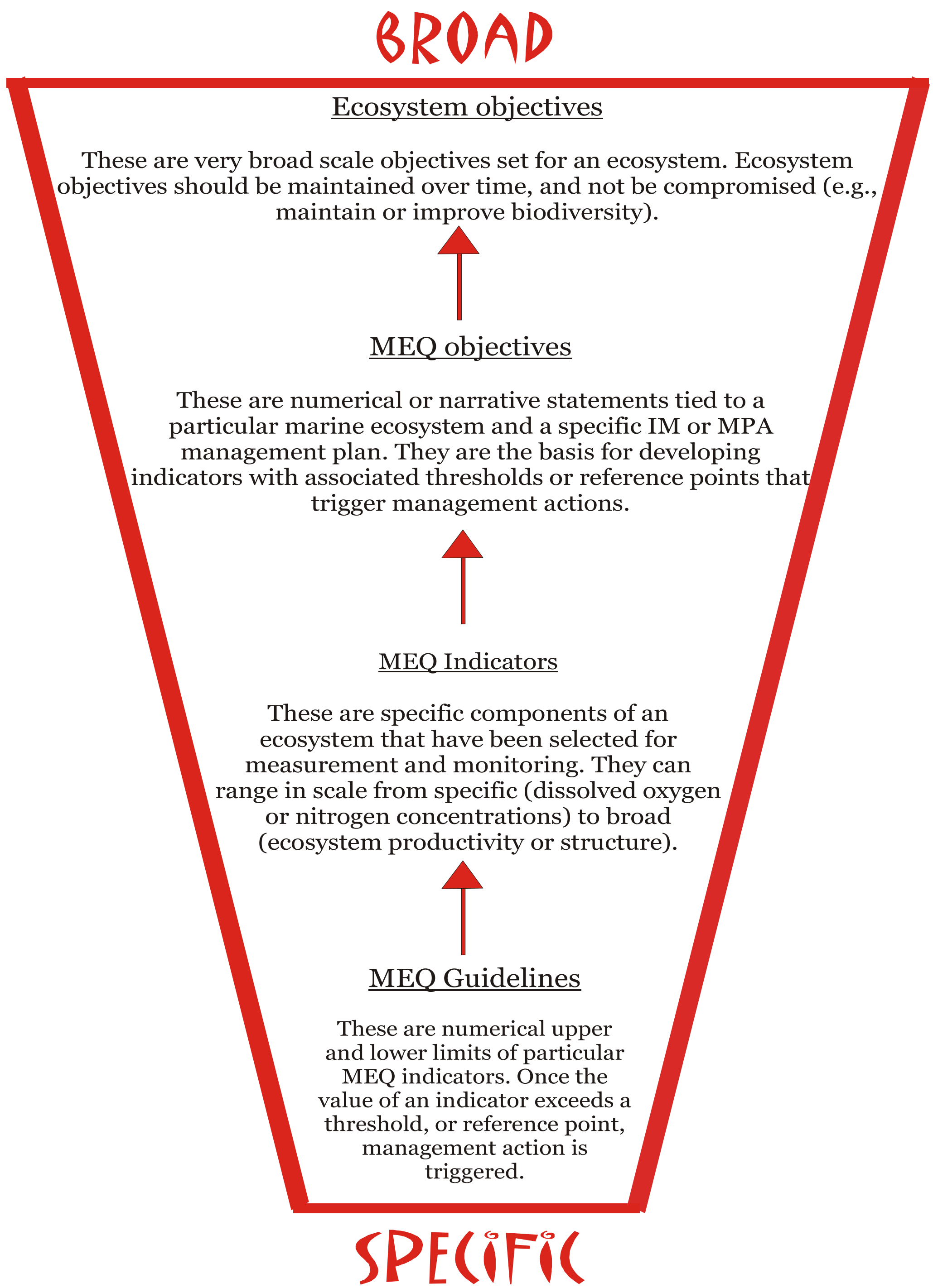


Figure 2. The 'nested components' of marine environmental quality



PANEL DISCUSSION CHAIR

Chair: Graham Daborn
Rapporteur: Pat Hinch
Panel Members: Maxine Westhead, Robin Musselman, Pat Hinch, Barry Jones, Tony Bowron, Karen Beazley

Question 1. *Why is there a Minas Basin Working Group and what are its objectives and roles?*

Graham Daborn – The Minas Basin Project is an experiment in integrated coastal management. We have spoken to coastal communities and to government agencies concerning the use of integrated management systems. We do not have accumulated experience on this issue, but we know that it is beyond the scope of individual disciplines to deal with. The Minas Basin Project is trying to apply integrated coastal management to a significant piece of the maritime region, while at the same time learning how to deal with the issues and finding the best ways to approach communities. The community forums of the Minas Basin Project have had a similar format to that used for discussions of the Biosphere Reserve proposal. However, our approach has been to try to develop the forum agenda as we went out to each of the communities. In contrast, the Biosphere Reserve meetings presented a predetermined proposal for evaluation and this typically created an immediate conflict situation. In most instances you really don't know the dynamics of groups of people and how they will respond to any particular issue. The Minas Basin Project is thus very much an ongoing experiment in how to approach integrated management.

When you initiate such activities you create an expectation that something will happen. However, there are some fundamental things we don't know about some of the issues. In addition, the Working Group has no power to make certain things happen. What happens after this workshop? Don't we at some point need the legislative authority to take action, and where does this fit into the integrated management process?

Barry Jones – In 1997, the integrated management concept was put into the Oceans Act, and since that time the Department of Fisheries and Oceans has been struggling with finding out how to make this concept a reality. The Minas Basin Project came along at a time when DFO was looking for an appropriate mechanism. It looked like a viable marriage. Unfortunately, in the aftermath of the events of September 11, 2001, funding for many newer initiatives was reduced. There must be support from the community if the process is to be of value to the community. Such local support will undoubtedly come because a few key people are now motivated enough to generate the interest in the wider community. Information about this developing initiative will be passed on to the appropriate decision-makers. Thus, now is the time for a groundswell of support by communities to make the concept happen. Integrated management is already in the legislation. What we need now is community activation to make it a reality.

Graham Daborn – The Minas Basin Project does not have the capacity to do new research or gather more information. Pitifully little is known about the dynamics of the Bay of Fundy. If you look at the people involved in this project, you will see that they are associated with a wide variety of groups and disciplines. The ongoing activities of these different organisations could help us to fill in some of the enormous data gaps that exist. We need to scavenge support and information from wherever we can find it. The local forums are also an opportunity for us to garner more information from coastal communities to bring to the table.

We need to do something concrete now. A history of the previous attempts at implementing integrated coastal management shows that there is usually a window of opportunity when effective action can best be initiated.

Does BoFEP have a sense of the scope of this window of opportunity and time over which action should be initiated?

Graham Daborn – The time is now; five years ago would have been better! However, we've been struggling to obtain funding. This hasn't been successful yet, in spite of the fact that the project fits the criteria for the Gulf of Maine Council Action Plan. We are also constrained at the political level in seeking available funding. Prior to September 11 there were a number of opportunities for funding, but since then many of these have dried up. We also have a window of opportunity for involvement with the communities. I've been through a number of similar information gathering exercises before, where nothing much happens subsequently. We can't afford to allow things to languish for any extended length of time. Our present window of opportunity will close if we don't take action very soon.

An expectation is building within the various communities already visited. What will happen after we hold the fourth community forum?

Graham Daborn – The plan is to go back to the people in the communities to identify leaders and other individuals who are interested in participating in action groups to work on some of the priority issues. We will need to ask these action groups to define specifically what they want to do and how they are going to do it.

One of the good things about the ACAP initiative is that many successful projects have been implemented. For instance, ACAP has collected the longest available data set on water quality in the Annapolis River. ACAP has been able to do this and other such projects largely because government has funded it. Where is the government support in relation to the Minas Basin project?

To be fair to the government, ACAP would not now exist if Environment Canada had not been willing to take a gamble. Environment Canada did this in 1989–90, largely as a result of one individual in the Department taking the initiative. Success came from picking sites where there was an issue already identified and on the table and then making a commitment for funding a full-time co-ordinator. Within five years the designated ACAP sites were expected to develop a comprehensive management plan for their watershed. However, the Clean Annapolis River Project Society (CARP) wanted to start some concrete projects. Thus there was some delay before CARP got a valid, comprehensive management plan in place. But there was plenty of initiative from the community to begin specific activities. Our experience has been that once you start such a process it will usually take off on its own.

That's part of the struggle involved in the whole process. We need to determine what communities can and will do. We are largely counting on communities to do much of the work themselves. Are they going to do it? Are they going to take up the challenge?

Barry Jones – There are many people who are not sure about their relationship to the Minas Basin Working Group. The onus is on the Working Group to start the process and lead the charge. This isn't always clear within the communities.

Graham Daborn – We got a bit off-track at the Parrsboro forum because both a watershed management plan and a Biosphere Reserve proposal were put on the table at the same time. It is difficult enough for us to understand what is needed, let alone for the community to do so. We need to identify what resources the community groups need. Many available resources never see the light of day. The state of the environment in the area is often not well known. One of our important roles as a Working Group is to identify what information presently exists and what capacity is available in the scientific community and government to fill in the blanks. If we look at the example of the Ecology Action Centre, we can see that it does not take a lot of funding to gather and disperse information. A significant amount of money is being spent for environmental assessment relating to the Highway 101 twinning and on the proposed widening of the Windsor Causeway. We may be able to tap into some of this funding.

Has there been any discussion about standardising sampling protocols and identifying specific study sites, since these are essential keys to effective long-term monitoring programs?

That's a very good idea, although the Minas Basin Working Group is presently focussed on the community involvement angle, not so much on the science. The Working Group recognizes a priority for implementing changes and is working in small steps to make such changes happen.

The Saltmarsh Working Group is also talking about establishing sampling standards and the development of protocols for collecting comparable ecological data and other information.

This raises an interesting question about who makes up the "community". What about establishing links between the Working Group efforts and students who might potentially be involved in the research. Can the Working Group identify specific areas where we need more information or data? Many others, such as students, could contribute their expertise to the process. Is the community really composed of only farmers and fishermen? They are only a part of the community. There are also researchers, scientists and students. I get tired of being discounted as a community member simply because I am from a university.

I also wonder if, from the standpoint of community forums, we are not getting too caught up in discussing the concept of integrated coastal management. There are communities that already know what they want to do and how to put it into effect. The Minas Basin Working Group, as an integrated management group, should be the one to gather the necessary information and help the communities out with their proposed activities. The Working Group should not worry about having a plan that is integrated from the start but rather let people work on their own individual plans. Eventually, although they are not initially integrated, many similar things will be going on which will further stimulate the communities initiatives. We really need to get on with the activities.

That is a good point. Clearly the issues can, and should, be worked on from many directions. For example, in Summerville one group could be monitoring the bloodworm harvest while other groups could work to stop clearcutting or herbicide spraying. Yet others could work on promoting energy conservation or wise resource use to ensure that people are using the land and water in a sustainable fashion. Another question relates to the sources of the data that is needed, and who should we be talking to in government about this?

In BoFEP and the Minas Basin Working Group we have discussed the use of the concept of "integrated management" for similar reasons. Our intent was to try to work from the top down as well as from the bottom up, feeling that there would be nested levels of integration involved. What we have been suggesting all along is the kind of approach that we are now moving toward.

Another important issue is effective communication. We are not asking communities to develop management plans but to do what they can do to move forward on some of the more important issues. We are asking them: How would you like to deal with the issues and how can we help you to bring people together and encourage them to work together?

This was where Environment Canada made its first mistake. It decided to give funds to the ACAP sites but then wanted something tangible to come back fairly soon. This is where the concept of developing comprehensive management plans came from. The communities were not initially interested in preparing five-year management plans, but only later recognized the value of strategic plans for the identification and prioritisation of issues and for developing work plans. What was important about the ACAP process was that communities were eventually allowed to move forward with their own activities. Projects were never fully developed into a comprehensive action plan until the community identified the need for one.

Communities really do not know where they stand. They need a clear mandate and adequate funding for community initiatives.

Question 2. *Do we know enough about the dynamics of Minas Basin to develop a management strategy? What will be included in such a management strategy?*

No, we do not know enough about the dynamics but yes, we can develop a management strategy, not because we know everything but because we need one. We should start with something simple and then move forward. What the communities told us was that they wanted to see a state of the environment (SOE) report. They wanted to know if a SOE report could be a product of the Minas Basin Working Group that might help identify any information gaps by bringing together all the available information from governments, communities and other sources. Development of a comprehensive management strategy and an economic strategy are considered more distant possibilities. To start developing a SOE report merely requires the collection of information from various sources and communicating with the public to make people aware of the initiative. You do not need to have a comprehensive management plan to produce a SOE report.

At the Wolfville forum we were struck by the scale and diversity of the geographic area involved. At some point it will be useful to identify sub-watersheds. What may be an issue in one location may not be in another nearby area.

We need to focus on the different components involved in the process. Throwing community concerns together with scientific issues is not necessarily appropriate or useful. We need to subdivide the process to have one group focussing on the scientific aspects and another on the community issues; perhaps having a session on science and another on community issues. We are trying to integrate everything, and we simply cannot. None of us is capable of dealing with all these different aspects. This is a huge issue. Everyone is trying to deal with everything. We are trying to sensitize people in the communities. We are aware of the importance of integration, but to be a good scientist you really need to focus on science. If you are focussing on community issues then you cannot properly focus on science. The working group is lacking a clear focus. It needs to focus on the different components separately.

About 10-15% of scientists are now working in association with communities and such local involvement is extremely important. The strength of the Minas Basin Working Group is that it is trying to perform the integration function. There is a great need for a multidisciplinary approach that brings everyone together. You cannot keep all the different aspects separate.

We are losing out on the science. We have new people looking at many of the same old issues from twenty years ago. We need to field many balls at once. We need to design an approach whereby individuals can focus primarily on their particular area of expertise. We also need to identify knowledge gaps.

Question 3. *How can community members be motivated to get involved and contribute needed resources?*

In-kind support from communities is already happening. We have had more people coming forward during the community forums to ask to be part of the Working Group. Others have expressed an interest in being leaders in their communities and becoming more involved in BoFEP.

Question 4. *What are the present and future issues facing the Minas Basin watershed?*

Issues of importance to the communities have already been identified in the community forums. What are the science questions that people here feel have not been addressed or need to be addressed? I would suggest that you line up your scientists to tackle the important questions. You do not have a hope of taking out the Windsor causeway because you do not have the science pertaining to its environmental impacts. There may be as much biological production resulting from the presence of the causeway as was lost by its construction. You need to generate the necessary science data pertaining to this issue. It is important to ensure you have scientific understanding and to make sure you are fully prepared for the question, especially when you know that it is coming fairly soon.

The causeway has moved the head of the tide 20 km downstream. In time, productivity will probably build up again. We need to have science data that will stand up in a court of law. We need to know the cause of any damage and prove that such damage has in fact occurred. There is no retroactivity in the Fisheries Act. There is another causeway being proposed across the Avon River, or perhaps just an expansion of the existing one. The basic question is whether we want to have the existing one taken out or not.

Question 5. *How will the Minas Basin Working Group respond to other community or environmental groups with particular issues?*

One way is through more community forums. For those groups who participated in the forums there was an opportunity for dialogue and for initiating actions.

The Minas Basin Working Group has already interacted with some fisheries groups. A group came forward with a fisheries management issue. The Working Group then raised the issue with the whole BoFEP group and proposed that another working group, comparable to the Minas Basin Working Group, be set up to deal specifically with fisheries issues. This raised the profile of the issue enough to move it forward. A proposal for resolving the issue is now being considered by DFO. The Integrated Fisheries Management Working Group is now working with the fishing community to determine how they can work together to identify a specific project and how they can each contribute to it.

Some members of the Minas Basin Working Group are also on other BoFEP Working Groups. Thus some of the needed communication and integration structures may already be in place.

Question 6. *How could the government respond, going from where we are now, to identify projects to address specific issues?*

By working with Community Action Groups on issues related to the mandates of their departments and perhaps also through other activities such as the Salmon River project and similar initiatives.

Question 7. *Are there any other comments or observations?*

Scientists need to know about community issues and the impacts of human activities on ecosystems. It is important not to be 100% science-focussed because you are then isolated from the issues. We need to understand what issues are influencing science projects. We need to know which land-based activities are having an impact on marine environmental quality and also be aware of activities affecting such things as cold water coral “forests”. We need to be relating to almost everything. It is important that we all have an opportunity to speak on any issue. You really need to bring many diverse views and interests together to be successful.

Education and awareness were important issues identified in the community forums.

It is important that we recognize where science fits into the big picture. We need to ask why we are doing this and how does it fit in? Maybe it is time to take the specific issue of the Windsor Causeway to a forum and to figure out what really needs to be studied. The Causeway is going to be constructed after 2005, so we have time to focus, obtain scientific information and leverage the necessary funding. We are attempting to pool resources and co-ordinate them one piece at a time. We need to pull together all the available information into something more comprehensive.

There is a window with respect to the Windsor Causeway. We need to summarize the research information on mudflats and look at what we have lost in terms of river and estuarine productivity and what we have gained in salt marsh productivity. We need to allow for fish passage, perhaps by replacing the causeway with a bridge.

Is it appropriate to consider a Working Group focussing on the Windsor Causeway? Yes, maybe this is something that BoFEP could consider. If BoFEP does not, then perhaps the local community might want to address this issue. I would suggest that BoFEP set up a Working Group to look at the entire issue, with the purpose of eventually providing sufficient data to make an informed decision.

Session Eight

ECOTOURISM: OPPORTUNITIES AND IMPACTS

Chair: Tom Young,
Bay of Fundy Product Club, Parrsboro, Nova Scotia

GAINING AN EVEN KEEL IN CANADA'S COASTAL ZONE: TOWARDS SUSTAINABLE TOURISM DEVELOPMENT

Peter W. Williams

Centre for Tourism Policy and Research, Simon Fraser University, Burnaby, BC.
peter.williams@sfu.ca

Introduction

Commercial fishing has been an important resource-based industry along Canada's coasts throughout its history. However, over a series of decades, a combination of short-sighted resource exploitation practices, unfettered environmental degradation, as well as ill-conceived government policy and management decisions have led to the demise of many long-standing commercial fishing operations along the nation's shorelines. This has created a growing, and in some cases urgent need, for alternate revenue sources for many fishing towns, villages and hamlets. One needs to look no further than the tourism industry for a set of development options that offer the potential of combining the resources of coastal zones with other localized cultural and heritage assets to create sustainable coastal tourism communities and businesses. This paper discusses some of the key planning principles and challenges which must be addressed for these communities to make the transition from being resource-dependent communities to becoming more multi-faceted resource and service centres.

Coastal Tourism Development

Government and industry travel statistics are generally not compiled in a manner which documents the nature of coastal zone tourism's magnitude and management components. Yet it is clear that coastal and marine areas are the focal point for a significant portion of tourism development and activity around the globe. As well, the natural attributes of the coastal zone (terrestrial and marine) are frequently used as the key attractions in the marketing of many tourism destinations. There are many ways in which the coastal and marine environment has been used to differentiate one tourism destination from the next. The coastal zone has been used to position destinations as surface water based activity destinations (e.g., surfing - Hawaii; windsurfing - Washington state; sailing - New Zealand, Massachusetts; sea kayaking - Belize); underwater-based activity destinations (e.g., diving - Cayman Islands, Maldives; fishing - Mexico, Trinidad and Tobago); terrestrial-based activity destinations (e.g., sunbathing - Canary Islands, Seychelles, and Florida; beach sports - Virginia and southern California; camping - Texas's Gulf coast). From a nature-based perspective destinations have positioned themselves on the basis of their unique marine wildlife (e.g., Mexico's Baja California gray whales; Argentina's birdlife); vegetation (e.g., Costa Rica's coastal tropical rainforests); terrestrial wildlife (e.g., Northwest Territory's polar bears); geological formations (e.g., Australia's Great Barrier Reef; the Republic of Maldives' coral reefs and atolls; Fiji's coastal mountains; Mauritius' coastal lagoons); and unique ecological characteristics (e.g., Ecuador's Galapagos Islands).

In each of these cases, the tourism destinations have been able to successfully use their area's outstanding coastal attributes to attract new and growing numbers of travellers, create new forms of economic development, and assist in the enhancement of the quality of life for local people. However, in all of these examples, there have been an ongoing set of challenges associated with planning and managing the environments of these areas, whist still meeting the needs and expectations of travellers. This paper outlines some of these overriding challenges in the context of coastal tourism in general and the Bay of Fundy region in particular.

Coastal Tourism Development and Management Issues

Coastal regions provide a range of abiotic and biotic attractions for visitors within ever-changing natural areas. Each destination offers the opportunity to tell its own story to interested travellers. The Bay of Fundy's geological and ecological characteristics provide a unique but challenging competitive advantage for communities interested in using tourism to encourage sustainable economic and social-cultural development in the region. In many respects, the region's tidal, fossil, wildlife and community attributes have the kind of exaggerated distinctiveness which represent non-replicable competitive advantages. However, some of these same features also represent distinct disadvantages that may limit the destinations appeal in the marketplace. In particular, the Bay's cool water temperatures, at times aggressive and dangerous tides, frequent foggy periods, and relatively short warm travel season represent challenges to the development of tourism. On a more positive note, these same destination attributes also serve as natural inhibitors to potentially heavy traffic flows which might place undue stress on many of the area's sensitive environments and smaller coastal communities. There are many cases where tourism destination's faced with the same types of challenges are successfully moving forward with various forms of nature-based coastal tourism. Innovative North American examples include cold water destinations such as British Columbia's Clayoquot Sound and Queen Charlotte Islands, Washington state's San Juan Islands Marine Sanctuary region, Oregon's network of coastal tourism communities, Ontario's Bruce Peninsula and Fathom Five Provincial Park region, and Quebec's Saguenay - St. Lawrence Marine Park destination.

While all of these are exciting examples of what can be done to stimulate nature-based tourism development in the coastal zone, none of them have attempted to build the type of formalized and systematic strategic partnerships that have been initiated by this region's fledgling Bay of Fundy Product Club initiative.

Organizing the Product Components of Coastal Tourism Destinations

Communities and destinations such as those associated with the Bay of Fundy region must consider at least three critical components when developing their coastal tourism product portfolios. The three components are: a set of distinctive core attractions, related peripheral support services, and high quality destination and touring packages. In various combinations and depending on the market for which they have been created, these components form the foundation for a wide-ranging set of coastal touring and destination experiences.

Core Attractions

The core attractions for most coastal destinations are intimately linked to the region's natural and cultural/heritage attributes. These assets provide the distinctive character and basis for establishing a unique position in the marketplace. By definition, these core attractions should offer enough distinctiveness and appeal to be able to draw travellers to them. For instance, various elements of the Bay of Fundy region's distinctive marine, geological, terrestrial, and wildlife resources should form the core attractors in the creation of coastal tourism products. These include but are not limited to:

- The tidal phenomena—vertical and horizontal dimensions of tidal change as well as tidal currents (tidal rips, whirlpools, and tidal bores).
- The coastal topography—cliffs and coastal formations caused by the tides making it one of the most distinctive coastal regions in eastern North America.
- The ecological phenomenon—habitat for the rare Northern Right Whale and seven other species including Fin and Humpback and a critical feeding area for flocks of up to 100,000 Semipalmated Sandpipers (90 % of the world's population).
- The natural history—one of the oldest and most important Triassic-age dinosaur discoveries in the world as well as Carboniferous-age fossils exposed through erosion.
- The cultural history—first European settlement in Canada (in fact, first on the North American continent north of Florida) and site of the expulsion of the Acadians 150 years later. The lifestyles and activities of the fishers, farmers and foresters who followed them.

Peripheral Support Services and Facilities

Although the core attractions are the essential magnet for tourists, they must be complemented by a set of supporting peripheral features which ensure the level of comfort, convenience and essential services needed for sustained enjoyment of the core attraction. In the Bay of Fundy region these services and facilities are found to varying degrees in many small to medium-sized communities. The peripheral facilities and services typically include appropriate levels of food and beverage, accommodation, transportation, and information services and, in some cases, supplemental tourism activities. Developing and delivering these in forms which are seamlessly and appropriately linked to the carrying capacities of the core attractions is a key to the long-term sustainability of the region's resource base.

Market-Matched Destination and Touring Products

Coastal communities must compete with other domestic and international destinations for marine-oriented travellers. To do this requires a strong appreciation of not only the natural and cultural assets of the coastal destination that are potentially available for attracting visitors, but also those assets which match best with travellers' needs and interests. Coastal communities that have such market intelligence can make more informed decisions about tourism product and market development.

Information concerning the travel preferences, product requirements and travel planning characteristics of coastal tourists is particularly useful in this regard. The following section summarizes information from a secondary analysis of long-haul pleasure travel market information concerning travellers from the United Kingdom, Germany and Canada (Williams and Dossa 1999). The information presented relates to the survey responses of an extensive sample of international and domestic travellers who indicated that "remote coastal attractions like fishing villages or lighthouses" were either always or often important places to visit on their long-haul pleasure travel trips. The distinguishing traits of these coastal travellers included tendencies for them to be:

- married baby-boomers from households with two or more members over 18 years old;
- looking for value oriented multi- as opposed to uni-dimensional experiences;
- motivated to travel by varying factors (e.g., U.K. travellers are particularly cost and value conscious; German tourists are seeking places with strong natural and environmental qualities; Canadians are motivated to visit places which offer a combination of these traits);
- selecting Canadian destinations for its perceived advantages linked strongly to the environmental quality of its natural and wilderness areas, as well as remote coastal areas;
- different with respect to their vacation trip patterns:
  1. U.K. coast travellers took pleasure/vacation trips of 15–28 nights travelling with their spouse or significant other. They booked their trip shortly after planning it, and used travel agents as their most important sources of information to help make these decisions. They stayed at least one night at the home of friends/relatives and partook in sampling local foods, photography and shopping.
  2. German coast travellers took pleasure/vacation trips of similar duration (15–28 nights) which also involved travelling with their spouse or significant other. Travel agents were the most important source of information used to help plan their trips. They planned their trips quite far in advance but did not book it until a month prior to their departure. They tended to stay at least one night at a mid-priced hotel and pursued photography, sampling local foods and shopping opportunities.
  3. Canadian coastal travellers took pleasure/vacation trips of shorter duration (5 to 7 nights), often planned by their spouse or significant other. Advance planning for their trip was very short (a week or less) and they used friends/family members as their most important sources of information. They stayed at least one night at the home of friends/relatives and participated in informal/casual dining with table service, photography and dining in fast food restaurants/cafeterias most frequently.

Depending on their scope (e.g., geographic range, accessibility), permanency (e.g., seasonal availability) and drawing power (e.g., uniqueness, abundance, quality, breadth of appeal) core attractions and their supporting peripheral services are normally the central ingredients in the development of destination (extended stay) or touring (short stay) products. For destination tourism products the core attraction must have sufficient appeal to attract visitors to a destination for several days (e.g., 3–15 days). In such cases, there must be sufficient things to see and do to keep all members of the travel party occupied in enjoyable pursuits. Such destination products require a well-developed combination of core and peripheral components which match with the needs and interests of the travel markets. In the case of the Bay of Fundy region, the variety of products and services suited to retaining visitors at coastal destinations is currently limited. If communities are seeking to attract and hold visitors to the region, more must be done to create and promote a more dynamic and integrated range of cultural and nature-based activities. This type of development is dependent on destination communities providing opportunities for tourists to interact with local residents as well as with the natural attributes of such areas. Ensuring the sustainability of such endeavors requires the active involvement of local communities in planning, managing and monitoring the size, scope and impacts of such initiatives.

Touring products cater to visitors for much shorter periods of time (e.g., a few hours to a full day). Primarily designed for day use or transient travellers, these products are dependent on not only the presence of distinctive natural or cultural features but also ready access to well developed or promoted transportation routes. The Bay of Fundy's Evangeline Trail and emergent Bay of Fundy Ecotour trail represent routes which serve to link and provide thematic understanding of the region and its places for coastal travellers. Given the limited scale and carrying capacity of most existing communities in the region, this form of product development matches well with the needs of the region and the interests of the market place.

Encouraging Sustainable Tourism Practices

Beautiful and healthy physical and cultural environments provide the foundation for sustainable tourism development in most coastal destinations. However, such foundations can be easily eroded with inappropriate tourism activity. It is particularly critical that communities and their residents play leading roles in determining the type and extent of tourism to be promoted in their areas. Managing tourism's growth should be first based on sound environmental principles. Environmental degradation related to excessive water and energy consumption, problems of waste and sewage disposal, shoreline erosion, vegetation disturbance, the loss of marine habitat and wildlife species are well documented repercussions associated with developing and operating tourism businesses in coastal zones. As a consequence, more and more tourism operators and the communities which are associated with them are faced with mounting pressures to improve their environmental performance. These pressures come from a growing body of environmental regulation which tends to assign liability directly to polluters, as well as a more informed travelling public that is familiar with the possibilities of environmental risk and less tolerant of environmental degradation.

As a consequence, for coastal tourism to flourish on the Bay of Fundy, there must be a firm commitment to the principles and practices of sustainability. This commitment should be transparent to not only industry partners but also to the travelling public. To create this readily apparent position with respect to issues of sustainability, the region's tourism operators should undertake at least four strategic initiatives. These include: developing a universally agreed upon set of operating principles or code of conduct with respect to environmental and social dimensions of the partner's activities, translating these principles into "greening practices", and implementing a credible monitoring and accreditation system to encourage continuous improvement of partner operations and to increase recognition of these activities in the market place.

Stage 1: Implement Codes of Conduct

Codes of conduct can be encouraged for two primary target groups. These are travellers to the Bay of Fundy region, and the tourism industry partners linked to the development and delivery of coastal tourism opportunities. Codes of conduct aimed at travellers emphasize respect for other cultures and encourage sensitive resource use. Many examples of such codes exist. For example the Tourism Industry Association of Canada has developed and adopted a comprehensive Code of Ethics for Sustainable Tourism for both industry and tourists. As well, the National Audobon Society has been a leader in developing such codes for travellers. Similarly, since the release of the Brundtland Report, *Our Common Future* in 1987 and the International Chamber of Commerce's *Charter for Sustainable Development* in 1991, several tourism associations have produced their own codes of conduct. Examples of these include the World Travel and Tourism Council's Environmental Guidelines and the Pacific Area Tourism Association's Code for Environmentally Responsible Tourism. While developed to address the needs of their specific stakeholder groups, each code has incorporated one or more overriding actions required for a more sustainable tourism industry. All of these codes offer excellent examples of what might form the foundation of an appropriate set of principles for guiding the tourism behaviour of product club members and their customers. A particularly relevant prototype that might be suited to this project is produced by New Brunswick, Nova Scotia and East Coast Ecosystems. Developed for the region's whale watching community, this model is comprised of two critical components. The first component is a Whale Watching Code of Conduct signed by the Bay of Fundy whale watching operators "for the protection and safety of the whales and other marine wildlife, and the safety and understanding of passengers". The second component is a Citizen's Guide to Whale Watching which has been produced to inform the public about what they should know about whale watching so they can determine whether or not their tour operator is acting responsibly. This prototype may have direct applicability to other Bay of Fundy coastal tourism operators who might jointly incorporate such principles into their practices.

Stage 2: Implement Sustainable Tourism Practices

Coastal tourism stakeholders are typically comprised of a range of industry and community-based organizations and individuals. Many of those partners are related to the accommodation, food and beverage, transportation and tour operator sectors of the tourism industry, and others are linked to more diverse community environmental and cultural groups. Given the nature and marine-oriented character of most tourism which occurs in the coastal zone, all of them will be encouraged to adopt "greening" initiatives. On a global basis, the industry's accommodation, restaurant, and transportation sectors have received the most attention for their greening programs. Hotel and other forms of lodging sustainability programs have concentrated on waste reduction, energy conservation, and water conservation, the use of organic foods, non-toxic cleaning products, and chemical-free pest management techniques. In the transportation sector, airline programs for noise reduction, fuel efficiency, and emissions reduction have been the most widely developed. Greening activities practiced in the restaurant sector have focused mainly on solid waste and energy reduction, as well as broader community conservation activities. For the most part, these sustainability practices have concentrated on activities that reduce the environmental effects of operations by means of improved methods of waste reduction, energy conservation, and emissions control. As well, a few tourism organizations are now going beyond their immediate environment by encouraging more sustainable practices amongst their suppliers and other related organizations. In the case of the Bay of Fundy region, significant opportunity exists to use community organizations to lead in the implementation of sound environmental programs. Without such community commitment, it is unlikely that other private sector-based initiatives achieve their intended impacts.

From a coastal tourism development perspective, emphasis should be placed on creating not only "low impact or traceless" visitor activities, but also strong community-based initiatives which reduce the impact of traditional industrial and residential development on the coastal zone. While Canada's coastal zone has traditionally been the waste disposal system of preference for community and industrial wastes, many destinations are now recognizing the potentially tremendous and longer term economic and social value associated with keeping waterfronts, shorelines, and marine habitats clean. Numerous market surveys clearly indicate that the destinations of choice for most pleasure travellers are characterized by safe and clean air, water and soil. Their stays in such areas produce significant benefits for the communities and industries which host them.

Stage 3. Implement an Assessment and Product Enhancement Program

The third component in a comprehensive program designed to encourage sustainable tourism practice typically involves creating a monitoring and performance enhancement system. In this third stage, companies and communities participating in coastal tourism development should assess the effectiveness of their operational practices. Environmental auditing has been the overriding term used to describe many of these tracking processes. In the context of coastal tourism it entails reviewing ongoing operations to determine how well the companies are safeguarding the environment through their on-site practices. Typically such auditing is accomplished through a combination of self-administered and third party operated testing and verification procedures. From a self-auditing perspective, many self-assessment models exist. In this regard, the Tourism Industry Association of Nova Scotia has developed *A Question of Balance: Sustainable Tourism Self-Audit Workbook* which provides a good basis of guiding the development of such practices by tourism operators. However, an important component of any due diligence initiative by coastal tourism organizations should be a periodic professional third party assessment. In the context of the Bay of Fundy region, there are several reputable third-party monitoring organizations available for such auditing. While each of these monitoring organizations offers its own range of assessment services, some of them offer another advantage in the form of an eco-label or "stamp of approval". Such accreditation can be used to competitively position coastal tourism destinations and their operators favorably in the minds of travellers. The practice of eco-labeling tourism products has progressed significantly over the past few years, and some organizations have been particularly successful in this regard. The following monitoring and eco-labelling models are particularly useful options to examine in the context of the Bay of Fundy region: World Travel and Tourism Council's Green Globe 21 Program (URL: <http://www.greenglobe21.com/>; Pacific Asia Travel Association's Code for Sustainable Tourism (URL: <www.pata.org>); TerraChoice Environmental Services' Audubon Green Leaf™ Eco-Rating Program (URL: <http://www.terrachoice.ca/hotelwebsite/indexcanada.htm> and HVS Eco Service's ECOTEL (URL: <www.hvsecoservices.com/ecotel.htm>). As an alternative to these more commercial eco-labeling processes, the Bay of Fundy region might want to develop a more "made at home" tourism destination and product accreditation process along the lines of that developed by the Saskatchewan Sustainable Tourism Council with the assistance of the Saskatchewan Watchable Wildlife Association. While experiencing some growing pains, this model is positioned as a consensus based approach to meeting the need for transparent and credible assessment of tourism destination environmental practices.

Conclusions

The opportunities associated with tourism development are especially appealing but also quite challenging for coastal communities. Faced with unanticipated and unplanned tourism development, communities and their surrounding environments can be harmed in insidious ways. However, when provided with opportunities to plan and manage tourism development in a sustainable fashion, tourism can create the option of an economic engine, which delivers ongoing social and environmental benefits. In coastal areas such options are becoming more appealing, as the realities of changing market demands and more exploitive forms of resource development become apparent. Together, communities and their industry partners must work towards keeping an even keel in managing the growth of coastal tourism in their regions.

Reference

Williams, P. W. and K. B. Dossa. 1999. *Potential Coastal Tourism Travel Markets: United Kingdom, Germany and Canada*. Centre for Tourism Policy and Research, Simon Fraser University, Burnaby, BC.

COMMUNITY-BASED TOURISM CASE STUDIES

Thomas Young

Bay of Fundy Product Club, Parrsboro, NS. tmyoung@auracom.com

The development of tourism projects and infrastructure has been an important community development strategy for many coastal communities in the Bay of Fundy region during the past decade. Tourism development has been seen as a way to offset the decline in traditional resource industries and to diversify rural economies.

This study reviews three examples of community-based tourism development projects, examines the reason for each project, and their effectiveness in contributing to economic and other community goals.

In 1993 a plan for economic development in West Cumberland was prepared for the West Cumberland Development Association (WCDA). The plan highlighted a number of important trends that affect the future of coastal communities in West Cumberland.

Census data showed that the population of West Cumberland declined by 15% between 1980 and 1990. The population of Parrsboro, the only incorporated village in the district, declined by just under 10% during the same period, the most recent episode of a long-term decline stretching to the turn of the century. The population of Parrsboro was roughly 50% greater in 1910 that in 1990. Employment statistics show that during the 1980s, there was a corresponding decline in employment (although employment among the female portion of the workforce actually increased).

These trends have led to a number of issues that affect the economic viability of small communities. With the decline in employment there has been a decline in community services, including critical health and education services. Retail and other local services face similar pressures.

In the 1993 report, a survey of community groups and businesses was conducted to determine what actions could be taken to mitigate these pressures on coastal communities. Included in the survey were local sawmill owners, a bank manager, retail associations, and non-profit development and heritage groups. In total, 25 interviews were conducted. Each respondent was asked to identify new projects that would contribute to economic and community viability. Of the projects identified, 75% were tourism related (Young 1993). This is consistent with the results of other community surveys which have shown that tourism is frequently a priority for development. For example, in an unrelated door-to-door survey of 350 residents (cottage and permanent) between Tidnish and Pugwash, 63% said they would like to see an increase in tourism traffic in their area (Young 1993).

Why Tourism?

This preference for tourism as a community development strategy may be explained by several factors. Tourism generates investment and provides employment (although in rural areas it is often seasonal). Clearly tourism is a step in diversifying economies of coastal communities, in addition to existing primary industries such as fishing, However, tourism development is also a way to maintain community infrastructure, both public (museums, parks, transportation) and private (food and beverage, entertainment, etc.).

In the Minas Basin region of Nova Scotia, much of the development has been initiated by local groups or community interests. Indeed, these community interests have often taken a lead role in the development and operation of these projects. The following are three examples:

1. The Age of Sail Heritage Centre, Port Greville

The Age of Sail Heritage Centre is an example of a small facility, owned and operated exclusively by a local group. Its focus is on local heritage. It incorporates heritage architecture, and its small scale results in a limited environmental footprint.

In 1992, the Port Greville Museum Society proposed a local museum to preserve the shipbuilding heritage of the North Minas region and to stimulate economic development in the area. Over 400 wooden ships were launched in various shipyards of the Upper Minas Basin. Port Greville was the last of the wooden shipbuilding yards of the Bay of Fundy, closing in the 1970s.

With assistance through a local industrial adjustment committee of Human Resources Development Canada (HRDC), the group prepared background historical research, undertook fund raising, and presented a concept plan and proposal to several federal and provincial agencies. While there were significant funds provided through the museum assistance program and related federal and provincial sources as well as local fund raising, a bank loan secured through personal assets of community members was needed to achieve the capital requirements.

The project, when completed, incorporated a 150-year old heritage building on a site donated by Scott Paper Ltd. The building was saved from demolition and dismantled before being transported to its present location. Shipbuilding artifacts were incorporated into a high quality interpretive display. When it opened, the project won an award for architectural design.

The Port Greville project is an example of a small-scale, high quality community heritage facility that has received positive acclaim. It has assumed an important role in housing artifacts and commemorating local heritage. It has generated a reasonable level of traffic (2,000–3,000 visitors annually) and helped stimulate new private sector tourism development. However the facility does not generate sufficient revenues to employ more than 2–3 seasonal staff and requires significant input from the local group. Importantly, it is part of a network of high quality tourism attractions which collectively comprise an attractive destination for visitors.

2. The Devils Bend Trail

The Devils Bend Trail Project was proposed and administered by the Kenomee Trail Society. In 1998, this group from the Economy and Great Village communities proposed the development of a trail though Crown land to Economy Falls in Colchester County. In 1999, the group applied to Human Resource Development Canada for a Youth Services Program grant to plan and construct the trail.

The Project involved the development of a seven kilometre hiking trail on a combination of private and publicly owned land. Sixteen young people were employed for six months to work on the trail. The Project incorporated a two-week training period that covered basic ecological principles and environmental management, as well as trail planning and development techniques.

The Project also included the establishment of a water quality monitoring program managed and administered by the local school. The Trail Society acquired funds through the Shell Foundation to finance the school environmental monitoring project for two years. Together with the trail development project, this field program was instrumental in developing the knowledge and capacity of the young people in the community to understand the dynamics of the local ecosystem.

The Kenomee Trail Project led to several forest management actions that effectively protected the watershed of the lower Economy River. First, in support of the trail project, the Department of Natural Resources agreed to conduct a pilot integrated management plan on the Crown land along the Economy River. This resulted in guidelines that would help maintain the integrity of the forest ecosystem in the river valley. Secondly, the province acquired a 200 hectare parcel of land encompassing Economy Falls from the forestry conglomerate Kimberley Clarke through a land trade. This put the falls, one of the most significant natural features of the area, in public hands.

The Devils Bend Trail has been highly successful in attracting visitors. At least one tour company conducts several trips on the trail annually, staying at local accommodations and using local restaurants. Participation of local landowners provides a level of community support that may not exist where all land is publicly owned.

The weakness of the Project is in operational funding. There is no established fee system and all maintenance activities are done by volunteers.

3. Cape Chignecto – Advocate Harbour

The project to develop Cape Chignecto Provincial Park is an example of a government/community partnership. The scale of this project is significantly greater that the preceding case and, as a result, there has been a much greater investment of public resources. In addition, there was an extensive process of planning and consultation.

In 1989 the Province of Nova Scotia acquired 6,000 hectares of land and coastal property at Cape Chignecto from Scott Worldwide through a land exchange. Several local residents supported, indeed strongly promoted, this acquisition for the creation of a new provincial park. The area encompassed forested coastal valleys with stands of old growth red spruce that were considered to have significant heritage value.

A 1991 study examined the potential economic impacts of a park development at Cape Chignecto. The study forecast that park operations would provide from 11 person years (low-case scenario) to 55 person years (high-case scenario) of employment annually (Gardiner Pinfold 1992). This report was used to encourage the province to designate the area as a provincial park.

In 1992, the minister of Natural Resources delegated an advisory committee to provide input into the project as required in the 1988 Nova Scotia Parks Policy Paper. The committee was charged with preparation of a management plan for the new provincial park at Cape Chignecto. The advisory committee consisted of 15 residents of Advocate and surrounding communities. The management planning process included the identification of standards of use for the park, zoning, trail development options, proposed camping, etc.

During the planning process, the province informed the committee that it would not fund park development or operation. They were willing however to consider a management agreement to allow the regional development association to construct and operate park facilities including a 35 km coastal hiking trail. In 1994, the province entered into a management agreement with the Cumberland Regional Economic Development Association (CREDA) on behalf of the advisory committee. The advisory committee continued to provide the primary source of local input into the development process.

This structure was intended to provide a community planning and management framework, where a local organization acting on behalf of the community would obtain and manage resources in order to bring the park into operation. The park was to generate new income to the community.

In 1995, CREDA obtained a commitment of funds through HRDC for a training and development program in park construction, management and operation and construction of the hiking trail over a two-year period. During this period (from 1995–1997), a 35 km coastal hiking trail was constructed by 15 workers under CREDA's administration. On-site training was conducted during the winter season. Dr. Marguerite Cassin (Dalhousie University) was employed under contract for training along with several other sessional trainers. Communications with the local community included newsletters distributed monthly to all households in the community and open house events approximately each quarter.

During this period, the Nova Scotia Department of Natural Resources (DNR) further developed the management plan. Park planners developed operational standards, site plans for camping, entry area design and function, and other general planning aspects. These plans were presented to the advisory committee at each stage, and incorporated in open house events and special presentations in Advocate.

In 1998 the park began operation. However, within a year, complaints and criticism began to be heard about restrictions on access to areas of traditional community use. This led to the formation of an advocacy group that challenged the park advisory committee and several of the principles of park use included in the management plan. There was no resolution to these conflict over a period of two to three years.

There are several factors that may have caused this conflict situation once the park was in operation. The community development process is based on local ownership, and control of the project must be responsive to local input and involve compromise. Park planners on the other hand determined that it was in the public's interest to establish non-negotiable regulations that support conservation objectives. The public (served by DNR) represents a large population outside the local community, including the urban population of the province. The project has both dimensions of a community development project and those of a provincial park project. This dual role fails to meet some fundamental criteria of community economic development and ultimately led to unresolved conflicts.

The Economic Argument

A 2000 study determined that the number of room nights sold in the North Minas region from Glenholm to Advocate had increased by 50 percent over five years. Accommodations in this area are primarily a combination of seaside cabin facilities and bed and breakfast establishments. This growth in room sales accounted for an increase of roughly half a million dollars in annual room sales. Since accommodations generally account for less than 20% of travel expenditures (*Nova Scotia Statistical Review 1998*), the total increase in revenues (net of any multiplier) is in the range of two and a half million dollars each year.

Heritage and Environment Values

In each of the case studies cited above, there has been a significant component of heritage conservation. This includes cultural heritage (history of Port Greville's local shipbuilding industry) and natural heritage (the forested coastal valleys of Cape Chignecto). A heritage conservation ethic is a key criteria in community-initiated tourism projects.

Indeed, in the case of Cape Chignecto, the economic argument alone could not support the cost of the project. In fact it is a mix of economic and conservation objectives which supported the decision by the Crown to acquire the land and provide resources to develop the recreational infrastructure and for other agencies to invest. The Economy Falls project further integrated the natural and ecological values of the watershed into the school curriculum.

The Community

Port Greville is owned and operated by the local group and seems to be well accepted and appreciated locally. The Economy Falls project appears to have community acceptance largely because of the significant involvement of young people in the project. Cape Chignecto on the other hand has resulted in some significant criticism within the community due to the conflict between community development and park management approaches. Some negotiated settlement may alleviate this conflict.

Conclusion

Community development can have strong local benefits and support. The contribution to economic sustainability appears to be significant in the North Minas Region. There is a strong component of heritage conservation in most of these projects. The presence of a local champion strongly influences the level of community acceptance and support. Likewise, the degree of local investment also influences the extent to which the community will support the project. Conversely, a high degree of public investment means that management decisions will fall more in the hands of departmental staff. This can put project managers in conflict with local stakeholders.

References

Gardiner Pinfold Consulting Economists. 1992. Northport Marina: Feasibility Study. Unpublished report prepared for the Northport Marina Association and the Amherst Industrial Commission.

Nova Scotia Statistical Review 1998. Halifax, NS: Voluntary Economic Planning Division, Department of Finance and Economics.

Young, T. 1993. Turning the Tide, A Plan for Economic Development in West Cumberland. Unpublished report prepared for the West Cumberland Development Association.

FUNDY NATIONAL PARK HUMAN USE IMPACT PILOT PROJECT

Sean Murphy

Fundy National Park, Alma, NB. sean_murphy@pch.gc.ca

This was the first project to attempt to integrate social and ecological sciences in order to study the impacts of visitor use on national parks. Multidisciplinary research and analysis was conducted over the peak summer season of 2001 at Fundy National Park, New Brunswick. The study was comprised of five components. Trail surveys were administered to gather visitor attitudes towards trail crowding and to develop a standard for the number of hiker groups that become unacceptable on specific trails. Trail assessments were also included to gather physical data regarding specific trails. The assessments were conducted at 20 m intervals and information such as vegetation trampling, social trails, slope, surrounding vegetation, tree damage, etc. was gathered. Campground surveys were administered to gather camper opinions on their campsite and to develop some social indicators. Campsite assessments were also performed on roughly 50% of the campsites at two campgrounds (similar information as collected the on trail assessments). The fifth component was comprised of detailed scientific analysis of ten campsites regarding such items as plant cover percentage by species, mineral soil exposure, soil compaction, area of vegetation loss due to camping, etc. All of the information collected had a geomatics focus and it is expected that results from the social science section will be merged with data from the Park's ecological section to look at the overall impact of visitors on the Park environments in these locations.

FROM CON*SERV*ATION TO CON*VERS*ATION— WHY BIOSPHERE RESERVES MATTER

Munju Monique Ravindra

Fundy National Park, Alma, NB. munju_ravindra@pch.gc.ca

Abstract

Biosphere reserves are established as places where people are living in harmony, or trying to understand how to live in harmony, with the natural environment. Participation in the development of a regional biosphere reserve is not a panacea for the problems of parks and protected areas, however, such participation offers an opportunity for protected areas to work co-operatively with the broader community to resolve conservation and land-use concerns. A biosphere reserve can be a mechanism for the protected area to be involved in a 'big picture' approach to planning and management. It can foster a multidisciplinary approach to improving the knowledge and understanding of the region through the engagement of institutional and academic partners, but also through the engagement of the local population in setting the research agenda and conducting research. A biosphere reserve is a framework for co-operation, requiring the protected area to go outside of its traditional bailiwick and to collaborate with groups and organizations who have different perspectives on 'what is best'; and it is a place where the experiments in sustainable design and innovation necessary for living in harmony with the natural environment occur.

A Going Concern

After an extended period in relative obscurity, biosphere reserves appear to be newly 'hip' in Canada. In May 2002 there were eleven places in Canada recognized by the United Nations Education, Scientific, and Cultural Organization (UNESCO) as 'biosphere reserves', and almost half of these have been designated since January 2000 (Canadian Biosphere Reserves Association 2002). Five of the designated biosphere reserves, and all four of the most active proposals, include national parks as 'core areas'. Assuming the current proposals remain active, almost a quarter of Canada's national parks will be part of biosphere reserves within the next few years. One of these is Fundy National Park—proposed as a 'core area' within the Upper Bay of Fundy Biosphere Initiative (Resource Management Associates 2000).

This paper summarizes how the development of a regional biosphere reserve might be relevant to national parks and other protected areas. It also identifies several ways in which the process of developing a biosphere reserve in the upper Bay of Fundy region can support ecological integrity across the land and seascape.

A Fundamental Notion

The 'biosphere reserve' concept is based on the fundamental notion that people and their communities are an integral part of a broad natural system. Learning to recognize and to live within the limits imposed by ecological systems is perhaps the greatest challenge of the 21st century. Biosphere reserves are recognized by UNESCO as places where people are figuring out and demonstrating how they can meet their own needs while at the same time maintaining the health of the ecosystems that support them (UNESCO 1996). Otherwise put, biosphere reserves are places where people are getting international recognition for *learning to live on the earth without spoiling it*.

How It Works

The process of seeking and receiving such international recognition is often a long one—requiring the construction of healthy and functioning partnerships between communities, organizations, institutions, and governments. Together, these groups work on three complementary biosphere reserve functions:

- the *conservation* of landscapes, ecosystem, species and genetic diversity;
- local *development* that is culturally, socially and ecologically sustainable;
- and the building of local *capacity* for research, monitoring, education, training, and information exchange related to conservation and development (UNESCO 1996).

In the biosphere reserve model, it is the dynamic relationship (and the ongoing study and communication of that relationship) between benchmark protected areas, sustainably managed unprotected areas, and the life of the broader community that enables a region to fulfill these functions.

Why Does This Matter to Protected Areas?

Signs of Failure

National parks and other protected areas can be seen as an admission of failure (McNeely 1996). Their very existence reinforces the fact that, unlike most other species on the planet, human beings have failed to live in harmony with the world around us. We have therefore had to 'set aside' representative pieces of nature where natural processes can carry on, ostensibly without our interference (Livingston 1981). A history of expropriation, 'command and control' management approaches, and, more recently, an emphasis on consultation rather than collaboration, has created a widespread sense of mistrust in many communities adjacent to parks and protected areas, culturally isolating these areas from the communities that could support them.

Isolated Islands

From a conservation biology perspective, the problems with this approach are well known. In setting aside bits of nature, we have created isolated 'islands'—often too small to effectively conserve the species and processes they claim to represent (Soulé and Wilcox 1980). The lack of integration with the 'outside world' means that protected areas often end up with hard boundaries, for example, clear cuts or agricultural areas to the border of a national park. These edges limit the ability of a park or protected area to adapt to turbulent conditions, or to massive change, such as the changes in climate currently taking place (IPCC 1995). Bill Freedman (2001) points out that this ecological difference between many protected places and their surrounding landscapes results in their being "embedded within a hostile landscape". The challenge facing parks and protected areas today is to reduce that 'hostility'—both in ecological and in socio-cultural realms.

Blinkered

Because the land-use and other decisions that affect biological diversity and ecosystem health are decisions *people* make, the conservation of that diversity and health is necessarily a *social* process. Protected areas have, however, tended to focus on scientific tools (such as biological research and monitoring) for conservation with little twin emphasis on social tools (such as communication, co-ordination, or partnership). There is, therefore, often a gap between what protected area managers and scientists understand about the health of the ecosystem and what resource users and visitors are doing that directly or indirectly affects that health.

Opiates

While the constraints faced by parks and protected areas in carrying out their proclaimed task of conservation are well known in conservation circles, the general public tends to be far less aware. In part, this is because protected areas work as opiates—lulling the public into believing that conservation of biodiversity and ecosystem health is 'under control'. Communication and interpretation programs play into this myth by presenting fascinating nature facts and astonishing close-up photographs of wild or rare species. Such programs tend to focus on the value of the protected area or protected area system to the conservation of biological diversity rather than articulating the state of the ecosystem and the risks to ecological integrity or ecosystem health these areas, and their surrounding regions, actually face.

How Can the Development of a Biosphere Reserve Help?

The development of a regional biosphere reserve cannot solve all of the problems faced by parks and protected areas. Nevertheless, by participating in the development of a biosphere reserve, protected areas are able to engage constructively with each other and with the broader community in the protection and maintenance of ecological integrity. Some benefits of participation in a biosphere reserve can bring to protected areas are outlined in the following paragraphs.

1. **A 'big picture' approach to protection and management**. The Upper Bay of Fundy Biosphere Initiative (UBoFBI) is seeking UNESCO recognition for the two upper basins of the Bay of Fundy—Minas Basin and Chignecto Bay. From a conservation perspective, this means taking a large-scale view of the area and developing the partnerships necessary to effectively protect, maintain, or restore ecosystem health. The 'big picture' approach necessary for development of a biosphere reserve can foster the development of a regional protected areas *network*, and this has been one of the initial priorities identified in the UBoFBI draft plan (2002). Such a network provides opportunities for collaboration on diverse protected areas activities, including scientific research and monitoring, communication programing, and staff training.

Under the auspices of the proposed biosphere reserve, managers, planners and ecologists working with regional protected areas have formed a 'conservation working group'—the first step in the development of a protected areas network. The aim of this group is to develop a protected areas strategy for the UBoFBI area. An early project will be the identification and mapping of corridors needed for wildlife and species movement between protected areas. Identification of these areas helps to establish the groundwork for a broad collaboration with industry and landowners on stewardship and conservation approaches in 'working landscapes'. Collaboration with the forest industry to determine a cutting cycle that accommodates the needs of wildlife is an example of the kind of initiative that could be taken in this 'big picture' approach to conservation.

Participating in these kinds of collaborative approaches with other protected areas, industry and private landowners encourages protected areas to share the responsibility for conservation and for use (e.g., tourism) with the greater community, promoting a collective responsibility for conservation, use management and protection.

2. **Multidisciplinary approach to improving knowledge and understanding of region**. One of the functions of a protected area is to serve as a benchmark for scientific research and monitoring (Batisse 1997). While there have been some limits to the successful carrying-out of this role (inconsistent quality of research, lack of co-ordination in ecological monitoring, and ineffective communication of results to managers and the public are some of the complaints), it is an essential role protected areas play within biosphere reserves. The development of a regional biosphere reserve can help to strengthen this benchmark role by connecting local research and monitoring to national and international networks for information management and exchange (such as the Ecological Monitoring and Assessment Network (EMAN), or Biodiversity Resources for Integrated Monitoring (BRIM)) (Francis 1993).

The development of a biosphere reserve also necessitates the development or strengthening of partnerships with research institutions, universities, communities, and international researchers. These partnerships in turn can contribute to an improvement in the quality and thoroughness of research and can help to attract research funds to the area.

Although thousands of land use and management decisions are made every day by people who own, work and manage the land surrounding protected areas, these same people are rarely engaged in the setting of protected area research agendas or in doing the research and monitoring that takes place. By explicitly exploring opportunities for the local community to get involved in setting the agenda and conducting research, development of a biosphere reserve can act as a kind of framework for a more regional approach to the creation and sharing of knowledge. In the UBoFBI case, engagement of the local community in the monitoring of ecological and social integrity indicators (and eventually marine environmental quality indicators) is an identified priority (UBoFBI 2002), and the prospective biosphere reserve plans to participate in the nascent Canadian Community Monitoring Network (itself a joint project of the Canadian Nature Federation and EMAN). Local involvement in research and monitoring in the greater ecosystem provides baseline reference data for comparative analyses, as well as information on change over time. Furthermore, it can generate knowledge that local residents and resource users identify and need and that can be used by the community in order to more effectively 'live on the earth without spoiling it'.

3. **Framework for co-operation**. All biosphere reserves in the world require community participation. In Canada, they require community *leadership* (Birtch 2001, pers comm). Biosphere reserves cannot be established by protected area managers or by government agencies. Rather, local representatives of government agencies and protected areas sit together with local residents, non-governmental organizations and other citizens, in some sort of local committee, to develop a co-operative plan for their prospective biosphere reserve (Ramsay and Sian 2000; Ravindra 2001).

The committee of the Upper Bay of Fundy Biosphere Initiative includes members from government agencies, community development organizations, universities, heritage sites, non-governmental organizations, and industry. Merely by bringing together these diverse groups in order to look at the big questions of local and regional sustainability, constructive collaboration is achieved. In the early stages of the UBoFBI, for example, representatives of conservation organizations and the tourism industry—two sectors that had previously had little contact with one another—sat down together to try to find constructive solutions to the problem of visitation impacts on habitat conservation. It was a step in the right direction. A biosphere reserve cannot solve every problem relating to the intersection of conservation and sustainable development, however, it can provide the co-operative framework and connections through which issues such as this one are resolved.

Because of its emphasis on equal, transparent co-operation, a biosphere reserve can function as a forum for taking protected area managers out of an environment where they know 'what is best', to a roundtable environment where there are multiple other perspectives (such as tourism, fisheries, or local development) on 'what is best'. This kind of direct engagement requires a degree of transparency and accountability from protected areas managers, so that, for example, research conducted in protected areas is properly communicated to the community and resource users in order that they can engage in an informed discussion about how to live and make a living without compromising the ability of future generations to do the same.

Decisions made at the local, municipal, and county level have a significant influence on the ecological integrity of the region and of individual protected areas (Parks Canada Agency 2000). As participants in a regional biosphere reserve, protected areas have the opportunity to contribute (as a member of the community) to regional planning processes, collaborating with citizens and groups on the planning of tourism, lodging, educational activities and so on from a conservation and sustainable community development perspective. Once again, the biosphere reserve functions as a forum for communication and co-operation between the protected area and the greater community. This collaboration can allow a kind of blurring of the boundaries between park and 'non-park', encouraging collective responsibility not only for conservation, but also for other park activities such as lodging or interpretation. In this way, the ecological integrity values of a protected area can be communicated beyond its boundaries and the cultural, spiritual or economic values of the local community can be shared with protected area visitors.

4. **Design innovation for sustainable communities**. Protected areas are fundamentally conservative—mandated to protect representative parts of ecosystems and biological diversity unimpaired for *the future* (Canada National Parks Act 2000). The state of the world today is such, however, that in order to get to the future, human beings need to make some fundamental changes in the way we are doing things *today*. Because biosphere reserves are focused on the long-term survival of human communities and the natural systems that sustain those communities, they are fora to work out how to make the changes required to maintain and restore ecosystem health while at the same time meeting the needs of local communities. Some of these changes may involve rethinking and redesigning the way we live and work in order to minimize our impacts on ecosystem health. Innovations in the design of energy, transportation, agriculture or housing systems are the kinds of things that would be experimented with in a biosphere reserve, finding solutions or developing ideas that are then shared with the wider community. Such creative, change-oriented thinking is outside of the purview of protected areas, however, for the reasons summarized above, it is essential to their long-term survival.

The collaborative, multidisciplinary approach necessary to the development of a functional biosphere reserve seems the appropriate way to find landscape level design solutions to problems of conservation and development. For example, during the construction of a new highway in an area recognized as a biosphere reserve, conservationists could work with engineers to protect sensitive wetlands or to create artificial dens or hibernacula for certain species. Parks and protected areas have tended to avoid or have little power in these kinds of 'political' decisions that are outside of their borders, but which nevertheless affect their ecological integrity. Co-operation with planners, industry and government agencies through the biosphere reserve mechanism affords protected areas a way to participate constructively in finding a solution.

So, Why do Biosphere Reserves Matter?

In order to survive over the long-term, protected areas need to be embedded in healthy, sustainable, 'non-hostile' landscapes. They need, as much as possible, to decrease the ecological difference between protected areas and their surrounding landscapes and to decrease the social and cultural distance between conservation-thinking and community survival-thinking.

Biosphere reserves matter because they are a step in this direction. They are a framework through which citizens can try to resolve one of our most basic challenges—how can we maintain natural ecosystems while at the same time meeting the material needs and wishes of human beings? They provide a forum for the resolution and integration of conflicting interests and pressures through co-operation. They are areas where we can experiment with approaches of *how* to live sustainably in our landscapes (through design innovations or transportation alternatives, for example). And they are places where applied research can be done that is locally *relevant* to the very same land uses and management approaches which are sometimes perceived as 'threats' to protected areas. Finally, they matter because they are a venue and motivation for learning, researching, and information exchange—a kind of regional and global *conversation* about how to live on the earth without spoiling it. Protected areas, of necessity perhaps, have a more narrow focus. They are in the protection business and are therefore conservative, unable to make decisions about regional sustainability and human livelihoods. By participating as an equal member of a broader community in the development a biosphere reserve, protected areas can work towards conservation *through* conversation.

References

Batisse, M. 1997. Biosphere reserves: A challenge for biodiversity conservation and regional development. Environment 39(5): 7–15, 31–33.

Birtch, J. Executive Secretary of Canadian Biosphere Reserves Association. 2001. Personal communication.

Canadian Biosphere Reserves Association (CBRA). 2002. CBRA URL: <www.cbra-acrb.ca>. Accessed May 1, 2002

Canada National Parks Act. 2000, c. 32. An Act respecting the national parks of Canada.

Evernden, N. 1992. *The Natural Alien: Humankind and Environment*. Second Edition, University of Toronto Press, Toronto.

Francis, G. 1993. Towards a Great Lakes biosphere reserve: Linking the local to the global. In: *Managing the Great Lakes Shoreline: Experiences and Opportunities*. P. L. Lawrence and J. G. Nelson (Eds). Occasional Paper 21. Heritage Resources Centre, University of Waterloo, Waterloo, Ontario.

Freedman, B. 2001. Presentation at National Forum on Protected Heritage Areas Planning and Management, Halifax, Nova Scotia, 29-31 October 2001.

Intergovernmental Panel on Climate Change (IPCC). 1995. *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge.

Livingston, J. 1981. *The Fallacy of Wildlife Conservation*. McClelland and Stewart, Toronto.

McNeely, J. 1996. Presentation at World Conservation Congress, Montreal.

Parks Canada Agency. 2000. *Unimpaired for Future Generations? Conserving Ecological Integrity Within Canada's National Parks. Report of the Panel on Ecological Integrity of Canada's National Parks*. Panel on the Ecological Integrity of Canada's National Parks, Ottawa.

Ramsay, D. and S. Sian. 2000. Canada's biosphere reserves: Examination of different models for organization, implementation and community action. Paper presented at Fourth International Conference on Science and the Management of Protected Areas, May 14-19, University of Waterloo, Ontario.

Ravindra, M. 2001. So, you want to be a biosphere reserve? Information sheet available from Canadian Biosphere Reserves Association.

Resource Management Associates. 2000. Exploring the Bay of Fundy's Potential as a Biosphere Reserve. Discussion Paper, Resource Management Associates, Parrsboro, Nova Scotia.

Soulé, M. E. and B. A. Wilcox (Eds). 1980. *Conservation Biology: An Evolutionary-Ecological Perspective*. Sinauer, Sunderland, Massachusetts.

UNESCO. 1996. *Biosphere Reserves: The Seville Strategy and the Statutory Framework for the World Network*. UNESCO, Paris.

Upper Bay of Fundy Biosphere Initiative (UBoFBI). 2002. Upper Bay of Fundy Biosphere Initiative Draft Plan – Co-operation for conservation and sustainable development. Unpublished.

CONSIDERING CONSERVATION AND ECOTOURISM: FROM THE BIOSPHERE TO THE CLASSROOM AND BACK

Bradley B. Walters

Geography Department, Mount Allison University, Sackville, NB. bwalters@mta.ca

Biosphere reserves depend for their success on building local constituencies of support and brokering partnerships that further conservation objectives. This paper will describe one such early example of a partnership whereby efforts to further the Fundy Biosphere Reserve concept led to the redesigning of a course and participation of a class of students from Mount Allison University. Working with representatives of the proposed Fundy Reserve, students did background research in support of a planning workshop and pursued independent projects exploring specific sites of conservation interest in the proposed Fundy Biosphere Reserve. The process demonstrates well the kind of win-win partnership that biosphere reserves aspire to achieve. Key findings from the student projects will be presented to illustrate what they learned and how their findings may be of benefit to the proposed Fundy Biosphere Reserve.

PANEL DISCUSSION

Chair: Tom Young
Rapporteur: Munju Ravindra
Panellists: Sean Murphy, Jon Percy, Joel Richardson, Colin MacKinnon, Peter Williams

Question 1. *What do you consider to be critical issues with respect to tourism development and its impact on coastal environments of the Bay of Fundy?*

Sean Murphy – Although I do not have a lot of experience in Fundy specifically, I would consider the main ecotourism issues to be sustainability, promotion of tourism outside the region, and communication and education about the environmental impacts of tourism.

Jon Percy – I do not have any particular expertise in the tourism industry, but I do live on the Bay of Fundy and I am involved in co-ordinating the activities of naturalist groups who could be considered locally-based ecotourists. One of the important issues is the impact of the rapidly expanding ecotourism industry on the environment. We particularly need to think carefully about tourism activities that are generally incompatible with nature and wildlife conservation. Recent ads in national newspapers urged people to come and see the shorebirds of Fundy. Such visitors like to see the large flocks on the wing at the very times when it is in the birds' best interest to rest and conserve energy. Clearcutting is an activity that is essentially incompatible with ecotourism; it is becoming increasingly difficult to enjoy a wilderness experience anywhere in the Maritimes without encountering large clear-cut tracts. Clearcutting is even done right up to the boundaries of provincial and national parks and other protected areas, greatly diminishing their aesthetic value and ecological integrity.

Joel Richardson – I am with the New Brunswick Tourism and Parks Department and am involved in looking after the rapidly proliferating outdoor adventure companies that cater to ecotourists. There is a continuing shift in the demographics of ecotourists, so that it is no longer only younger people who are interested in nature-based and adventure tourism. There is a need to shift our focus from just the marketing perspective to preparing an inventory of existing and potential ecotourism opportunities and to the development of new tourism products. There has been a positive change in the level of environmental awareness among tourists. Communications and collaboration between government and the tourism industry is improving and this needs to continue.

Colin MacKinnon – I am a biologist and also a local historian. I think two very important considerations in the ecotourism context are the occurrence of cumulative environmental effects and the need to apply the precautionary principle in developing the industry. There are a number of different perspectives on nature involved in developing ecotourism ranging from concerns about its conservation to exploiting it for economic benefit. I have seen a change in the ecotourism business, with an increasing number of participants mainly in it for the money.

Peter Williams – Within the tourism market there is a tendency toward a rising level of expectation on the part of the visitors. Clearly consumer choices are changing and nowadays visitors want clean, reasonably natural environments. Another important point is that ecotourism depends on using shared natural resources – it doesn't have its own resources. An intangible element in the development of tourism products is that the people of the area are often closely involved in the process. Working with the communities of people in the area becomes the real challenge. Thus the sharing of information is very important to the decision making process.

Question 2. *What community issues relate to tourism development in positive or negative way?*
Question 3. *What management options can serve to mitigate or address impacts?*

Sean Murphy – ASC (Parks Canada – Atlantic Service Centre) does research on tourism and tourism products. They conducted a large study to assess the motivations for tourism travel. It found that "learning travel" is one of the fastest growing markets. The ecotourism market is clearly there, but we need to work with communities on tourism development.

Parks generally want non-intrusive management options. They prefer to avoid closing down trails or campsites in order to mitigate impacts. Some mitigation options might involve identifying times for viewing particular natural phenomena when ecological impacts are likely to be least, or somehow spreading out or diffusing the visitors in time or space to reduce their impacts.

Jon Percy – I sometimes get a bit concerned about the over emphasis on ecotourism as a commercial "product" or an economic development opportunity. I sometimes feel that governments and industry think that the "eco" in ecotourism stands for "economy" not "ecology".

At present around the upper Bay of Fundy there is no effective control of tourist access to shorebird bird roosting areas. We need to look at comparable wildlife areas, such as Cap Tourmente in Quebec, where a system of boardwalks and blinds allow tourists get close to the Snow Geese without disturbing their critical feeding. In Fundy, some critical shorebird areas should probably be declared off limits to visitors. Many of the existing shoreline areas that are designated as reserves are not really legally protected. One difficulty that sometimes arises is resistance from local communities to any sort of controls or regulations that limit their access to traditionally used shoreline areas.

Joel Richardson – New Brunswick is doing a good job in developing and promoting ecotourism. They are carrying out a lot of research on consumer preferences. Much of their product development is based on this consumer research. Surveys indicate that there are three main motives that bring people to New Brunswick: swimming beaches, whale watching and other natural attractions. New Brunswick Tourism can alter the exposure they give to a particular site or attraction in their various tourism promotion publications and thus change the relative positioning of any given product.

Colin MacKinnon – At Johnson's Mills, the Canadian Wildlife Service (CWS) has been working with the Nature Conservancy of Canada (NCC) and other groups for the last 10 years. Ten years ago there were no controls on visitor access in place. The village of Dorchester organized a shorebird "festival". They did this in consultation with CWS and the Tantramar Tourism Association. An old cottage was acquired and turned into an interpretation centre. It is important to continue building relationships with communities and non-governmental organizations such as the NCC. Expanding communications and dialogue with the growing tourism industry is also critical. One management option might be to encourage visitors interested in waterfowl to visit areas such as the Sackville Waterfowl Park and thus leave the hinterland areas of the Tantramar Marsh largely undisturbed.

Peter Williams – There is need for capacity building in the ecotourism industry. There are examples of local people making good, informed decisions in this regard. Sometimes there is a need to augment their knowledge about some of the newer things that are happening. An example of a community "doing the right thing" occurred in British Columbia where there is a land resource management planning (LRMP) Process. Prince Rupert residents are using the LRMP process to understand how best to incorporate cruise ship activity into their region. Communities can make good decisions but sometimes need a little support.

Question 4. *What specific strategies are there for the Bay of Fundy region to address potential environmental impacts?*

Sean Murphy – There is a need to increase the level of research activity, particularly multidisciplinary research in this area. Related to this is a requirement to improve the communication of research results and scientific information. On the positive side, there are many groups out there, such as various "friends of parks" organizations and other environmental groups, whose members are very knowledgeable and dedicated. We also need to encourage more collaborative activities with local communities.

Jon Percy – Coincidentally, 2002 has been designated as the Year of Ecotourism by the United Nations. One of the objectives is to raise awareness of the impacts of ecotourism on biodiversity. What are some of the other things that need to be done? There is a great need for education of tour operators and tourists about their possible impacts on the environment. There also has to be more dialogue with local communities that are likely to be affected by expanding ecotourism. The proposed Upper Bay of Fundy Biosphere Reserve might be a useful tool for doing this and for working towards sustainable ecotourism. The existing interactions between the Canadian Wildlife Service and the tourism industry needs to be continued and expanded in order to ensure that any growth in ecotourism is compatible with wildlife and habitat conservation.

Joel Richardson – It is good to see tourism on the agenda for a science workshop. Provincial, federal and municipal governments have to get more involved with the scientific community in order to raise awareness about the potential impacts of tourism on ecosystems.

Collin MacKinnon – The ACAP program is an ongoing experiment in environmental democracy. It is a community-based stakeholder initiative to take care of their own environment. The innovative process is still taking root and it is important that communities be given time to grow with it. It is also important to involve people and their communities in the research programs that are taking place in their area. Government people sometimes tend to exist in boxes, often with little contact with the local communities that are influenced by their activities and decisions. It is important that they do not burn bridges to the local communities and that they foster openness and dialogue in their dealings with them.

Peter Williams – If they are provided with the necessary resources and guidance students can assist greatly in field research and monitoring. We need to capitalize on our connections with universities to encourage more student participation. The participation of graduate students can make a great difference in carrying out research programs.

General Discussion

Judith Swindell – I appreciate that most people here see the world through their own eyes and in the light of their own experiences and backgrounds in the natural sciences. I see the world through the eyes of a social worker (crisis intervention and suicide prevention officer). To me, the most important consideration is the sustainability of human life and all the things that this entails, from agricultural jobs to recreational opportunities. We must fight to ensure that the process for developing ecotourism is truly democratic; a process in which people share their ideas, listen to others and work co-operatively together for the common good.

Brad Walters – What about the use of best practices and guidelines in ecotourism? Should we be thinking about regulating access to the use of this natural resource – if indeed it can be considered a resource-based industry? Or instead, should we be promoting voluntary, industry-led approaches to self-regulation?

Peter Williams – If the people involved in the industry do not believe in the fairness or efficacy of the regulations then they will cheat on them. Community-based regulatory systems work through voluntary monitoring of activities. People tend to follow the accepted guidelines because of a fear of being shamed or reproved by their peers and neighbours. This is what seems to be happening at Gwaii Haanas in British Columbia.

Jon Percy – In the outer Bay of Fundy, where whale watching has expanded rapidly in recent years, the tour boat operators have adopted a voluntary code of ethics concerning their interactions with the whales. Often, it is a few tourists who try to bend the guidelines by urging boat captains to approach closer to the whales than specified. However, the guidelines are usually posted prominently and most tourists are sufficiently environmentally aware to understand the need for such restrictions.

Tom Young – There is a new accreditation program for whale watch operators in the Bay of Fundy region of Nova Scotia and New Brunswick. Successful completion of the program leads to the designation of the business as a “Bay of Fundy Recommended Experience”. The process also includes a “mystery shop” evaluation by an “undercover tourist”. The adoption of the 16-point whale watch operator’s code of ethics are a part of this accreditation process.

Renee Wissink – I am a park ecologist at Fundy National Park where we have huge numbers of visitors every year. One important question is when do we reach the threshold of too many tourists for such an area to sustain? We need a much better and more comprehensive scientific assessment of thresholds of tourist numbers. Also, what efforts are the New Brunswick Department of Tourism making to assess the sustainability of new projects like the Fundy Trail Parkway?

Joel Richardson – The Fundy Trail Parkway is a private industry initiative, so New Brunswick Tourism has no direct control over it. However, there is an environmental assessment process for the project and we would expect to hear from Fundy National Park if there are any particular issues that need to be addressed.

Peter Williams – In these situations adequate collaboration often does not take place in a timely fashion.

Renee Wissink – We really need to sit down together with all the interest groups to discuss potential issues at the concept stage of any such large projects rather than waiting until it is designed and then use the environmental assessment process to check for potential issues.

Jon Percy – Years ago when I visited Mount McKinley Park in Alaska they were determined not to have the same problems of overuse by visitors that was plaguing Yellowstone and other national parks at that time. They controlled visitor access by using a shuttle bus system for travel within the Park.

Munju Ravindra – Are there any plans to consider such a system in Fundy and other Eastern Canadian Parks?
Not really.

Joel Richardson – At present in New Brunswick there is a moratorium on government financial assistance for campground development.

Summary Comment – Tom Young, Chair

Tourism in the Bay of Fundy is largely motivated by the extraordinary natural landscape of the Bay. With this in mind, tourism development representatives promote tourism development as a way to support the economies of local communities. Wildlife officials see the economic development agenda as a threat to the safety of vulnerable species and habitats. The purpose of this panel is to explore these two perspectives and share information, to better understand the issues in each case and to work towards a common sustainable tourism strategy. As a “shared” resource there must ultimately be a co-operative relationship between users and managers.

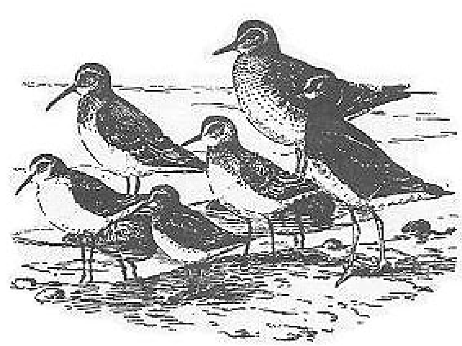
The topic of sustainable tourism is confused somewhat by the interpretation of the word eco-tourism. Ecotourism means environmentally responsible travel. But there is no control over who can use the word ecotourism, and its use is frequently the domain of marketers. Perhaps we should consider a sustainable tourism strategy that does not rely on this easily borrowed concept.

The one point that stands out among all the panellists is the need for local communities to become stewards of their local resources. There were a number of examples cited, but it was pointed out that this can take time to develop. The outcome of this panel generally suggests that a broad strategy can only work in conjunction with local community-based initiatives.

The Bay of Fundy Coastal Forum*

TAKING THE PULSE OF THE BAY

Co-Chairs: Janice Harvey, Conservation Council of New Brunswick, Waweig, New Brunswick
and
Peter G. Wells, Coastal and Water Science Section, Canadian Wildlife Service, Environmental Conservation Branch, Environment Canada, Dartmouth, Nova Scotia



* ***Note***: Full text of discussion and results of the Forum is being published as a separate report (04/04).

TAKING THE PULSE OF THE SEAS: CAN IT BE DONE?

J. B. (Jack) Pearce

Buzzards Bay Marine Laboratory, Falmouth, MA. buzbay@cape.com

During the almost half century that I have been concerned with marine habitat quality and fisheries, there have been numerous positive changes in pollution sources, fates and effects. To a great degree this has been the result of ongoing research and monitoring by academics, government agencies and environmental organizations. The question remains today, what else must be done? You will find this an interesting question.

The literature is 'fat' with published papers documenting the effects of contaminants and physical disruptions, as well as the interactions between these and the natural environment and certain cyclic environmental changes. Today I want to document how managers in recent years have measured the *health* of marine habitats and their contained living marine resources (LMR). By health I mean the assessment of "the condition of being sound in body ...; freedom from physical disease", or "the general condition of the body", i.e. the bodies of food chain organisms culminating in fish.

To assess relative health we must always keep in mind water quality, 'a peculiar and essential character', or 'an inherent feature'. What was the quality of the habitat *before* man compromised the water (or sediment) quality? This has most effectively been accomplished using 'case studies' and emphasizing 'historical perspectives'. The scientist-manager must be willing to accept that data and information from one habitat or zoogeographic region (or large marine ecosystem) can be used in another. Moreover, one must agree that changes observed or measured two centuries ago are valid today. In other words, we must think in the context of 'ecology through time'. Just such a program was suggested in a recent issue of *Science*, where Jackson et al. (2001) considered "Historical overfishing and the recent collapse of coastal ecosystems" and Sugden and Stone (2001) wrote on "Filling generation gaps", a short essay on long-term monitoring.

These thoughts were further elaborated upon in more recent issues of *Science* where an author, Malakoff (2002), suggests that scientists might be "Going to the edge to protect the sea" and other authors ask, "Can we defy nature's end?" (Pimm et al. 2001). To address the consequences of mankind's effects now, and in the future, scientists are considering new (and old) tools, high tech themes, and 'new ways forward'. As Editor of *Fishery Bulletin* and North American Editor of the *Marine Pollution Bulletin* I have, over the past decade, reviewed some 1,700 manuscripts dealing with these issues in some manner. My files suggest that I have read another 5,000+ titles published in other journals. Over the past half decade there has been a crescendo of titles in those fields concerned with 1) 'bioinvasions', changes in diversity, 2) use of refuges or reserves for management of marine species, 3) management and protection of marine mammals (and other endangered species), and 4) overfishing and its effects on target species, incidental catches, and habitat quality. I have found that it is nigh impossible for any one human to 'digest' the resulting voluminous literature, much less to summarize it effectively so as to allow for rational use of these data and information! Yet most of these papers and reports have, or will have, some applicability to the wide range of the marine environmental literature.

As this paper is being drafted, a new National Report – *The State of the Nation's Ecosystems* – is being published by the Heinz Center (see Shouse 2002). This report grew out of the interests of the White House Office of Science and Technology Policy and had, as an important component, the development of *indicators* which integrate "biophysical and sociocultural measures". Some scientists are negative about such recommendations because "no attempt is made ... to relate human activities to the changes in American ecosystems, and no attempt is made to evaluate the health of US ecosystems" (again, see Shouse 2002). Most of the remainder of this (my) paper deals with past attempts to demonstrate through history, and monitoring, how people's activities have compromised estuaries and marine habitats and their contained LMR.

Over two decades ago I was working in Washington, DC as Director of NOAA's National Estuarine Program Office. A colleague, and close friend, Dr. James Thomas, suggested that this then new NOAA office should organize a series of major seminars on the theme "NOAA's Estuarine Seminar of the Month". As these seminars were expedited, it emerged that it was possible to garner data of an historical nature which demonstrated clearly how and where urbanization and industrialization reduced the quality of estuarine and coastal habitats, and *measurably* affected the abundance and distribution of LMRs. One case study that I have used involves the whaling and fishing port, New Bedford, Massachusetts (see Pesch et al. 2001; Pesch and Garber 2001). Briefly, the authors have divided the ecological history of New Bedford into four eras or periods: agriculture, 1650–1780; whaling, 1750–1900; textile, 1880–1940; and post-textile, 1940–present, which involved electrical equipment manufacturing, increased harbour modifications, and transportation infrastructure. Although I will use some 40 viewgraphs in my oral presentation, a few from New Bedford Harbour can serve here to detail how coastal habitats change with development! Pesch and her co-workers have done an admirable job in using indicators of development *and* simultaneous habitat degradation to suggest future management steps necessary to preventing further habitat degradation and losses of LMRs. Figures 1–6 include some variables that indicate degradation in the context of time.

In addition to having an *historical understanding* of habitat quality and the status of the biota, agencies responsible for management of LMRs, and the status of habitats, must have current information on key variables, i.e. those biological, chemical, geological and physical parameters necessary to assess the health of estuaries, coastal and marine ecosystems. The Heinz Report – *The State of the Nation's Ecosystems* – notes that many variables necessary to an assessment of environmental health are NOT being measured, or are being measured so infrequently or inefficiently that the data are meaningless (see Heinz Center 2002)! This situation has continued for some four decades in spite of the implementation nationally and internationally of scores of marine monitoring and research programs. Recognizing the need to understand the status of key variables in specific zoogeographic provinces, 'large marine ecosystems' and fishery management areas, the Northeast Fisheries Center of the National Marine Fisheries Service (NMFS) commissioned *Characterizations of the Middle Atlantic Wa-*

ter Management Unit and Gulf of Maine (see Pacheco 1988; Reid, Ingham and Pearce 1987). Agencies in Canada and northern Europe were doing and have done much the same. Most recently, the Northeast Fisheries Science Center has produced the reference document, *Status of the Northeast US Continental Shelf Ecosystem* (Link and Brodziak 2002), an update on the earlier *Characterizations*.

More recently, the concept of the large marine ecosystem (LME) has been elaborated upon by Sherman and Skjoldal (2002). This latest volume in a series addresses changes in environmental quality and resource status in certain LMEs of northern Europe. Particular emphasis is now placed on *sustainability* as based on information from studies of: 1) productivity, 2) fish and fisheries, 3) pollution and ecosystem health, 4) socio-economics, and 5) governance (management?). Almost simultaneously, Elsevier has published its *Seas at the Millennium: An Environmental Evaluation* (Sheppard 2000). A three volume set, the title includes 106 chapters covering "manageable regions" around the world, and in all hemispheres. A much smaller volume, published by the Worldwatch Institute, provides a wealth of information on *Safeguarding the Health of the Oceans* (McGinn 1999). Again, McGinn 1) covers the world's seas, with illustrations of "hot spots", 2) discusses the bridging of information gaps (similar to the Heinz Report), and 3) considers international policies and national and local efforts to "protect oceans".

Finally, almost all chapters in titles noted above ultimately conclude that the principal issues bearing on habitat quality and status of LMRs are centered in *overpopulation* (and over use of resources) and *urbanization*. The Worldwatch Institute, again, addresses the latter in its small volume, *Reinventing Cities for People and the Planet* (O'Meara 1999). Its basic conclusion is that if we are to manage, effectively, the coastal zone we *must* change how we allow our cities and industry to grow. Urban and industrial planning and population planning are *absolutely essential*, and not only in the coastal zone but in all riparian habitats leading to the seas; river basins are key "conduits" for contaminants from inland areas.

Because *almost* all the above reports and advisories are critical of past research and monitoring, it is essential that future research and habitat monitoring address the concerns brought forth from this late twentieth century introspection. It is particularly important that interagency and international monitoring programs 1) review past monitoring and research, 2) identify appropriate historical and case studies and 3) make those adjustments necessary to ensure that *all* data collected will be meaningful, and useful, to the processes of management, prevention and rehabilitation.

A starting point in these regards is the use of papers such as the ICES volume *Biological Effects of Marine Pollution and the Problems of Monitoring* (McIntyre and Pearce 1980). Although written two decades ago, its focus was the defining of adequate monitoring strategies, a problem as current today as in 1979 when the workshop was held at the Duke University Marine Lab. Working within the structure of the Marine Environmental Quality Committee (MEQC) of the International Council for the Exploration of the Seas (ICES), we established that responses to contaminants and habitat degradation were best measured in the field, where *changes* in population dynamics and structure could be observed and measured *at the same time* as toxicity of contaminants, nutrient overloading and stress due to physical degradation. Since then, scores, yes hundreds, of volumes have been written on the subject of environmentally appropriate research and monitoring. The monitoring of fish stocks has continued from 1963 to the present using the same sampling gear. But even with robust biannual cruises, and consistent use of sampling gear, the *exigencies* of the fisheries and fishing community may force the adoption of new methodologies (see Frasier 2002): Science, especially applied science tangential to 'economics', is rarely simple or straightforward (see Bonner 2002)! The earlier mentioned volume, *The State of the Nation's Ecosystems*, in Chapter 5, "Indicators of the Condition and Use of the Coasts and Oceans", now suggests that past indicators and research may not be useful in assessing the status of habitats and contained LMRs (Heinz Center 2002). This will surely be questioned by the hundreds of scientists and agencies which have conducted and sponsored thousands of research projects in order to evaluate man's effects on marine and estuarine habitats.

For my part I remain convinced that many programs have measured successively and successfully short and long-term changes in habitats and the contained biota. In fact, we *have* frequently taken the *pulse* of the seas. Moreover, many of the past studies have yielded data and findings which form the base and indicators for future long-term monitoring and research. What we must do now is to effectively educate the public and body politic as to the significance of past and future findings! As I read the final hand draft, my radio tells me that our local Congress-person has just countered a judicial decision to restrain fishing so as to maintain some semblance of fish stocks in the northeast. It is more important (politically?) to him to support a crowd of marginal fishers, rather than use excellent science to manage the fisheries!

Literature Cited

Bonner, J. 2002. *Lives of a Biologist: Adventures in a Century of Extraordinary Science*. Harvard University Press, Cambridge, MA. 215 pp.

Fraiser, D. 2002. Enmeshed in dispute. *Cape Cod Times*, 3 October, Hyannis, p. 1.

Heinz Center. 2002. *The State of the Nation's Ecosystems*. The H. John Heinz Center for Science, Economics and the Environment, Washington, DC. 270 pp.

Jackson, J. and 18 co-authors. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629–638.

Link, J. and J. Brodziac (Eds.). 2002. *Status of the Northeast US Continental Shelf Ecosystem*. NMFS/NOAA Northeast Fisheries Science Center (Woods Hole) Reference Document 02-11. 245 pp.

Malakoff, D. 2002. Going to the edge to protect the sea. Science 296: 459–461.

McGinn, A. 1999. *Safeguarding the Health of Oceans*. Worldwatch Paper 145. The Worldwatch Institute, Washington, DC. 87 pp.

McIntyre, A. and J. Pearce. 1980. *Biological Effects of Marine Pollution and the Problems of Monitoring. Proceedings from an ICES Workshop, Beaufort, NC, 26 February - 2 March 1979.* ICES, Copenhagen. 350 pp.

O'Meara, M. 1999. *Reinventing Cities for People and the Planet*. Worldwatch Paper 147. The Worldwatch Institute, Washington, DC. 94 pp.

Pacheco, A. (Ed.). 1988. *Characterization of the Middle Atlantic Water Management Unit of the Northeast Regional Action Plan*. NOAA Technical Memo NMFS-F/NEC-56, Woods Hole, MA. 322 pp.

Pesch, C., R. Voyer, J. Copland and J. Lund. 2001. *Imprint of the Past: Ecological History of New Bedford Harbour*. US Environmental Protection Agency, Region 1, New England, Narragansett, RI. Lab. Paper 901-R-01-003.

Pesch, C. and J. Garber. 2001. Historical analysis, a valuable tool in community-based environmental protection. Marine Pollution Bulletin 42(5): 339–349.

Pimm, S. and 32 co-authors. 2001. Can we defy nature's end? Science 293: 2207–2208.

Reid, R., M. Ingham and J. Pearce (Eds.). 1987. *NOAA's Northeast Monitoring Program: A Report on Progress of the First Five Years (1979–84) and a Plan for the Future*. NOAA Technical Memo NMES-F/NEC-56, Woods Hole, MA. 138 pp.

Sheppard, C. (Ed.). 2000. *Seas at the Millennium: An Environmental Evaluation*, Vols. 1-3. Pergamon (Elsevier) Press, Amsterdam. 2080+ pp.

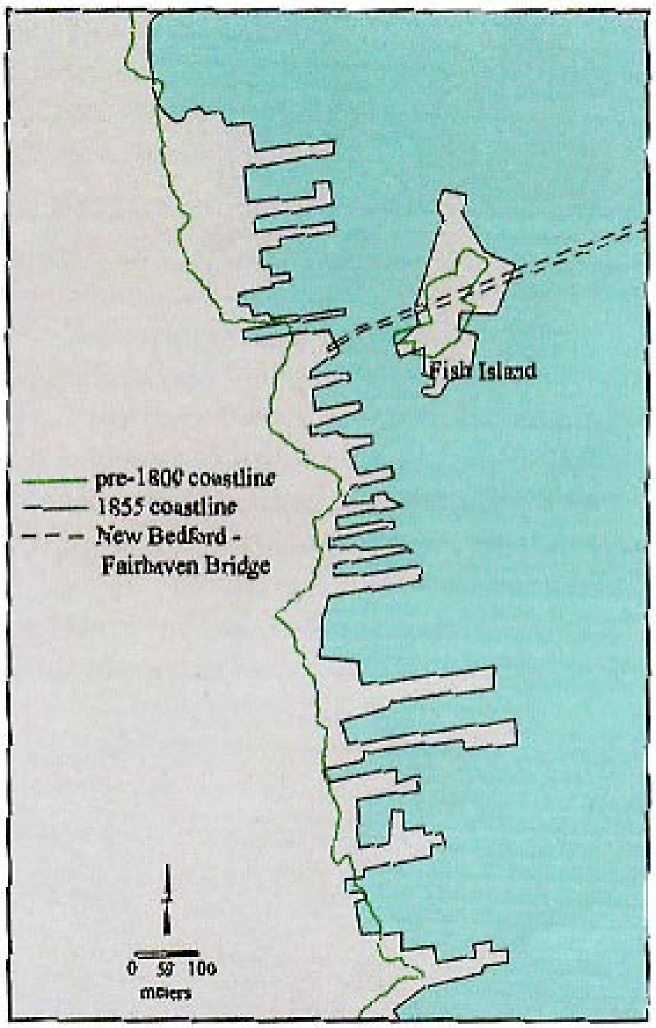
Sherman, K. and H. Skjoldal. 2002. *Large Marine Ecosystems: Changing States and Sustainability*. Elsevier, Amsterdam. 449 pp.

Shouse, B. 2002. Report takes stock of knowns and unknowns. Science 297: 2191.

Sugden, A. and R. Stone. 2001. Filling generation gaps. Science 293: 623.

Voyer, R., C. Pesch, J. Garber, J. Copland, and R. Comeleo. 2000. New Bedford, Massachusetts: A story of urbanization and ecological connections. Environmental History 5(3): 352–377.

Figure 1. The coastline in 1855 (surveyed by H. F. Hatting) shows that a considerable number of wharfs were built and some land gained since before 1800 (coastline from map of Original Purchasers of lots in New Bedford, 1753 to 1815, E. C. Leonard) when no wharves were present. (From Pesch et al. 2001.)



Reproduced with permission of D. Pesch

Figure 2. During the mid-nineteenth century, industries along the coast in what is now the historic section of New Bedford. Most industries not directly on the shore or a stream had access to the sewer system, which was installed in 1852. Sewer lines were located on east-west orientated streets and emptied directly into the harbour. (From Pesch et al. 2001)

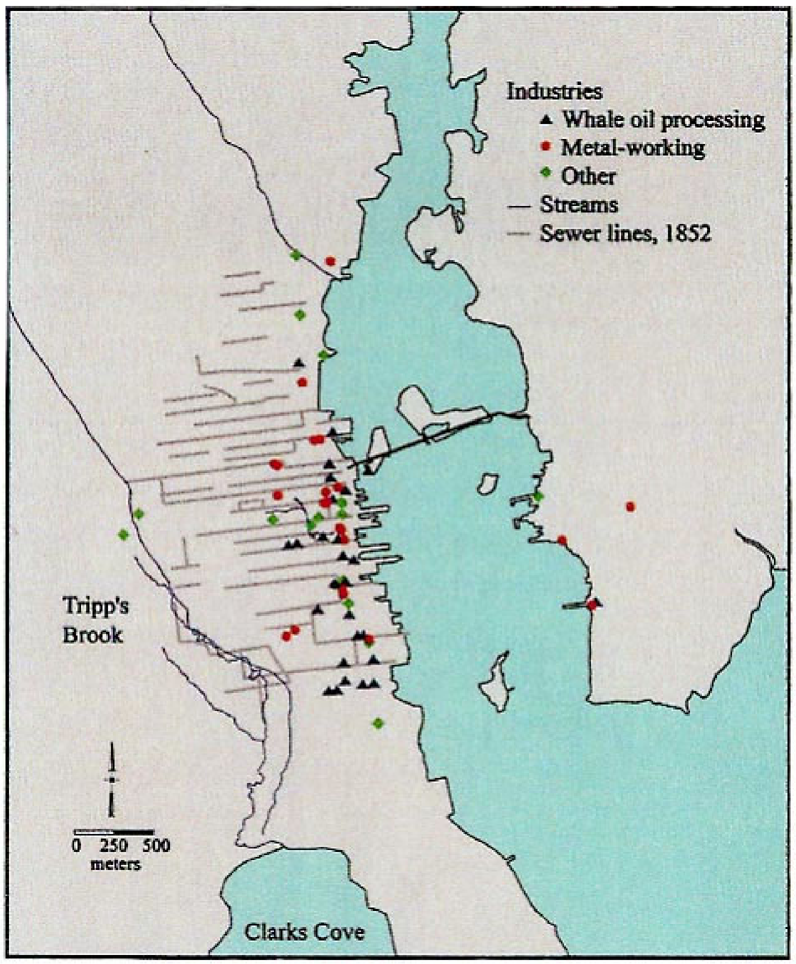
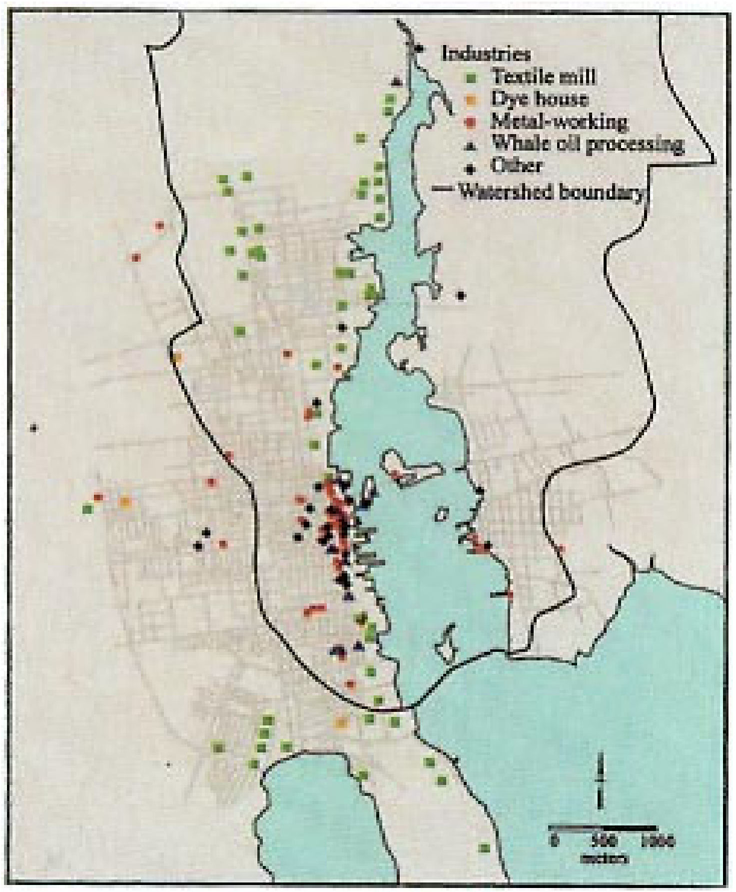
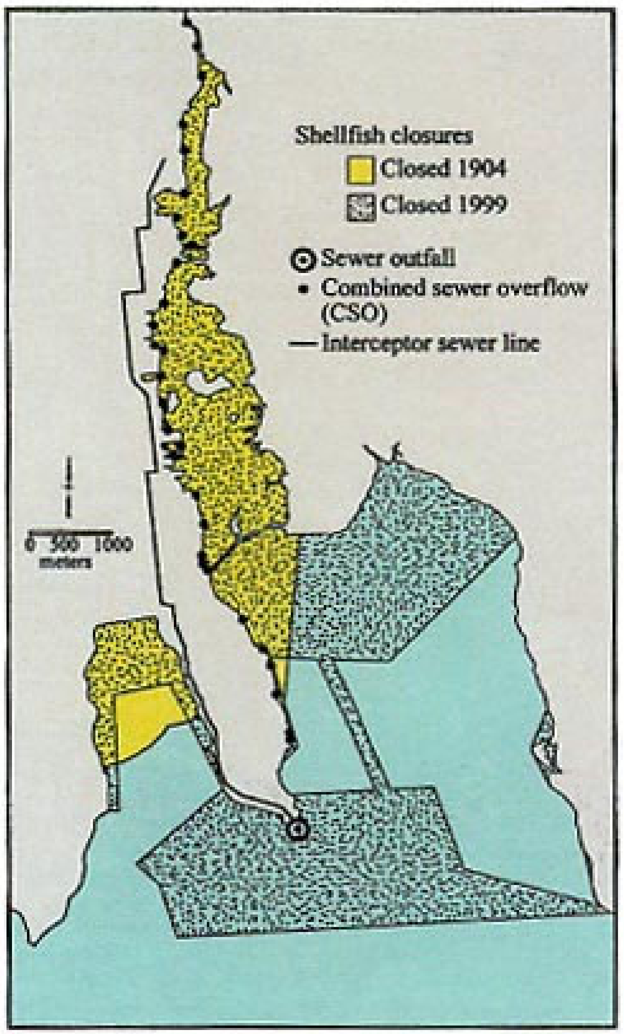


Figure 3. Locations of industries that may have released pollution during the textile period (1880–1940). (From Pesch et al. 2001)



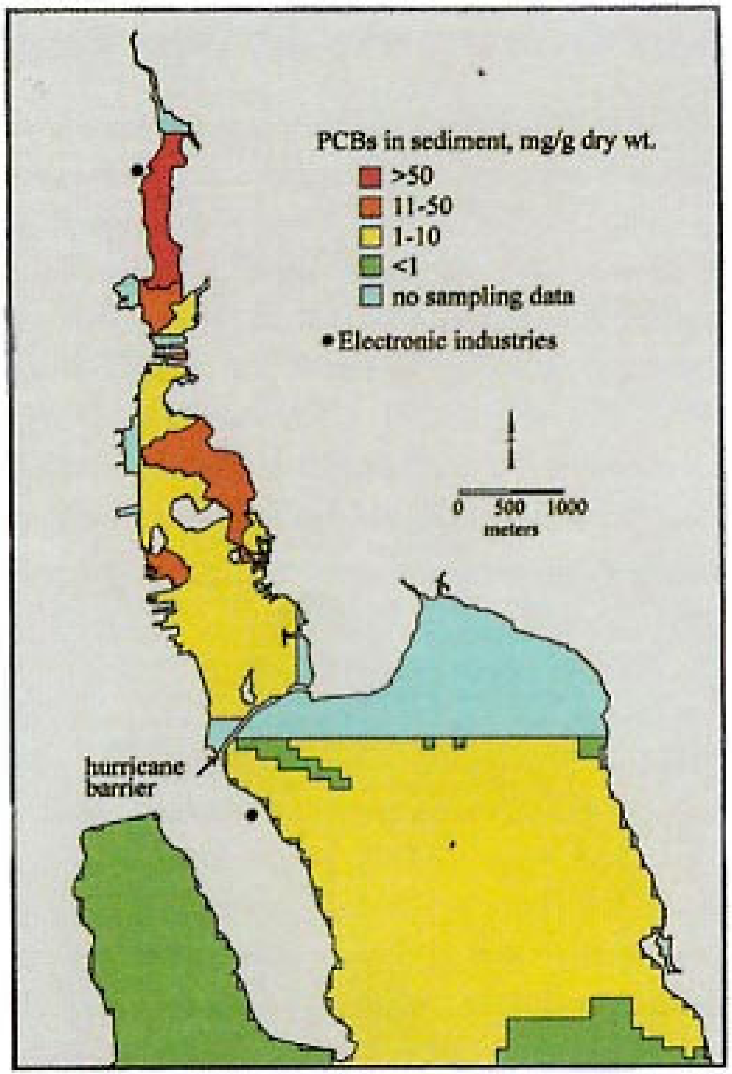
Reproduced with permission of D. Pesch

Figure 4. The State Board of Health closed the Acushnet River to shellfishing in 1904 and that section has remained closed since then. Raw sewage still enters the harbour through combined sewer overflows (CSOs) during periods of high rainfall. Additional areas in the outer harbour were closed after the interceptor sewer line diverted the outfall off Clarks Point. On this map, the four classifications for shellfish closures for 1999 were collapsed into two groups: open (approved and conditionally approved) and closed (prohibited and restricted). (From Pesch et al. 2001)



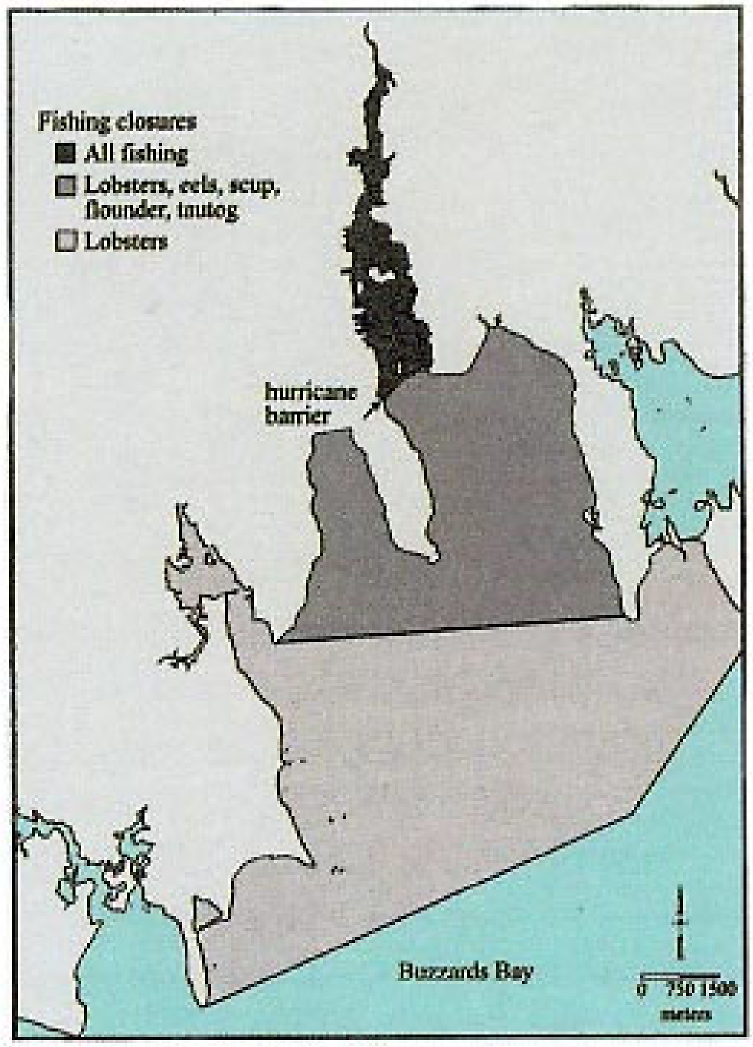
Reproduced with permission of D. Pesch

Figure 5. Concentrations of PCBs in sediments in New Bedford Harbour were exceedingly high in the upper harbour adjacent to the electronics part manufacturing company. (From Pesch et al. 2001)



Reproduced with permission of D. Pesch

Figure 6. In 1979, the harbour and areas south of the hurricane barrier were closed to fishing and/or shellfishing because PCB residue in fish and shellfish exceeded the FDA action level of 5 mg/kg. (From Pesch et al. 2001)



Reproduced with permission of D. Pesch

TWO HUNDRED YEARS OF ECOSYSTEM CHANGE IN THE OUTER BAY OF FUNDY PART I – CHANGES IN SPECIES AND THE FOOD WEB

Heike K. Lotze[1], Inka Milewski[2] and Boris Worm[1]

[1] Department of Biology, Dalhousie University, Halifax, NS. hlotze@is.dal.ca
[2] Conservation Council of New Brunswick, Fredericton NB. milewski@nbnet.nb.ca

Abstract

The Quoddy Region and Grand Manan Archipelago form a hotspot of marine species diversity and productivity in the Northwest Atlantic. We present the history of major human impacts and their consequences on the ecosystem over the last centuries. Using all available data, we reconstructed historical changes that occurred in species of all trophic levels, from phytoplankton and invertebrates up to fish, birds and mammals.

Selective fishing and hunting, and increasing effort, efficiency, and spatial extent of exploitation over time resulted in marked declines of target species abundance and size. This resulted in major shifts in dominance patterns and food-web structure, and shifts from high to low trophic level harvesting. Habitat degradation and destruction and chemical contamination reduced the amount of critical spawning, breeding, nursing, and feeding habitat. Multiple pollutants affected health, survival and reproduction of many species, and increasing human activities in coastal waters enhanced the level of stress and disturbance. Nutrient loads altered phytoplankton and phytobenthos communities, thereby favouring less edible or toxic species and mass occurrences of annual seaweeds. We demonstrate that this unique ecosystem over time expressed well-known signs of degradation typical for human-impacted coastal waters worldwide. Multiple human impacts affected species and their interactions on all trophic levels. This reduced productivity of traditional fisheries and predictability of the ecosystem. Compared to other degraded ecosystems, however, there is still potential to sustain a diverse and productive marine flora and fauna which could be restored if wise management actions are chosen.

Introduction

The Quoddy Region and the Grand Manan Archipelago form a hotspot of marine species diversity and productivity in the Northwest Atlantic. Ocean currents and circulation patterns, high tides, upwelling, and short, energy-efficient food chains support high concentrations of primary and secondary producers (Hardie 1979; Thomas 1983; Lotze and Milewski 2002). These lower trophic level species attract a wide range of birds, predatory fish and mammals which depend on the area for at least part of their life. In addition to the rich food supply, the diverse underwater and terrestrial landscapes provide an extraordinary variety of habitats fulfilling the species-specific needs for breeding, spawning, nursing, foraging, hiding and resting (Hardie 1979; Thomas 1983; Lotze and Milewski 2002). This habitat diversity, combined with the rich food supply, maintain the hotspot diversity and productivity.

Human Activities in Coastal Waters

The archeological record shows that Indigenous peoples have recognized and valued these diverse and abundant marine resources for several thousand years. Around Passamaquoddy Bay, prehistoric people focussed especially on marine resources and used a more diverse shellfish fauna than their neighbours in the Maritimes and Maine. Their distinct lifestyle was recognized as the 'Quoddy Tradition' in the Maritime Woodland period (2200-350 B.P.) (Black and Turnbull 1986). In their words, 'Passamaquoddy' denotes a "bay full of pollock" and "fishers of pollock" (Gatschet 1897). As hunters and gatherers, they targeted species from all trophic levels at low rates due to simple fishing and hunting methods and low population size. Therefore, we may describe them as 'low-impact omnivores'. Faunal remains from archaeological sites suggest that large cod, pollock and herring were used as food resources for more than 4,000 years without a visible decrease in body size, usually the first sign of overfishing (Black and Turnbull 1986; Spiess et al. 1990; Steneck 1997).

With European settlement in the late 18th century and subsequent industrialization in the late 19th century, human activities have altered this ecosystem at a rapidly increasing rate. Fishing and hunting pressure as 'top-down' impacts increased, especially on large species that were easy to catch. Whales were hunted from shore operations, seals were hunted for a bounty, and Harbour Porpoises were hunted by native people to trade oil with the Europeans (Ingersoll and Gorham 1978; Gaskin 1983; Percy 1996b). Birds were hunted heavily for food, but egg and down collection also occurred (Christie 1979). Large groundfish, especially cod and pollock were caught in the area, and herring was fished for bait (Perley 1852; Huntsman 1953). Thus, humans became 'top predators' in the food web, and by 1900 they had almost extirpated many birds and mammals.

In the case of fish, the first signs of overexploitation could be observed around 1900, when clear shifts in size distribution were observed. The size of cod and pollock strongly declined and the herring fishery shifted from large adults to medium "stringers" and further to small "sardines" (Perley 1852; Huntsman 1953). In the early 20th century, legal protection for some birds and mammals initiated slow recovery of some top predators. However, humans increased their pressure on fish, especially groundfish and herring through increasing effort, efficiency and spatial extent of fishing grounds (Steneck 1997, Percy 2000). Humans became 'highly efficient top predators'. Finally in the 1970s, a strong decline in abundance of groundfish and herring could be observed (Lotze and Milewski 2002). These strong recent declines or collapses of certain fisheries may be not only the result of actual high fishing pressure, but also of overfishing for decades and even centuries in the past. Jackson et al. (2001) suggested that extended time lags might occur between the onset of overfishing and the visible consequences. In our study area, the decline in formerly dominant groundfish species such as pollock and cod resulted in a shift in dominance patterns. Dogfish, hake and small groundfish such as sculpins increased in abundance over the last 20 years (Lotze and Milewski 2002).

The scarcity of traditionally abundant and valuable species induced the search for new resources and a shift to low-trophic level harvesting. Over the last 10–20 years, new fisheries for crabs, sea urchins and rockweed were developed, while traditional fisheries for periwinkles, scallops and lobster were intensified (Lotze and Milewski 2002). Further plans to develop fisheries for sea cucumbers, krill and mussels exist (Percy 1996a). This increasing exploitation of species at lower and lower levels of the food web has been identified as a global pathology, called "fishing down the food web" (Pauly et al. 1998). Many of these species are important prey or (in the case of rockweed) habitat-building species for upper trophic levels, including those species which were the traditional targets of the fishery. On the other hand, the fishery for large pelagic fish such as tuna, swordfish and sharks is of renewed interest.

Human Impacts in Coastal Waters

Around 2000, humans became 'top omnivores' targeting all trophic levels with increasing intensity. These strong top-down impacts resulted in clear shifts in food-web structure and species interactions. The loss or decline of high trophic level species resulted in shifts in species composition at the same and lower trophic levels because of the release from competition and predation pressure. In extreme cases, successive changes can be observed at several lower trophic levels known as "trophic cascades" (Steneck 1998).

In addition to top-down impacts, humans activities also altered species composition and productivity by 'bottom-up' impacts such as nutrient enrichment and shifts in nutrient ratios (N:P:Si). Nutrient sources include sewage, aquaculture (fish food, fish excrements), municipal runoff (garden and lawn fertilizer), organic discharges (food processing plants, pulp and paper mills), agricultural runoff (fertilizer, animal waste), burning of fossil fuel and atmospheric deposition (Bricker et al. 1999). This over-enrichment of the environment with the limiting plant nutrients nitrogen and phosphorus has severe consequences on the species composition and productivity among primary producers. Compared to the 1930s, we find a clear shift in the phytoplankton community from non-harmful diatom dominance to increasing amounts of less edible or toxic diatoms and dinoflagellates (Gran and Braarud 1935; Martin et al. 1999). In the phytobenthos, altered nutrient conditions result in a decline of long-lived rockweeds and eelgrasses, an increase in the amount of annual algal blooms, and partially a shift to the dominance of filter feeders. These changes are most visible close to nutrient point sources such as sewage outlets or fish farms (Worm 2000; Worm and Lotze 2000). In a recent eutrophication survey of estuaries in the United States, the St. Croix River/Cobscook Bay estuary was listed among the 44 out of 138 estuaries which showed the highest levels of expression of eutrophic conditions, which were expected to worsen towards 2020 (Bricker et al. 1999). Wastewater treatment plants were listed as the most important measure to mitigate nutrient inputs into rivers and the sea (Bricker et al. 1999).

When Europeans settled in the area, their activities led to a successive alteration, degradation and destruction of the coastal environment, which reduced habitat availability, heterogeneity and complexity, as well as sediment and water quality. Damming of rivers, settlement on islands, coastal constructions, dyking and draining of wetlands, bottom trawling and dragging, aquaculture operations, and other activities reduced the overall amount of undisturbed high-quality habitat in rivers, on land, and in the sea (Percy 2000). Organic loads from pulp and paper mills, lumber harvest, fish processing plants and aquaculture operations decrease water quality and clarity and degrade benthic habitat (Wildish et al. 1993; Pohle 1999). Chemicals from municipal and industrial discharges impair health, fecundity and survival (Wells et al. 1997). Moreover, increasing boat traffic, increasing noise, light and smell 'pollution', and increasing human recreational activities such as whale, seal and bird watching increase the level of stress for animals (Percy 1996b). All these impacts can be called 'side-in' impacts, which have severe consequences on the extent and quality of habitat for reproduction and recruitment (breeding, spawning, nursery), feeding and foraging, refuge from predators, and simply living (e.g., settling, growing, staging, resting, wintering) (Rangeley 1994, 2000; Percy 2000). For example, during several periods in the past, the St. Croix and Magaguadavic Rivers were not accessible (dams without functioning fishways) or had lethal water conditions to anadromous fish such as Atlantic salmon and gaspereau (Marshall 1976). Human settlements on shorelines and islands destroyed breeding colonies of many birds (Christie 1979). Dragging and trawling, as well as recent rockweed harvesting, destroys important three-dimensional seafloor habitat (kelps, rockweed, eelgrass, mussel reefs, sponges, corals) for recruitment, nursery and feeding as well as refuge for many fish, bird and invertebrate species, many of which are of commercial interest (Rangeley 1994, 2000; Steneck 1997; DFO 1999; Percy 2000). Many aquaculture operations are located within important feeding, nursing and recruitment habitat for fish, birds, mammals, and lobsters.

In essence, the hotspot of marine diversity and productivity became also a hotspot of human activities. Over time, this unique ecosystem expressed some well-known signs of degradation, which are typical for human-impacted coastal waters worldwide (Vitousek et al. 1997; Pauly et al. 1998; Jackson et al. 2001). Unfortunately, many human activities concentrate within critical habitats that are used by many species at once such as West Isles archipelago, Grand Manan Archipelago, the Wolves and Maces Bay (Lotze and Milewski 2002).

Conclusion

Today, most species are simultaneously affected by multiple top-down, bottom-up and side-in effects that can create synergistic and feed-back effects. The cumulative effects of multiple human stressors on single species and entire food webs are hardly—if at all—predictable on the base of our current knowledge of species and food-web interactions (Worm and Lotze 2000; Lotze and Milewski 2002). This has important implications for any attempt of 'species' or 'ecosystem management'. It might be more appropriate to consider strategies for 'human-impact management'. Any integrated management approach should include not only the diverse human interests but also the critical needs of marine species such as adequate food and habitat and undisturbed space and time (Lotze and Milewski 2002).

Although human impacts widely affect coastal ecosystems, there are some encouraging conservation and restoration successes. In the Quoddy and Grand Manan regions, protection efforts enabled many birds and some mammals to recover (Christie 1979; Lotze and Milewski 2002). Periods of lower fishing pressure during World War II and after the extension of the 200-mile limit in the 1970s have enabled fish stocks to increase in abundance until fishing effort increased again (Lotze and Milewski 2002). Restoration of river habitat and effective fishways enabled gaspereau populations to increase (Lotze and Milewski 2002). The use of acoustic 'pingers' in gill nets reduces the by-catch of Harbour

Porpoise (Trippel et al. 1999). In other marine habitats, effective sewage treatment plants reduced nutrient loads in the Baltic (Savchuk and Wulff 1999). Designation of protection zones resulted in the recovery of benthic habitat and the increase in fish biomass in tropical and temperate marine reserves, with beneficial effects on adjacent fisheries (Roberts and Hawkins 2000; Roberts et al. 2001). Therefore, we strongly recommend reducing the use of destructive and unselective fishing gear, protecting critical habitats, reducing nutrient pollution and chemical contamination, and reducing stress and disturbance on species.

For the full report on this topic refer to: Lotze H.K. and I. Milewski. 2002. Two-hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy. Conservation Council of New Brunswick, Fredericton, New Brunswick, 188 pp.

References

Black, D. W. and C. J. Turnbull. 1986. Recent archaeological research in the insular Quoddy region, New Brunswick, Canada. Current Anthropology 27: 400–402.

Bricker, S. B., C. G. Clement, D. E. Pirhalla, S. P. Orlando and D. R. G. Farrow. 1999. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, Silver Spring, MD.

Canada. Department of Fisheries and Oceans (DFO). 1999. *The Impact of the Rockweed Harvest on the Habitat of Southwest New Brunswick*. DFO Maritimes Regional Habitat Status Report 99/2E. Maritime Regional Advisory Process, Department of Fisheries and Oceans, Dartmouth, NS.

Christie, D. S. 1979. Changes in maritime bird populations, 1878–1978. Journal of the New Brunswick Museum 1979: 132–146.

Gaskin, D. E. 1983. The marine mammal community. Pages 245–268. In: *Marine and Coastal Systems of the Quoddy Region, New Brunswick*. M. L. H. Thomas (Ed.). Canadian Special Publication of Fisheries and Aquatic Sciences 64. Department of Fisheries and Oceans, Ottawa.

Gatschet, A. S. 1897. All around the Bay of Passamaquoddy – with the interpretation of its Indian names of localities. National Geographic Magazine 8: 16–24.

Gran, H. H. and T. Braarud. 1935. A quantitative study of the phytoplankton in the Bay of Fundy and the Gulf of Maine (including observations on hydrography, chemistry and turbidity). Journal of the Biological Board of Canada 1: 279–467.

Hardie, D. 1979. West Isles natural area of Canadian significance. Pages 101–107. In: *Evaluation of Recent Data Relative to Potential Oil Spills in the Passamaquoddy Area*. D. J. Scarratt (Ed.). Fisheries and Marine Services Technical Report 901. Fisheries and Marine Services, St. Andrews, NB.

Huntsman, A. G. 1953. Movements and decline of large Quoddy herring. Journal of the Fisheries Research Board of Canada 10: 1–50.

Ingersoll, L. K. and S. W. Gorham. 1978. A history of the mammals of Grand Manan. Grand Manan Historian 20: 31–54.

Jackson, J. B. C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J. Bourque, R. H. Bradbury, R. Cooke, J. Erlandson, J. A. Estes, T. P. Hughes, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. A. Tegner and R. R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629–638.

Lotze H. K. and I. Milewski. 2002. *Two Hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy*. Conservation Council of New Brunswick, Fredericton, NB. 188 pp.

Marshall, T. L. 1976. *Historical Perspectives of Resource Development Branch Activities in Restoring Anadromous Fishes to the St. Croix River, New Brunswick – Maine*. Internal Report Series MAR/I 76-2. Freshwater and Anadromous Division, Resource Branch, Fisheries and Marine Service, Halifax, NS. 30 pp.

Martin, J. L., M. M. LeGresley, P. M. Strain and P. Clement. 1999. Phytoplankton Monitoring in the Southwestern Bay of Fundy during 1993–96. Canadian Technical Report on Fisheries and Aquatic Sciences 2265. 132 pp.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese and F. Torres Jr. 1998. Fishing down marine food webs. Science 279: 860–863.

Percy, J. A. 1996a. Expanding Fundy's harvest – Targeting untapped treasures. Fundy Issues, Bay of Fundy Ecosystem Partnership fact sheet 10. URL: <http://www.auracom.com/~bofep/underuti.htm>. Date accessed: 3 September 2002.

Percy, J. A. 1996b. Right Whales – Wrong places? North Atlantic Right Whales in the Bay of Fundy. Fundy Issues, Bay of Fundy Ecosystem Partnership fact sheet 6. URL: <http://netshop.net/~bofep/right.htm>. Date accessed: 3 September 2002.

Percy, J. A. 2000. Fishing in Fundy - Harming seafloor habitats? Fundy Issues, Bay of Fundy Ecosystem Partnership fact sheet 14. URL: <http://www.auracom.com/~bofep/Publications/Fundy%20issues/disturbance.htm>. Date accessed: 3 September 2002.

Perley, M. H. 1852. *Reports on the Sea and River Fisheries of New Brunswick*. Queen's Printer Fredericton, NB. 294 pp.

Pohle, G. 1999. Benthos Assessment at Fallow Sites. Final Report to the New Brunswick Department of Fisheries and Aquaculture. Atlantic Reference Centre, Huntsman Marine Science Centre, St. Andrews, NB. 39 pp.

Rangeley, R. W. 1994. The effects of seaweed harvesting on fishes: A critique. Environmental Biology of Fish 39: 319–323.

Rangeley, R. W. 2000. Aquatic macrophytes as foraging and refuging habitats for fish. Pages 18-23. In: *Gulf of Maine Rockweed: Management in the Face of Scientific Uncertainty*. R.W. Rangeley and J. Davies (Eds.). Huntsman Marine Science Centre Occasional Report 00/1. Huntsman Marine Science Centre, St. Andrews, NB.

Roberts, C. M. and J. P. Hawkins. 2000. *Fully-protected Marine Reserves: A Guide*. WWF Endangered Seas Campaign, 1250 24th Street, NW, Washington, DC 20037, USA and Environment Department, University of York, York, Y010 5DD, UK.

Roberts, C. M., J. A. Bohnsack, F. Gell, J. P. Hawkins and R. Goodridge. 2001. Effects of marine reserves on adjacent fisheries. Science 294: 920–1923.

Savchuk, O. and F. Wulff. 1999. Modelling regional and large-scale response of Baltic Sea ecosystems to nutrient load reductions. Hydrobiologia 393: 35–43.

Spiess, A. E., E. Trautman and T. Kupferschmid. 1990. Prehistoric Occupation at Reversing Falls. Unpublished file report, Maine Historic Preservation Commission, Augusta, Maine, 28 pp.

Steneck, R. S. 1997. *Fisheries-induced Biological Changes to the Structure and Function of the Gulf of Maine Ecosystem. Proceedings of the Gulf of Maine Ecosystem Dynamics Scientific Symposium and Workshop, Hanover, NH*. Regional Association for the Research on the Gulf of Maine (RARGOM Report 91-1).

Steneck, R.S. 1998. Human influences on coastal ecosystems: does overfishing create trophic cascades? Trends in Ecology and Evolution 13(11): 429–430.

Thomas, M. L. H. 1983. *Marine and Coastal Systems of the Quoddy Region, New Brunswick*. Canadian Special Publication of Fisheries and Aquatic Sciences 64. 306 pp.

Trippel, E. A., M. B. Strong, J. M. Terhune and J. D. Conway. 1999. Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56: 113–123.

Vitousek, P. M., H. A. Mooney, J. Lubchenco and J. M. Melillo. 1997. Human domination of Earth´s ecosystems. Science 277: 494–499.

Wells, P. G., P. D. Keizer, J. L. Martin, P. A. Yeats, K. M. Ellis and D. W. Johnston. 1997. The chemical environment of the Bay of Fundy. Pages 37–61. In: *Bay of Fundy Issues: A Scientific Overview. Proceedings of a workshop, January 29–February 1, 1996, Wolfville, NS*. J. A. Percy, P. G. Wells and A. J. Evans (Eds.). Environment Canada Atlantic Region Occasional Report No. 8. Environment Canada, Atlantic Region, Environmental Conservation Branch, Sackville, NB.

Wildish, D. J., P. D. Keizer, A. J. Wilson and J. L. Martin. 1993. Seasonal changes of dissolved oxygen and plant nutrients in seawater near salmonid net pens in the macrotidal Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 50: 303–311.

Worm, B. 2000. *Consumer Versus Resource Control in Rocky Shore Food Webs: Baltic Sea and NW Atlantic Ocean*. Berichte aus dem Institut für Meereskunde 316. Institut für Meereskunde, Universität Kiel, Kiel. 147 pp.

Worm, B. and H. K. Lotze. 2000. Nutrient pollution, low-trophic level harvesting and cumulative human impact on coastal ecosystems. Pages 40–41. In: *Gulf of Maine Rockweed: Management in the Face of Scientific Uncertainty*. R.W. Rangeley and J. Davies (Eds.). Huntsman Marine Science Centre Occasional Report 00/1. Huntsman Marine Science Centre, St. Andrews, NB.

TWO HUNDRED YEARS OF ECOSYSTEM CHANGE IN THE OUTER BAY OF FUNDY PART II – A HISTORY OF CONTAMINANTS: SOURCES AND POTENTIAL IMPACTS

Inka Milewski[1] and Heike K. Lotze[2]

[1] Conservation Council of New Brunswick, Fredericton, NB. ccnb@nbnet.nb.ca
[2] Department of Biology, Dalhousie University, Halifax, NS. hlotze@is.dal.ca

Introduction

The history of contaminants in the outer Bay of Fundy region follows the history of settlement and industrial development. Numerous publications have documented the history of human settlement, communities development and industrial activity in the area. An extensive bibliography of these publications can be found in Harold Davis's (1974) comprehensive history (from 1604 to 1930) of the Canadian and American communities that straddle the St. Croix River and estuary.

Beginning in the late 1700s, the rivers, estuaries and marine waters of this area were used to transport logs, harvest fish and power sawmills. As the population of the region increased and other industries developed, they were used as waste dumps for a wide range of activities including logging operations, sawmills, fish processing plants, private septic systems, municipal sewage plants, pulp mills, and, more recently, aquaculture operations (Figure 1).

This paper is an extended summary of a review of some of the major classes of contaminants (suspended solids, persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), metals and metalloids) associated with major development activities in the Quoddy region, outer Bay of Fundy, over the past 200 years. Since not all contaminants found in this region were the result of direct discharges from an identifiable point source, the review also examined contaminants found in sediments, water and/or organisms that were likely the result of atmospheric deposition, run-off or other non-point sources. The complete review appears in *Two Hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy*, a publication of the Conservation Council of New Brunswick (Lotze and Milewski 2002).

The list of contaminants reviewed was by no means complete. It has been estimated that 100,000-500,000 chemicals are now in regular industrial use and most have the potential to enter the marine environment through a variety of sources (Parrett 1998). For the purpose of the review, a contaminant was defined as the introduction of any foreign, undesirable physical, chemical, or biological substance into the environment (Environment Canada 1991) and could include anything from sawdust to nutrients, suspended solids, pesticides, and industrial chemicals.

Oceanographic Setting

Fresh water discharges, currents, and water circulation patterns are key parameters in characterizing the presence and concentrations of contaminants in a marine system. In the Quoddy region, a chain of islands across the mouth of Passamaquoddy Bay effectively creates a 'sea within a sea'. Three main rivers, St. Croix, Digdequash and Magaguadavic, and many smaller rivers and streams discharge into Passamaquoddy Bay. Outflow from Passamaquoddy Bay is primarily through the Western Passage and to a lesser extent the Letete Passage. Ketchum and Keen (1953) estimated the flushing time for the St. Croix Estuary at eight days, and that an additional 16 days were required for the exchange of water in Passamaquoddy Bay with the Bay of Fundy. The flushing time for the Bay of Fundy has been estimated at 76 days (Ketchum and Keen 1953).

Within Passamaquoddy Bay, the surface currents move in a counterclockwise direction creating a gyre or retention area in the centre of the Bay (Bailey 1957; Trites and Garrett 1983). Despite strong tidal currents, thermal stratification does take place in Passamaquoddy Bay (Robinson et al. 1996). The Bay is relatively shallow (an average depth of 27–30 m) and is identified as a depositional area (Loring et al. 1998). In depositional areas, suspended material is more likely to form into large fast sinking aggregates which quickly settle to the bottom where little or no resuspension occurs after deposition (Loring et al. 1998). As for the outer Quoddy region, there is a weak clockwise gyre centered around the Wolves (Figure 2).

Summary and Conclusions

Initially, the goal of this review was to link the impacts of the entire range of human activities, including contaminants, to changes in the ecosystem and food web of the region. Incorporating the ecological impacts associated with exposure of animals to contaminants and subsequent changes in population size and abundance, and ultimately to the food web, proved to be ambitious and, for the time being, impossible.

One key reason is a general lack of data, in particular long-term monitoring data, for the Quoddy region. Unlike fisheries statistics where information on historic catch, abundance and distribution are more readily available, long-term monitoring data on the type, amounts and distribution of contaminants discharged from point and non-point sources are largely unavailable. This type of information is necessary in order to examine the link between exposure to a particular contaminant and changes in the health or abundance of a population or species.

Moreover, demonstrating simple cause-and-effect links between exposure to a contaminant and population-wide effects is difficult to do (Colborn et al. 1996; Johnston et al. 1996; Luoma 1999; Parrett 1998). Since natural populations can exhibit large year-to-year fluctuations in recruitment, it is difficult to isolate natural changes in population abundance from pollution effects. Furthermore, as this review demonstrated, the concentration of contaminants in organisms were often not limited to one compound. This fact makes interpretation of the results even more difficult because the additive, synergistic, and antagonistic effects of different contaminants must also be considered. Despite these limitations, some general conclusions can be made about the concentration, distribution and impacts of some contaminants.

Large quantities of organic material (in the form of suspended solids) have been discharged in the Passamaquoddy Bay/St. Croix Estuary over the past 200 years. A significant percentage of these discharges has likely remained in the area because of oceanographic conditions. An estimated three million tonnes of suspended solids were released into the St. Croix River from one pulp mill alone over a 60 year period. Pollution abatement measures to reduce and restrict the discharge of contaminants did not come into force until the mid- to late-1970s. Large volumes of suspended solids are still being discharged into the region.

A range of chemical contaminants have been released from point and non-point sources. The trend over time shows decreased concentrations of some of these compounds, particularly DDT, PCBs, and dioxins, in sediments and marine organisms. PAH levels remain high in some locations and the concentration of some metals (mercury, zinc and copper) and metalloids (selenium) are increasing in the tissues of some marine organisms and sediments. There is renewed interest in monitoring mercury levels.

The review identified two areas in the Quoddy Region as 'hot spots' where long-term habitat alteration and contamination have taken place: the St. Croix Estuary and the Letang Estuary. These areas have been and continue to be the focal points of considerable discharges from a wide range of sources. Direct and indirect evidence indicates that species composition and abundances in both estuaries have shifted and changed (Pohle and Frost 1997; see Lotze et al. this volume; Pohle et al. 2001). The evidence also identifies PAHs as the most significant toxic contaminant, particularly in the St. Croix Estuary.

The physical and oceanographic features of Passamaquoddy Bay (e.g., shallow, cyclonic circulation, stratified, and depositional) suggest that a significant portion of the large volume of organic material discharged into the Bay over the past 200 years may have remained in the Bay. If this is the case, several questions about the cumulative and long-term effects of organic enrichment on the benthic community of Passamaquoddy Bay arise. Are the relatively low redox values now observed in the sediments of Passamaquoddy Bay (Wildish et al. 1999) 'normal' (i.e., historic background levels) or do they reflect a modification from higher redox values to lower values as a result of two centuries of high sediment loading into the Bay?

If the benthic community in Passamaquoddy Bay has been affected by two centuries of organic enrichment, where along the pollution or benthic enrichment gradient, as proposed by Clarke and Warwick (1994) is Passamaquoddy Bay (Figure 3)? The response of marine/estuarine benthic communities to pollution, specifically organic enrichment, has been studied for relatively small (1–30 km^2) spatial and short (1–5 years) temporal scales (Poole et al. 1977; Pearson and Rosenberg 1978; Warwick et al. 1990; Clarke and Warwick 1994; Pohle and Frost 1997; Pohle et al. 2001). Larger regions such as Passamaquoddy Bay would benefit from this type of analysis as well.

Finally, if the benthic community structure of Passamaquoddy Bay has changed (e.g., reduced diversity) over the past 200 years, how have these changes impacted fish populations in the area? Cod and pollock were known to spawn in Passamaquoddy Bay as late as the 1950s, but those spawning stocks have since disappeared from the area (Coon 1999). Passamaquoddy Bay provided vital habitat for numerous other species such as haddock, herring, lobster, scallop, salmon, gaspereau, shad, smelt, and striped bass. The decline in fish populations began in the early 1960s and the groundfish fishery gradually dropped off to virtually nothing. After three decades of little fishing activity, and substantial improvements in the nature and quantity of contaminants released into the Bay (more recent salmon aquaculture developments notwithstanding), those fish have not re-populated the Passamaquoddy Bay ecosystem. The question is, why not? One part of the answer to these questions may well be linked to the gradual changes that may have taken place in the benthic community structure of Passamaquoddy Bay and the St. Croix Estuary over the past 200 years.

References

Bailey, W. B. 1957. *Some Features of the Oceanography of the Passamaquoddy Region*. MS Rep. Biol. Sta. 2. Fisheries Research Board of Canada, Atlantic Oceanographic Group, St. Andrews, NB. 30 pp.

Clarke, K. R. and R. M. Warwick. 1994. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. National Research Council, UK. 144 pp.

Colborn, T., D. Dumanoski, and J. Peterson Myers.1996. *Our Stolen Future: Are we threatening our fertility, intelligence, and survival? A scientific detective story*. Dutton, New York. 306 pp.

Coon, D. 1999. *An Ecological Sketch of Some Fundy Fisheries*. Conservation Council of New Brunswick. Fredericton, New Brunswick. 32 pp.

Davis, H. A. 1974. *An International Community on the St. Croix (1604–1930)*. Maine Studies no. 64. University of Maine, Orono. 412 pp.

Environment Canada. 1991. *The State of Canada's Environment–1991.* Ministry of Supply and Services, Ottawa, En21-54/1991E.

Johnston, P., D. Santillo, and R. Stringer. 1996. Risk assessment and reality: recognizing the limitations, pp. 223-239. In: *Environmental Impact of Chemicals: Assessment and Control.* M. D. Quint, D. Taylor, and R. Purchase (Eds.). Spec. Publ. 176, Royal Society of Chemistry, Great Britain.

Ketchum, B. H. and D. J. Keen. 1953. The exchanges of fresh and salt waters in the Bay of Fundy and in Passamaquoddy Bay. Journal of the Fisheries Research Board of Canada 10 (3): 97–124.

Loring, D. H., T. G. Milligan, D. E. Willis and K. S. Saunders. 1998. Metallic and Organic Contaminants in Sediments of the St. Croix Estuary and Passamaquoddy Bay. Canadian Technical Report of Fisheries and Aquatic Sciences 2245. Department of Fisheries and Oceans, Dartmouth, NS. 44 pp.

Lotze H. K. and I. Milewski. 2002. *Two Hundred Years of Ecosystem and Food Web Changes in the Quoddy Region, Outer Bay of Fundy*. Conservation Council of New Brunswick, Fredericton, NB. 188 pp.

Luoma, S. N. 1999. Emerging contaminant issues from an ecological perspective In: *U.S. Geological Survey Toxic Substances Hydrology Program, Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999*. US Geological Survey Water Resources Investigations Report 99-4018B, Vol. 2 of 3.

Parrett, A. 1998. *Pollution Impacts on North Sea Fish Stocks*. Prepared on behalf of the European Commission, DG XIV - Fisheries. World Wildlife Fund–UK, Surrey, England. 122 pp.

Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology Annual Review 16: 229–311.

Pohle, G., B. Frost and R. Findlay. 2001. Assessment of regional benthic impact of salmon mariculture within the Letang Inlet, Bay of Fundy. ICES Journal of Marine Science 58: 417–426.

Pohle, G. and B. Frost. 1997. *Establishment of Standard Benthic Monitoring Sites to Assess Long-term Ecological Modification and Provide Predictive Sequence of Benthic Communities in the Inner Bay of Fundy, New Brunswick*. Huntsman Marine Science Centre, St. Andrews, NB. 119 pp.

Poole, N. J., R. J. Parkes and D. J. Wildish. 1977. Reaction of estuarine ecosystem to effluent from pulp and paper industry. Helgolander wiss. Meeresunters. 30: 622–632.

Robinson, S. M. C., J. D. Martin, F. H. Page and R. Losier. 1996. Temperature and Salinity Characteristics of Passamaquoddy Bay and Approaches Between 1990 and 1995. Canadian Technical Report of Fisheries and Aquatic Sciences 2139. Department of Fisheries and Oceans, St. Andrews, NB. 56 pp.

Trites R. W. and C. J. R. Garrett. 1983. Physical oceanography of the Quoddy Region. Pages 9–34. In: *Marine and Coastal Systems of the Quoddy Region, New Brunswick*, M. L. H. Thomas, Ed. Department of Fisheries and Oceans, Ottawa.

Warwick, R. M,, H. M. Platt, K. R. Clarke, J. Agard and J. Gobin. 1990. Analysis of macrobenthic and meiobenthic community structure in relation to pollution and disturbance in Hamilton Harbour, Bermuda. Journal of Experimental Marine Biology and Ecology 138: 119–142.

Wildish, D. J., H. M. Akagi, N. Hamilton and B. T. Hargrave. 1999. A Recommended Method for Monitoring Sediments to Detect Organic Enrichment from Mariculture in the Bay of Fundy. Canadian Technical Report of Fisheries and Aquatic Sciences 2286. Department of Fisheries and Oceans, St. Andrews, NB. 31 pp.

Figure 1. Timelines

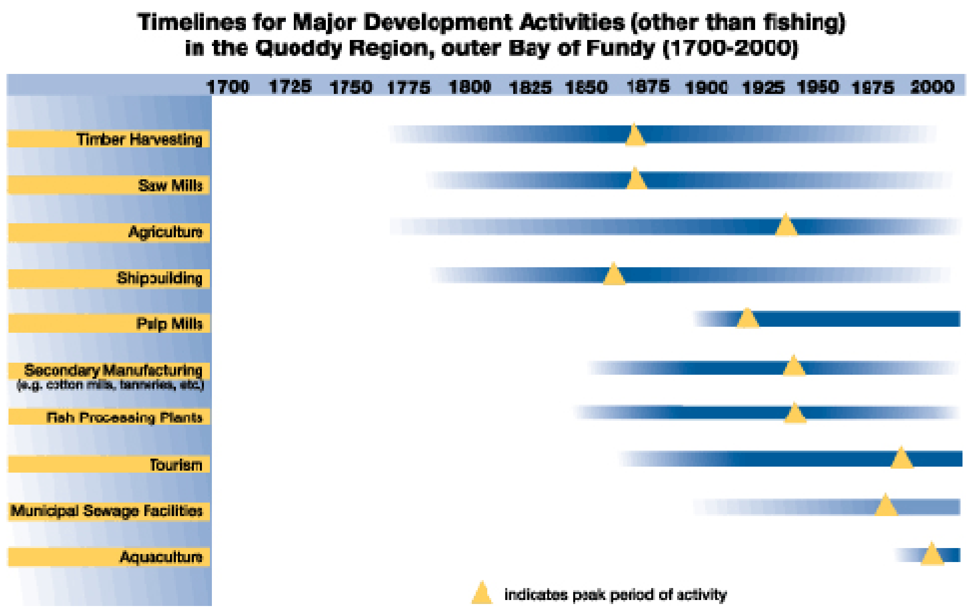


Figure 2. Circulation patterns in the inner and outer Quoddy region. Note the gyre in the centre of Passamaquoddy Bay. Adapted from G. Godin (1968) Natural Resources Canada, Neal Pettigrew (1996) University of Maine, and J. R. Chevries and R. W. Trites (1960) Journal of the Fisheries Research Board of Canada.

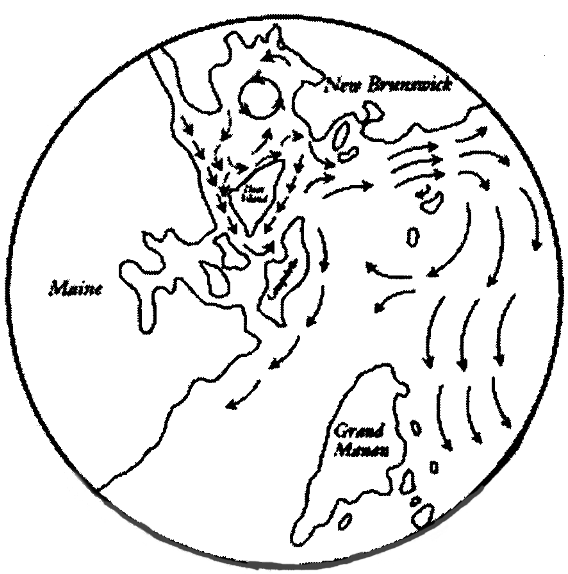
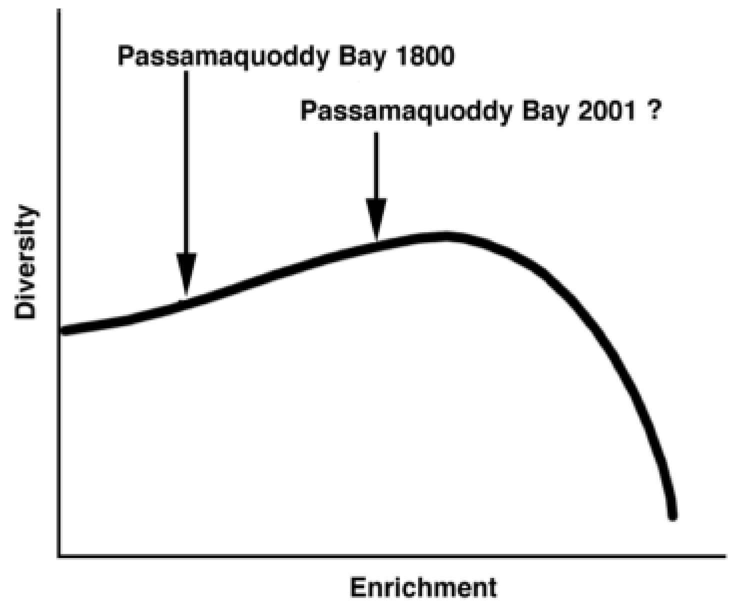


Figure 3. Influence of enrichment on diversity as proposed by Clarke and Warwick (1994). Where along the enrichment gradient is Passamaquoddy Bay today?



Poster Session

A. ORGANIZATIONS

GLOBAL PROGRAMME OF ACTION COALITION FOR THE GULF OF MAINE

Janice Harvey

Conservation Council of New Brunswick, Waweig, NB. ccnbharvey@nb.aibn.com

The Global Programme of Action Coaliton for the Gulf of Maine has instituted a two-year bottom-up process to assess the state of health of the Gulf of Maine. In 2002, a series of watershed and coastal forums will be held to produce local "state of" assessments. In 2003, a major Gulf of Maine summit will pull together local reports and add to these to create a status report on the overall Gulf ecosystem. This poster explains this process and how people can get involved.

SALT MARSH AND RESTRICTED TIDAL SYSTEMS – A BoFEP WORKING GROUP

Zsofi Koller

Conservation Council of New Brunswick, Fredericton, NB. zsofikoller@yahoo.ca

The BoFEP Working Group for Salt Marsh and Restricted Tidal Systems (SMaRTS) aims to advance knowledge, science, and action on behalf of the Bay of Fundy to mitigate growing concerns about the impacts of tidal barriers and salt marsh habitat loss. SMaRTS will achieve this goal through a plan to define and prioritize research goals and monitoring needs, and by developing a genuine valuation system for coastal, estuarine and wetland landscapes. SMaRTS is compromised of scientists, government employees, non-governmental organizations and concerned citizens working together to reduce the impact of tidal barriers and increase healthy salt marsh. SMaRTS' mandate, terms of reference, current on-going projects, and future goals should be expressed for open communication within the Bay of Fundy community.

CANADIAN CLIMATE IMPACTS AND ADAPTATION RESEARCH NETWORK (C-CIARN) ATLANTIC

Kyle McKenzie

Canadian Climate Impacts and Adaptation Research Network, Halifax, NS. kyle.mckenzie@dal.ca

C-CIARN Atlantic is the Atlantic region of the Canadian Climate Impacts and Adaptation Research Network (C-CIARN). Through this network, researchers and stakeholders will have a chance to interact with each other, determine research priorities, contribute to the understanding of the potential impacts of climate change on the Atlantic provinces, and develop adaptation strategies.

While not a funding agency itself, C-CIARN Atlantic can assist researchers and stakeholder groups find appropriate funding for their impacts and adaptation projects. Funding opportunities will be listed on the website, as they become known. C-CIARN Atlantic may be able to assist members in travelling to impacts and adaptation related events in the Atlantic provinces.

C-CIARN Atlantic organizes an annual climate change impacts and adaptation workshop. This event allows researchers, stakeholders, and policy makers from around the region to gather to discuss the issues that are important to this region. An important component of the workshop will be identifying knowledge gaps to help direct future research.

Joining the network is easy and free. Just go to the C-CIARN Atlantic website <http://atlantic.c-ciarn.ca> and click on "Join" under "The Network". A form will allow you to choose as many nodes as you care to participate in. Joining the network will help C-CIARN keep in touch with you, such as by e-mail when the website is updated. It will also facilitate networking among members interesting in contacting others with related interests or needs.

THE BAY OF FUNDY ECOSYSTEM PARTNERSHIP (BoFEP)

Jon Percy[1], Graham Daborn[2] and Peter G. Wells[3]

[1] Sea Pen Communication, Granville Ferry, NS. bofep@auracom.com
[2] Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS. graham.daborn@acadiau.ca
[3] Environment Canada, Dartmouth, NS. peter.wells@ec.gc.ca

The Bay of Fundy is a productive and diverse coastal ecosystem, rich in renewable resources. However, there are worrisome indications that all is not well with the Bay. Species and habitats are at risk, and the sustainable use of living resources is being increasingly compromised. Sustaining a healthy ecosystem requires co-operation among scientists, resource managers, business interests, resource users and residents of coastal communities. The Bay of Fundy Ecosystem Partnership (BoFEP) was established to foster such co-operative efforts. It is comprised of individuals and groups committed to promoting the acquisition of knowledge about the coastal ecosystems of the region, as well as environmental conservation, sustainable resource use and integrated management in the Bay and its watershed. BoFEP sponsors the Biennial Bay of Fundy Science Workshops to review progress in our knowledge of the Bay's ecosystems, to identify problems confronting them and to work towards finding solutions. Several Working Groups, dedicated to specific topics or issues, promote communication, co-operation and joint action among interested partners. BoFEP produces a variety of publications such as workshop proceedings, bibliographies, informative brochures and the Fundy Issues Series of fact sheets that review ecological processes and environmental issues in the Bay. A comprehensive website <http://www.auracom.com/~bofep> provides information about BoFEP and its activities, proceedings of its committees and working groups, copies of its publications, news from around the Bay, and links to information about the Bay of Fundy.

MARINE INVERTEBRATE DIVERSITY INITIATIVE (MIDI)

Jayne Roma[1], Peter G. Wells[2] and Derek Davis[3]

[1] MIDI Society, Dartmouth, NS
[2] Environment Canada, Dartmouth, NS. peter.wells@ec.gc.ca
[3] MIDI, Nova Scotia Museum of Natural History, Halifax, NS. ddavis@accesswave.ca

The Marine Invertebrate Diversity Initiative (MIDI) is producing a standard reference in the form of an interactive, on-line database of marine invertebrates of the Scotian Shelf, Bay of Fundy and Gulf of Maine (<http://www.fundyforum.com/MIDI>). Its ultimate goal is to "increase our knowledge of marine invertebrate biodiversity, and thereby to engage the widest possible audience in learning, conserving and caring more about the biodiversity of our oceans." This project was initiated to remedy the lack of commonly accessible and comprehensive information on marine invertebrate biodiversity in eastern Canada and the Gulf of Maine, as well as to incorporate knowledge of marine invertebrates fully into the management of human activities affecting marine habitats and resources.

The MIDI structure consists of five inter-linked databases for species, habitat, location, photo and reference data. It is an interactive system, meaning that users can both extract and contribute information. In this manner, the information available through MIDI will always be current. The MIDI website also includes a message board where users may post messages or photos, create discussions, and ask or answer questions.

MIDI has several applications to assessing the health of the Bay of Fundy's ecosystems, including the Minas Basin, living resources and coastal communities. All types of marine invertebrate data (species descriptions, photos, location, habitat and references) can be entered into the MIDI on-line database and be viewed and shared by a broad audience.

CURRENT ACTIVITIES OF THE *COROPHIUM* WORKING GROUP (BoFEP) IN THE UPPER BAY OF FUNDY

Peter G.Wells[1], Diana Hamilton[2], Myriam Barbeau[2], Peter Hicklin[3], Michael Brylinsky[4], and Graham Daborn[4], on behalf of Members of the Working Group

[1] Environment Canada, Dartmouth, NS. peter.wells@ec.gc.ca
[2] Department of Biology, University of New Brunswick, Fredericton, NB. dhamilt2@unb.ca and mbarbeau@unb.ca
[3] Canadian Wildlife Service, Sackville, NB. peter.hicklin@ec.gc.ca
[4] Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS. mike. brylinsky@acadiau.ca and graham.daborn@acadiau.ca

The Corophium Working Group, formed in 1997, functions as an active, research-oriented group, focussing on the biology and ecology of the amphipod*, Corophium volutator,* on the mudflats in the upper Bay of Fundy. Of particular importance are studies of factors controlling the abundance and distribution of *Corophium* on different mudflats. Several studies of the group have addressed this. Hamilton's studies have elucidated some of the primary factors of nutrients and inter-specific competition controlling numbers, conducting enclosure studies at Avonport Beach, and collecting at various beaches. Research by Barbeau has concentrated on the population dynamics of *Corophium* seasonally at a number of beaches on both sides of the Bay. Hicklin continues yearly sampling and studies in Shepody Bay in association with the predation by migratory shorebirds. Other studies continue on the ecology, ecophysiology, parasitology and genetics of this amphipod, largely centred at the Acadia Centre for Estuarine Research. The Group maintains a bibliography and collection of key literature to aid studies and encourages student theses (honours to doctorate) on various topics. The group meets once or twice a year to discuss findings and plan joint projects. Interested investigators are welcome to join this continuing interdisciplinary group.

B. PROJECTS

A MULTIDISCIPLINARY APPROACH WITH THE INTEGRATION OF THREE TROPHIC LEVELS (FISH/SHELLFISH/SEAWEED) FOR THE DEVELOPMENT OF SUSTAINABLE AQUACULTURE SYSTEMS

Susan Bastarache[1], Thierry Chopin[1], Shawn Robinson[2], Terralynn Lander[2], Bruce MacDonald[3], Katsuji Haya[2], Dawn Sephton[2], Jennifer Martin[2], Frederick Page[2] and Ian Stewart[4]

[1] Centre for Coastal Studies and Aquaculture and Centre for Environmental and Molecular Algal Research, University of New Brunswick, Saint John, NB. tchopin@unbsj.ca
[2] Department of Fisheries and Oceans, St. Andrews, NB.
[3] University of New Brunswick, Centre for Coastal Studies and Aquaculture, Saint John, NB.
[4] Atlantic Silver Inc., St. George, NB.

As present monospecific aquaculture operations in North America and other parts of the world are at environmental, economic and social crossroads, common sense suggests integrating different types of aquaculture to develop responsible practices, optimizing the efficiency of aquaculture systems and diversifying the industry, while maintaining the health of coastal waters through the understanding of their assimilative capacities. Nutrification of coastal waters is becoming a pressing issue worldwide, and the contribution of the organic and inorganic outputs of aquaculture to significant regional nutrient loading is becoming more widely recognized. To avoid pronounced shifts in coastal processes, a balanced ecosystem approach requires that fed aquaculture (finfish) be integrated with organic and inorganic extractive aquaculture (shellfish and seaweed). Such a bioremediative approach provides mutual benefits to co-cultured organisms, economic diversification by producing other value-added marine crops, increased profitability per cultivation unit, and cost-effective means for reaching effluent regulation compliance by reducing the internalization of the total environmental costs.

The present project is conducting research at an industrial pilot scale at a site in Passamaquoddy Bay, Bay of Fundy. Salmon, mussels, and kelp are being grown together to develop an integrated aquaculture model and train students and professionals in this innovative approach to aquaculture. The productivity and role of each component (fish, shellfish and seaweed) is being analyzed so that the appropriate proportions of each of them can be defined in order to develop a sustainable system in which metabolic processes counter-balance each other within acceptable operational limits and according to food safety guidelines and regulations. The ultimate goal of this project is to transfer this model to other sites and to make it a concept transferable to other aquaculture systems. The Canadian fish aquaculture industry is obviously here to stay in our “coastal scape”: it has its place in the global seafood supply and demand, and in the economy of coastal communities. To help ensure its sustainability, it needs, however, to responsibly change its too often monotrophic practices by adopting polytrophic ones to find increasing environmental, economic and social acceptability, and become better integrated into a broader coastal management framework.

CHANGES IN BIOLOGICAL PRODUCTIVITY INDUCED BY BARRIERS ON MACRO-TIDAL SYSTEMS: A STUDY OF THE WINDSOR CAUSEWAY AND ASSOCIATED SALT MARSHES

Tony M. Bowron

School for Resource and Environmental Studies, Dalhousie University, Halifax, NS.
tbowron@dal.ca

"… it must be confusing to dwell beside a river that runs one way and then the other, and then vanishes altogether." Charles Dudley Warner (Board of Trade 1909)

Introduction

This project looks at the type and range of ecological changes induced by tidal barriers, specifically in the Avon River system in northwestern Nova Scotia (NS). It draws on experiences elsewhere in Atlantic Canada and the Gulf of Maine to develop indicators of ecological change. These indicators will be utilized to gain a better understanding of the ecological changes that have occurred in the Avon River system as a result of causeway construction. One indicator, changes in the extent and location of salt marsh habitat, will be examined in detail.

The study will help to determine how the construction of the Windsor Causeway in 1970 affected the extent, distribution and productivity of *Spartina alterniflora* dominated salt marsh habitat in the Avon River system. Consideration will also be given to the potential impact of the proposed causeway expansion on current

Background

The productivity of salt marshes and tidal rivers in the upper Bay of Fundy (BoF) represents a significant contribution to the health and well being of the Greater Gulf of Maine ecosystem, providing important ecological services, food and habitat for a wide range of marine and terrestrial species and are a major source of food material for the marine ecosystem.

However, over the last 350 years human activities in the upper BoF have led to a significant reduction in the amount of salt marsh and free-flowing tidal river habitat. Many of these activities are of historical and social significance; however, the loss of habitat, productivity and species as result of the construction of modern tidal barriers (roads and causeways) also has significant ecological implications and is both preventable and repairable.

Tidal Barriers

Tidal barriers are obstructions constructed in or across a tidal body (salt marsh, tidal river or estuary) that change the tidal flow in all or part of the water body, both above and below the obstruction (Wells 1999). Tidal barriers and activities that have led to the alteration and loss of salt marsh and tidal river habitat around the BoF include dykes, dams, ditches, wharfs, breakwaters, railways, roads and causeways (with bridges, culverts and dams which are often improperly sized or placed). The known or suspected range of ecological changes induced by tidal barriers include:

- reduction in the length of tidal rivers;
- change in freshwater discharge;
- reduction or prevention of the movement of salt water upstream;
- change, often severe, in hydroperiod, sedimentation and erosion;
- alteration of flood pattern and potential increased flood risk;
- reduction of open salt marsh habitat;
- reduction of nutrient transfer (exchange) to the estuary; and
- restriction or prevention of the movement (migration) of fish, invertebrates and other wildlife (Wells 1999; Neckles and Dionne 1999).

Study Site

The Avon River, known at the time of European settlement as Pessyquid (Pisiquid), a Micmac word meaning “flowing squarely into the sea”, is situated in the north western portion of Hants County, Nova Scotia. It is a small river with a big estuary which flows into the Bay of Fundy’s Minas Basin. A rock-filled causeway was constructed across the Avon River in 1970, connecting Windsor and Falmouth. Where once the influence of the tides was felt as far upstream as Moses Mountain, today tidal flow stops at the causeway. A tidal gate, operated by the Nova Scotia Department of Agriculture and Fisheries, is manipulated to control water levels upstream in the head pond and river. Following construction, rapid accretion of sediment downstream of the causeway has resulted in the development of a mudflat that stretches more than 9 km downstream. A developing salt marsh (predominately of *S. alterniflora*) is clearly visible today on the portion of the mudflat immediately adjacent to the causeway.

Objectives

This project will identify the indicators that signal ecological change in a macro-tidal system following the construction of a major tidal barrier. The goal is the application of these indicators to the Avon River system in order to assess the extent of change that can be attributed to the construction and continued operation of the Windsor Causeway, with a focus on the changes in distribution and size of salt marshes both upstream and downstream of the causeway. It will also estimate the changes biological productivity (based on amount of *S. alterniflora* dominant habitat) of the Avon River system over time due to the construction of the Windsor Causeway and how the system would potentially respond to the planned expansion of the causeway.

Approach

The assessment of changes in the selected indicators in the Avon River system will encompass five steps:

1. strategic review of the available ecological information on the observed changes caused by tidal barriers elsewhere in the BoF and Gulf of Maine and methodologies for assessment of these changes;
2. analysis of historical information (particularly the interpretation and analysis of air photographs) available for the Avon River system both prior to and following causeway construction;
3. field verification of information and findings;
4. focussed analysis of the changes in size and distribution of *S. alterniflora* dominated salt marsh habitat over time; and
5. calculation of changes in productivity of available salt marsh habitat over time and extrapolation of these to predict impacts of future causeway expansion.

Benefit

The study will contribute to the growing body of literature on the range of ecological changes that may be induced by tidal barriers on macro-tidal systems. It will help to form a picture of the changes, particularly in salt marsh abundance, location and productivity that have occurred in the Avon River system over time and as result of causeway construction. Plus, provide information on appropriate indicators of ecological change.

Progress

The project is currently in the early stage of literature review, development and testing of methodology and data collection. All available air photographs spanning the Avon River from Hantsport (downstream) to Moses Mountain (upstream) from the last 80 years are being collected. These will be digitized and a time series of composite maps of the river will be produced. From these, it will be possible to interpret and analyze the changes that have occurred.

References

Board of Trade. 1909. Windsor-on-Avon. Windsor, Nova Scotia. Dedicated to History, Literature and Commerce. Printed by the Windsor Tribune Publishing Company Limited. Windsor, Nova Scotia.

Neckles, H. and Dionne, M. (eds.) 1999. Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine. A GPAC Workshop. Wells National Estuarine Research Reserve, Wells, ME.

Wells, P. G. 1999. Environmental Impact of Barriers on Rivers Entering the Bay of Fundy: Report of an *ad hoc* Environment Canada Working Group. Technical Report Series No. 334, Canadian Wildlife Service, Ottawa, ON.

IDENTIFICATION OF SENSITIVE MARINE AND COASTAL AREAS IN THE BAY OF FUNDY, GULF OF MAINE, CANADA

Maria-Ines Buzeta, Rabindra Singh and Sharon Young-Lai

Department of Fisheries and Oceans, Biological Station, St.Andrews, NB. buzetam@dfo-mpo.gc.ca

This document presents a summary of sensitive[1] marine and coastal areas in the Bay of Fundy, as defined by their ecological sensitivity, high biodiversity, ecological, educational or scientific importance, or their social or spiritual value. With the many pressures on our ecosystem, it is essential to identify these areas and ascertain those that may require special protection or that may require immediate attention.

The identification of these important sites can provide some of the groundwork towards plans for integrated management areas and a system of marine protected areas (MPA), following the criteria set out in Canada's Oceans Act. Upon a recommendation from stakeholders, the document provides a list of potential MPA sites in order to bring them to the "table" for discussion.

Sensitive[1] sites were identified through scientific literature, or suggested by experts and communities. Effort has been made to include local or traditional knowledge, along with scientific data, through a series of workshops. Many communities and local experts are yet to participate, however, the authors feel that discussion should begin on the information collected so far. Also, it is hoped that this document will promote more participation, and be seen as the first of a series of updates that will continue to include more scientific data and public knowledge.

The report contains a summary of existing information for each site presented as a series of maps. Also included are the results of information gathered during workshops held with communities and experts.

[1]Sensitive areas—This term is used to summarize the reasons associated with the scientific, social, economic or spiritual importance that people impart to areas of the sea.

PREDICTING MERCURY ABUNDANCES IN NORTHEASTERN NORTH AMERICAN FRESHWATERS USING GIS APPROACHES: FROM LOCAL TO REGIONAL PERSPECTIVES

Thomas A. Clair[1], Fan Rui Meng[2], Paul Arp[2], and David Evers[3]

[1] Environment Canada, Atlantic Region, Sackville, NB.
[2] Faculty of Forestry, University of New Brunswick, Fredericton, NB.
[3] Biodiversity Research Institute, Falmouth, ME 04105, USA

Though ubiquitous in freshwater environments, mercury (Hg) is not evenly distributed in water, sediments or biota. In this paper, we show that freshwater Hg concentrations in lakes and streams of southwestern Nova Scotia can be predicted by knowing their basins' geographical conditions. We develop a model which predicts annual total Hg (Hg_t) and summer methyl mercury ($MeHg^+$) concentrations in water, using basin and local wetness indices (calculated from abundances of flat areas creating conditions for wetlands), slope, and the maximum summer sunlight irradiance index. In winter, $MeHg^+$ is not generated in these basins and is found only at a low baseline level. The approach we developed for water is now being modified to apply it to biota and sediments. The method, which we developed in Nova Scotia, is now also being adapted to the whole of northeastern North America under a grant managed by the USDA and the Hubbards Brook Foundation. We have begun building a large regional database of water, sediment and biota data, which will be assessed using geographic information system (GIS) approaches in the upcoming year. In this presentation, we provide the data and organizational framework for this large-scale approach.

PRELIMINARY RESULTS OF A STUDY ON THE PREVALENCE AND BIOACCUMULATION OF METHYL MERCURY IN THE FOOD WEB OF THE BAY OF FUNDY, GULF OF MAINE

John Dalziel, Gareth Harding and Peter Vass

Marine Environmental Science Division, Bedford Institute of Oceanography, Dartmouth, NS.
dalzielj@mar.dfo-mpo.gc.ca

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

There is evidence in the Maritimes that our loon, which spends its life as a juvenile in coastal marine waters and subsequently overwinters there as adults, has body mercury burdens well above inland populations. More recently, it has been reported from a joint United States-Canada, Gulf of Maine-Bay of Fundy Mussel Watch Program that greater than 80% of the 56 study sites had mercury levels exceeding the US National Status and Trends median values.

Our overall research objectives are to:

1. Assess the bioaccumulation of methyl mercury at various trophic levels in the pelagic and demersal food webs of an East Coast, marine coastal ecosystem.
2. Assess the seasonal variation of methyl mercury in this ecosystem to better understand its dynamics.
3. Create a preliminary budget for methyl mercury in an East Coast marine embayment by quantifying the various inputs, outputs and sinks for the system.
4. Model methyl mercury dynamics in the Bay of Fundy as an east coast marine embayment cooperatively with Simon Fraser University (Frank Gobas and Elsie Sunderland).

Preliminary results support the hypothesis that methyl mercury is bioaccumulated in the pelagic food chain. Methyl mercury levels consistently increase from phytoplankton (63 : m; 0.33 ± 0.58 : g/gWet) to zooplankton (500 : m; 0.6 ± 0.6 : g/gWet) to macrozooplankton (2.0 mm; 1.4 ± 1.5 : g/gWet) to krill (8.0 mm; 4.4 ± 2.3 : g/gWet) to pelagic fish (herring; 24.6 ± 19.2 : g/gWet) to large pelagic fish (bluefin tuna; 726 ± 157 : g/gWet).

A study such as proposed here is a first step in determining whether current mercury levels are high enough to harm marine organisms or their consumers. This study will provide valuable insights into mercury biomagnification in a coastal ecosystem, and together with the integrated food-chain-contaminant modelling with our collaborators, should establish the basis for risk assessment of mercury in the marine coastal zone.

MODELLING SALT MARSH SEDIMENTATION, SEDIMENT ACCRETION RATES AND SEDIMENT BUDGETS FOR THREE DISTINCT MARSH GEOMETRIES

Marie-Therese Graf

Department of Geography, McGill University, Montreal, PQ. marie.graf@mail.mcgill.ca

How does the shape of a salt marsh affect its response to changing sedimentation and erosion regimes? Detailed studies of processes of sedimentation and erosion and measurements of salt marsh accretion rates are two ways in which insight is gained into the functioning of these dynamic land forms. The purpose of this study was to develop a model which could realistically recreate salt marsh sedimentation rates on an 'individual tide' time scale, and then use these rates to model sediment budgets of salt marshes over the time scale of centuries. The sedimentation model was calibrated using tidal sedimentation data collected by van Proosdij et al. (2000) at Allen Creek Marsh and validated against measurements made by Chmura et al. (2001) at Wood Point Marsh, directly adjacent to Allen Creek marsh. Sediment budgets were then modelled for three hypothetical marshes of identical volume but with distinctly different areal geometries and hence, different deposition and erosion rates. Results suggest that long narrow bands of marsh with long open coastlines exposed to wave activity (i.e., those often found seaward of dykes) may experience more rapid sediment loss by erosion than marshes that extend farther inland and have only short open coastlines (i.e., those found in estuaries). The process of selecting suitable sites for salt marsh restoration efforts could benefit from considering marsh geometry since this may minimize seaward edge erosion upon dyke removal, thus increasing the chances of successful restoration.

References

Chmura, G. L., A. Coffey and R. Crago. 2001. Variation in surface sediment deposition in the Bay of Fundy. Journal of Coastal Research, 17(1): 221–227.

Van Proosdij, D., J. Ollerhead and R. G. D. Davidson-Arnott. 2000. Controls on suspended sediment deposition over single tidal cycles in a macrotidal salt marsh, Bay of Fundy, Canada. Geological Society Special Publication No. 175. pp. 42–57.

UNINTENTIONAL USE OF ORGANIC CONTAMINANTS IN AQUACULTURE AND IMPACT ON SEDIMENTS

Joceylne Hellou[1, 2], Katsuji Haya[3], Les Burridge[3] and Sean Steller[1]

[1] Marine Environmental Sciences Division, Fisheries and Oceans Canada, Halifax, NS.
hellouj@mar.dfo-mpo.gc.ca
[2] Dalhousie University, Chemistry Department, Halifax, NS.
[3] St. Andrews Biological Station, St. Andrews, NB.

The offshore fisheries industry and land-based products are used in feed required by the inshore aquaculture. Contaminants' concentrations in feed will vary according to the type and origin of the components being used (Frank et al. 1993; Hietaniemi and Kumpulainen 1994; Lodovici et al. 1995). One ingredient that could be of concern because it is rich in lipids and therefore would contain lipophilic contaminants, is fish oil. Since salmon aquaculture is prospering in New Brunswick, the fate of unintentionally used non-polar organic contaminants and their deposition around cages was of interest in the present study. Commercial food pellets, fish oil used as an ingredient in feed, and sediments collected around cages in 1998 and 1999 were analyzed for three groups of priority contaminants, namely polycylic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and pesticides, including the DDT family. In 1998, sampling was done directly under the cages and 25 m away, while in 1999, sampling was extended further, going from 0 and 25 m to 50 and 100 m away from the centre of the cages. In most cases, sampling was done in the direction of the currents, but on one occasion, collection was done in a perpendicular direction to the currents. A remediated site was also examined.

In general terms, PAHs were more abundant than PCBs and pesticides in all sediments. Within the PAH group, alkylated naphthalenes (aNA) were detected in food pellets (25–51 ng/g, per aNA), fish oil (116–180 ng/g, per aNA) and sediments (<1–45 ng/g, dry, per aNA), where five compounds were predominant. A large number of parental PAHs were detected at variable levels in sediments only (e.g., 23–1605 ng/g, dry for pyrene). The signature of PAHs observed in feed was not identical to that in sediments, reflecting additional or different sources of alkylated PAHs in the aquaculture environment. Local combustion sources depositing in sediments could be deduced from examining the ratio of various PAHs in comparison to published data (Hellou et al. 2002). Some PCB congeners and p,p'-DDE were also detected at low levels in all samples. Our analytical approach was changed from somewhat more conventional gas chromatography-mass spectrometry (GC-MS) in the electron impact (EI) mode to GC-MS in the negative chemical ionisation (NCI) mode. This provided an improvement in the detection limits, from nearly 1,000 pg/g to 10 pg/g, for the congeners with more than four chlorine atoms. Therefore more data were obtained to interpret geographical and temporal variability. However, as observed with the PAHs, the PCB profile displayed in feed and oil was not identical to that determined in sediments, indicating a local background. The concentration of many organochlorine pesticides, except mainly for p,p'-DDE, were below detection limits using GC-MS-EI (<1 ng/g).

Trends were observed during the first year of sediment sampling, with up to 6–8 times higher organic carbon content (OC) and levels of PCBs and p,p'-DDE below the cages relative to 25 m away (Figure 1). During 1999 vs 1998 and therefore longer use of the sites, levels of p,p'-DDE and PCBs were somewhat reduced under the cages but detected up to 100m away from the cages (<1.8 vs <7 ng/g, dry, for p,p'-DDE and <1 vs <4 ng/g, dry, per PCB congener, 1999 vs 1998).

Three different types of sites were examined. Contaminants' results agreed with the classification of the sites done by the province of New Brunswick (Burridge et al. 1999). Sites rated as A had lower levels of contaminants around the cages than B and than C sites. Comparing sediment concentrations to those of other locations around the world indicated background levels for organochlorine compounds. However, variable and sometimes high concentrations, in the range of those observed in urbanised harbours were obtained for PAHs (Hellou et al. In Preparation). This latter observation would raise questions about the effect of the environment on salmon aquaculture and marine organisms living in the area. This study was continued with sampling at many of the same locations during summer 2000 to examine the fate of contaminants with longer use of the sites. Analyses of samples and interpretation of results is still ongoing.

The authors believe that it is important to determine if environmental changes are associated with the development of this new component of the aquatic food chain, to address the no net loss provision of the Fisheries Act.

Acknowledgements

Funding from the Environmental Sciences Strategic Research Fund (1999-2002) of the Department of Fisheries and Oceans is acknowledged.

References

Burridge, L.E., K. Doe, K. Haya, P. M. Jackman, G. Lindsay, and V. Zitko. 1999. Chemical analyses and toxicity tests on sediments under salmon net pens in the Bay of Fundy. Canadian Technical Report on Fisheries and Aquatic Sciences 2291, 12pp.

Frank, R., H. E. Braun and B. Thorpe. 1993. Comparison of DDE and PCB residue in the general diet and in human blood, Ontario 1986-87. Bulletin of Environmental Contamination and Toxicology 51: 146–152.

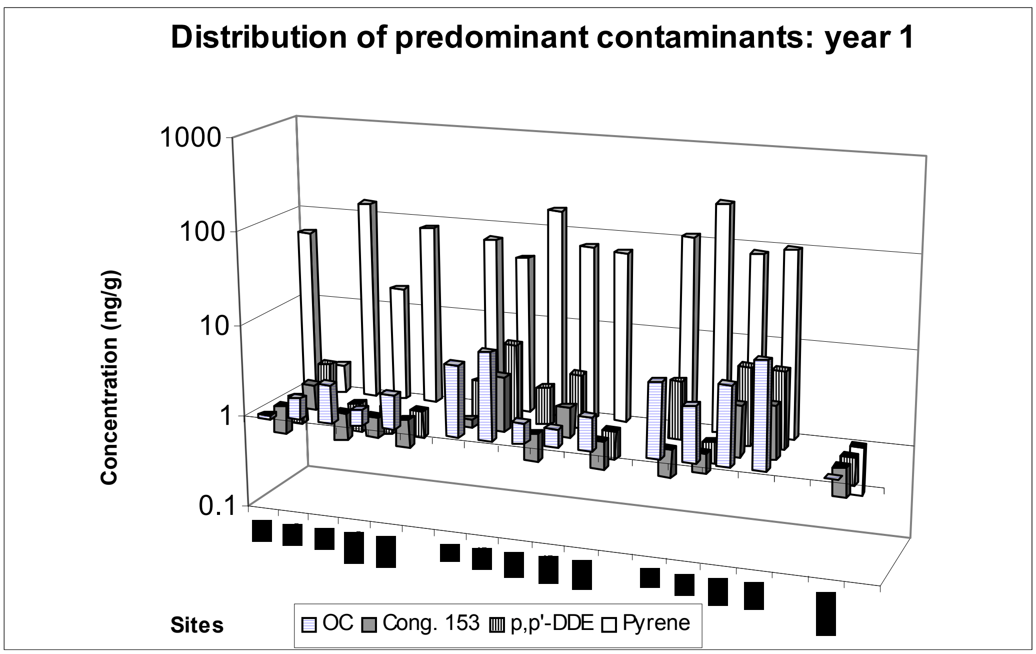
Hellou, J., S. Steller, V. Zitko, J. Leonard, T. King, T. Milligan, and P. Yeats. 2002. Distribution of PAHs in surficial sediments and bioavailability to mussels, *Mytilus edulis*, of Halifax Harbour. Marine Environmental Research 53: 327–356.

Hellou, J., S. Steller, L. E. Burridge, and K. Haya. In preparation. Unintentionally used organic contaminants in aquaculture and their fate in sediments.

Hietaniemi, V. and Kumpulainen. 1994. Isomer specific analysis of PCBs and organochlorine pesticides in Finnish diet samples and selected individual foodstuff. Food Additives and Contaminants 11: 685–694.

Lodovici, M., P. Dolara, C. Casalini, S. Ciappellano, and G. Testolin. 1995. Polycyclic aromatic hydrocarbon contamination in the Italian diet. Food Additives and Contaminants 12: 703–713.

Figure 1: Concentrations are in ng/g, dry weight, while OC is total organic carbon content expressed in %, dry. Site numbers are followed by letters referring to the New Brunswick classification. "25Ref" is a reference site away from aquaculture cages.



AUDIT OF TIDAL BARRIERS IN THE CUMBERLAND BASIN AND MEMRAMCOOK RIVER IN THE UPPER BAY OF FUNDY, 2001

Zsofi Koller

Conservation Council of New Brunswick, Fredericton, NB. zsofikoller@yahoo.ca

Tidal barriers in the Bay of Fundy have long been recognized as a serious environmental problem. To address this problem, it is useful to establish base-line information regarding the location and severity of the small to medium-sized tidal barriers in the Bay. 2001 was the second field season of a tidal barrier audit, initiated by the Conservation Council of New Brunswick and Environment Canada. The Cumberland Basin and Memramcook River systems comprised the study area. Using a two-phase evaluation system of barrier characteristics and impacts, a total of 32 tidal barriers were audited. Of the 32 sites investigated, it was concluded that 23 barriers showed either complete tidal restriction or were impacted by other sources of restriction. The results of this study support the concern that tidal barriers pose an environmental threat in the Bay of Fundy, and that restoration projects addressing this problem should be a priority for resource managers.

SPATIAL ANALYSIS OF *SPARTINA ALTERNIFLORA* COLONIZATION ON THE AVON RIVER MUDFLATS, BAY OF FUNDY, FOLLOWING CAUSEWAY CONSTRUCTION

Sarah Merrill Townsend and Danika van Proosdij

Department of Geography, Saint Mary's University, Halifax, NS. dvanproo@stmarys.ca

This poster presents results from a field study and geographic information system (GIS) analysis on quantifying the extent, distribution and rate of growth of *Spartina alterniflora* on a section of the Avon River mudflats in the Minas Basin since the construction of the Windsor-Falmouth Highway 101 causeway in 1970. The extent and distribution of both the mature and expanding juvenile colonies of *S. alterniflora* were measured using differential global positioning system (GPS) from October to November 2001. Data were collected during low tide and included observations of vegetation density within the colonies. The historic spatial distribution covered by *S. alterniflora* was determined from aerial photographs of the study area from 1972, 1981, 1992 and 1995. The annual rate of growth and change in total salt marsh area from 1969 to 2001 was quantified and analyzed using a GIS.

The area and rate of growth of the marsh vegetation have been increasing since causeway construction as conditions on the mudflat surface have become more favourable, i.e., with a lower tidal inundation and lower wave energy due to an increase in sediment deposition initiated with causeway construction. Through ice and wave rafting of rhizome material from limited shoreline marsh in the study area, and possibly other sources already in existence prior to causeway, the pattern of growth expansion is typical of other marsh study sites. Total area of marsh in 1973, 1981, 1992 and 1995 were 1,443 m^2, 4,146 m^2, 14,232 m^2, and 40,782 m^2 respectively. In 2001 the established-only marsh area was 199,083 m^2 (approximately 0.2 km^2) and the juvenile-only marsh area totaled 191,194 m^2 (approximately 0.2 km^2). The rate of growth of the total *S. alterniflora* on the Avon River mudflat study area was calculated to be 29% per year between 1992 and 2001. Based on regression calculations from the GIS analysis, the predicted area of the marsh for 2006 is 2.5 km^2. This research demonstrates that the Highway 101 causeway has acted as an important agent of change in this marsh/mudflat system.

MARINE ENVIRONMENTAL QUALITY (MEQ) INDICATORS FOR THE BAY OF FUNDY

Maxine Westhead

Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS.

Canada's Oceans Act was proclaimed in January 1997, and provides a legislative framework for Canada's oceans and marine resource management. The Oceans Act calls for the implementation of integrated management plans, the development of a national system of marine protected areas, and the establishment of marine environmental quality guidelines, objectives and criteria. In this context, three Oceans Act programs are presently being undertaken: marine protected areas (MPA), integrated management (IM), and marine environmental quality (MEQ).

The overall goal of the marine environmental quality program is to provide an ecosystem-based support mechanism for the development of integrated management and marine protected area plans. MEQ activities in the Bay of Fundy will help provide the information needed to make sound decisions, and will offer the ecological basis needed for effective IM and MPA plan development. MEQ makes the much-needed link between science and management, putting scientific information into a more usable format for managers.

This poster highlights a potential marine environmental quality framework and associated indicators for the Bay of Fundy, with an emphasis on the Minas Basin.

C. MANAGEMENT INITIATIVES

INTEGRATED MANAGEMENT OF CANADA'S OCEANS AND COASTS

David Duggan

Oceans and Coastal Management Division, Bedford Institute of Oceanography, Dartmouth, NS.
duggand@mar.dfo-mpo.gc.ca

Canada's estuaries, coasts and oceans are the focus of major economic activity and are an integral part of the country's culture and identity. The coastline of Canada is the longest of any in the world, and its seabed represents an area two-thirds the size of its land mass. Oceans support commercial, recreational and Aboriginal fisheries, oil and gas exploration and development, marine recreation and tourism, aquaculture, shipping and transportation, and a variety of other economic uses that directly contribute over $20 billion a year to Canada's economy. Oceans also support high technology and pharmaceutical industries, potential mining opportunities, and scientific and technical research.

The Oceans Act calls on the Minister of Fisheries and Oceans to lead and facilitate the development of a national oceans strategy that will guide the management of Canada's estuarine, coastal and marine ecosystems. The Canada Oceans Strategy provides the overall strategic framework for Canada's ocean-related programs and policies, based on the principles of sustainable development, integrated management and the precautionary approach. The central governance mechanism of the strategy is applying these principles through the development and implementation of integrated management plans.

Marine and land-based activities have an impact on coastal waters and ocean waters. Intensive fishing, shipping, land-based pollution and development all have an impact on coastlines and ocean waters. Developing an integrated management approach to oceans-related activities involves considering the impact that a variety of activities may have at an ecosystem level. Integrated management establishes advisory bodies that consider both the conservation and protection of ecosystems, while at the same time providing opportunities for creating wealth in oceans-related economies and communities. It brings together the environmental, economic and social considerations by planning for sustainable use.

INTEGRATED MANAGEMENT OF MINAS BASIN, BAY OF FUNDY—ACTIVITIES OF THE MINAS BASIN WORKING GROUP, BoFEP

Patricia Hinch[1], Michael Brylinsky[2], Robin Musselman[3], Jon A. Percy[4] and Peter G.Wells[5]
on behalf of Members of the Working Group

[1] Nova Scotia Department of Environment and Labour, Halifax, NS. hinchp@gov.ns.ca
[2] Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS. mike.brylinsky@acadiau.ca
[3] Minas Basin Working Group, BoFEP, Halifax, NS. r.musselman@ns.sympatico.ca
[4] Seapen Communications, Granville Ferry, NS. bofep@auracom.com
[5] Environment Canada, Dartmouth, NS. peter.wells@ec.gc.ca

The Minas Basin Working Group, initiated under the Gulf of Maine Council on the Marine Environment, is now operating as part of BOFEP (Bay of Fundy Ecosystem Partnership). Its purpose is to help the people living around the Minas Basin find ways to use the region's natural resources carefully and wisely, for the benefit of present and future generations. It will accomplish this goal by working with local residents and groups around the Basin, identifying opportunities and forums for new projects on the sustainable use, restoration and management of the Basin, and working towards a long-term integrated management plan for the Basin and its watershed. Membership is from a wide range of sectors, and meetings are generally held at the Acadia Centre for Estuarine Research. To date, the group has initiated a collection and bibliography of literature pertaining to the Basin; an inventory of non-government groups working on local issues and concerns; and a series of community workshops designed to identify issues and initiate action groups to address them. This poster shows examples of the group's accomplishments to date and encourages interested parties to join and contribute to the Group's activities.

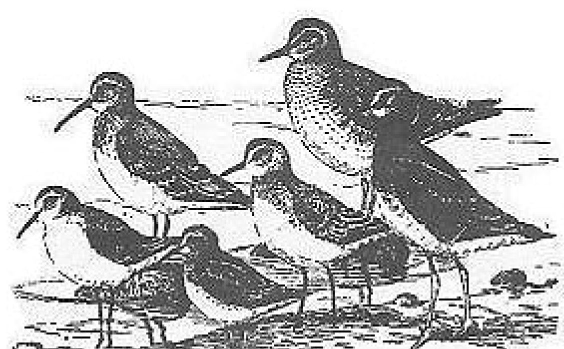
UPPER BAY OF FUNDY FISHERIES: AN INTEGRATED MANAGEMENT PILOT PROJECT

Barry C. Jones

Fredericton, NB. gryffyn@nbnet.nb.ca

The upper portion of the Bay of Fundy is a unique geographic region where natural conditions limit small-scale fishermen in their harvesting activities, one of the principal elements of local community economies. In recent years, larger vessels from outside the region have followed and harvested fish stocks as they migrate into the upper Bay. This more flexible and more powerful fishing pressure, added to the local community fishery, has significantly reduced upper Bay fish stocks and their availability to local economies. The management of these fisheries, exacerbated by the unknown effects of other local marine resource uses is obviously not ecosystem-based, nor is it integrated within local economies, both directions mandated under the recent federal Oceans Act administered by Fisheries and Oceans Canada. For this reason, upper Bay of Fundy fishermen and communities have banded together to request the right and responsibility to develop an ecosystem-based fisheries management pilot project in the area.

Minutes of the BOFEP Annual General Meeting



BAY OF FUNDY ECOSYSTEM PARTNERSHIP (BOFEP)
* ANNUAL GENERAL MEETING *
Acadia University, Wolfville, Nova Scotia
May 15, 2002
from 18:10 to 21:15 pm

Participants: Graham Daborn, Acadia Centre for Estuarine Research (Chairperson); **Nancy Roscoe-Huntley**, Acadia Centre for Estuarine Research (Scribe); **Hugh Akagi**, Passamaquoddy First Nation; **Peter Austin-Smith**; **Sean Brillant**, ACAP Saint John; **Mike Brylinsky**, Acadia Centre for Estuarine Research; **Maria-Ines Buzeta,** Dept. of Fisheries & Oceans; **Thierry Chopin**, University of New Brunswick, Saint John; **Chiu L. Chou**, Fisheries & Oceans, Canada; **Cameron Deacoff**, Dalhousie University, student – Dalhousie University; **Dave Duggan**, Dept. of Fisheries and Oceans; **Kathy Faulkner**, Baymount Outdoor Adventures Inc.; **Sheri Faulkner-Jackson**, student – Simon Fraser University; **Donald and Elaine Hendricks**, Acadia Univeristy, Irving Project; **Peter Hicklin**, Canadian Wildlife Service, Environment Canada; **Larry Hildebrand**, Environment Canada; **Patricia Hinch**, NS Dept. of Environment and Labor; **Marianne Janowicz**, NB Dept. of Environment and Local Government; **Barry Jones**, BoFEP Treasurer; **Marty King**, World Wildlife Fund Canada; **Charles LeBlanc**, Environment Canada; **Colin MacKinnon**, Canadian Wildlife Service; **Teresa Newcomb**; **Jon Percy**, BoFEP; **Peter Lawton**, Dept. of Fisheries and Oceans; **Angela Martin**, Huntsman Marine Science Centre; **Amanda McGuire,** Huntsman Marine Science Centre; Vincent **Mercier**, Environment Canada; **Lisa Paon**, Dept. of Fisheries and Oceans; **Pam Person**, GPAC; **Gerhard Pohle**, Huntsman Marine Science Centre; **Robert Rangeley**, World Wildlife Fund; **Bob Rutherford**, Dept. of Fisheries and Oceans-BIO; **Danika van Prooskij**, Saint Mary's University; **Brad Walters**, Mount Allison University; **Peter Wells**, Environment Canada; **Maxine Westhead**, Dept. of Fisheries and Oceans; **Renee Wissink**, Fundy National Park; **Thomas Young**, Resource Management Associates.

1. **Call to Order**
   Chair, G. Daborn welcomed members to the Annual General meeting and asked that everyone fill in the sign-up form and return to Nancy so we can have a record of those in attendance.

2. **Additions to/Acceptance of the agenda**
   Maxine announced an annual BoFEP run to be scheduled for tomorrow, May 16th, beginning at 6:30. All interested should meet in the lobby of Seminary House.

3. **Approval of Minutes of AGM on November 2nd, 2001 in Sackville, NB**
   Graham went through several points from the floor, including the interaction with the GPAC, points from the last AGM, the role of BoFEP in the Integrated Management proposal, and the process of electing a new Steering and Management Committee following the adjournment of this meeting. He noted that at the last AGM, BoFEP By-Laws were adopted.

   Item #12 from the last minutes referred to the Gulf of Maine Council and should have read "GPAC".

   Motion to approve the minutes Jones/Hildebrand. Motion carried.

4. **Business arising from the previous AGM**
   Dealt with in the previous item.

5. Acceptance of the BoFEP Strategic Plan

Jon provided an update of the BoFEP Strategic Plan he has been developing that will provide a framework to implement a work plan, providing direction to BoFEP. He noted the eight general areas that will be developed including both long-term as well as short-term goals. When final and approved by BoFEP, the Strategic Plan will be placed on the web site. Jon indicated he was not seeking acceptance since this is a working document requiring revisions. Copies will be circulated to members of the Steering Committee for review and comments. At the last BoFEP Steering Committee meeting the Strategic Plan was approved in principle and will be circulated in its final form prior to acceptance.

Moved by L. Hildebrand, seconded by J. Ollerhead that the Strategic Plan be distributed to all members of BoFEP.
The motion was then amended to include – to send out a ballot by email accepting, accepting with changes, or rejecting

Motion carried unanimously.

6. Update on BoFEP Working Group activities

Minas Basin Working group chaired by Pat Hinch reported that this group has been very active. She spoke on the Gulf of Maine Habitat proposal, the work of the community forums was discussed including the upcoming leaders' meeting.

Corophium group chaired by Peter Wells provided a brief update on recent meetings and activities. This is an active group and special thanks to Diana Hamilton for the successful panel discussion at the 5th Bay of Fundy Science Workshop.

Nutrification of Coastal Waters chaired by Thierry Chopin reported on the projects on which they are focusing. He also noted that a nutrient workshop may be planned for the Bay of Fundy region.

Tidal Barriers and Saltmarshes, co-chaired by Janice Harvey and Jeff Ollerhead reported that they have approximately 25 members as a result of two groups merging. They have met a number of times. Jeff noted the objectives they are focusing on and provided details.

Ecotourism chaired by Tom Young reported on the successful workshop held last fall with the financial assistance of BoFEP. He also reported on the activities of the Biosphere Reserve project, the committee structure as well as the problems encountered. An ecotourism fact sheet (#21) has been released at this workshop thanks to Jon Percy. Tom also noted that 2002 is UN's year of the tourist.

Defining stress/cumulative effects chaired by Mick Burt and reported via Peter Wells indicated that this is a small group, requiring additional members. They are in the early stages of a workplan. A PhD project at UNBSJ and the Huntsman Marine Science Centre is underway and being supervised by both Peter and Mick.

Sedimentation working group chaired by David Mossman have provided a term of reference. They are discussing an issue with the Tidal Group. This item will be placed on the Steering Committee's next agenda.

Fish Migration currently being chaired by Rod Bradford. He has voiced concern over not being able to continue to chair this group. Jamie Gibson will be asked to serve as chair for this group.

Resource Development- chaired by Peter Fenety began three years ago and has not been heard from since that time. This group was formed around the issue of mining. Following discussion it was agreed that Peter Fenety would be contacted. It was suggested that issues such as Titanium could be dealt with by the Minas Basin Working group.

Motion to strike this committee from the BoFEP working groups B. Jones/J. Ollerhead
Amended to say subsume into the Minas Basin Working group.
Following discussions on whether to merge this group or to keep the issue on the table, the question was called.

All in favour with the exception of one abstention vote.

This item would be placed on the next BoFEP Steering Committee agenda to see if someone is willing to come forward to establish a committee to meet the issues of this committee as well as to chair the group.

Moved by B. Rutherford, seconded by D. Duggan to invite Gordon Fader to attend a Steering Committee meeting to discuss issue dealing with Middle Bay).

Motion carried unanimously.

Toxic chemicals group currently needs an active chair. Following discussion, it was agreed to keep this working group on the books and an attempt will be made to find a chair as well as new members. If interested, please contact Graham or Peter.

Marine Protected Areas group chaired by Maria-Ines Buzeta advised that their next meeting will be held in Sackville, NB. Maria discussed issues of concern regarding finding a co-chair and the need for new members. Jon will review the membership forms to determine if there are members interested in joining this group (as well as other working groups and provide contact information to all chairs).

Graham provided clarification on what is a working group vs committee work. Emphasis should be on the work in progress.

Communications and Web Site- Jon Percy works single-handed on this committee, preparing various publications, posters and maintaining the BoFEP web site. Jon attends as many of the working group meetings as time permits. During the past year he has designed and constructed information kiosks that will be placed in various areas surrounding the Bay of Fundy; one is in the Visitors Centre at Fundy National Park, Alma, New Brunswick. Kiosks will be an ongoing project for Jon during the next several months. During the past year Jon has worked on the BoFEP By-Laws, and prepared a Strategic Plan. Jon noted he is trying to get more information into the Gulf of Maine Times. Editor of this publication, Andy Reardon, has been covering the workshop this week. Jon has been the initiator of the BoFEP Slide project. Anyone with slides, please contact Jon. Jon will scan, digitize, and eventually, there will be an available data base of slides to be used in presentations. Hugh is also working with elder, David Frances, to prepare a translation of fact sheets.

Integrated Coastal Management Working group is co-chaired by B. Jones and L. Hildebrand. At the last AGM, Barry made a proposal on Integrated Management. Since that time he has retired from DFO. Further discussions focused on the Oceans Strategy Act, and DFO's role.

Coastal Development chaired by Allison Evans did not have a report.

Zooplankton is chaired by Jack Fife but appears to be inactive at this time.

Motion by L. Hildebrand/seconded by B. Jones that the new Steering Committee contact chairs of inactive working groups and determine if they wish to continue or make a decision whether the group should be dropped.

All in favour, motion carried.

7. Update on the Steering Committee/Management Committee activities/decisions

Graham reported that the Steering Committee had met three times since the last AGM in November 2002, either in person or by conference call. They have discussed financial/budget concerns, a strategic working plan, the Integrated Management Plan, been involved with plans for the 5th Bay of Fundy Science workshop, and assisted working groups when necessary. A lengthy Integrated Fisheries proposal was prepared and submitted to the Federal Minister of Fisheries. They have also been involved in promoting interest in BoFEP and issues in the Bay of Fundy.

The Management Committee has dealt with financial requests from the Ecotourism Working group for assistance in a workshop as well as a request from the Minas Basin Working group to assist their coordinator to complete the work started on community workshops.

8. DF0 Proposal re: BoFEP role in integrated management in the Bay of Fundy (deferred)

9. Work Plans and proposed budget for 2002-2003

Barry Jones circulated financial statements for 2001-2002 and 2002-2003. After reviewing the 2001-2002 financial statement,

Motion from P. Pearson/seconded by D. Duggan to accept the financial statement from 2001-2002.

All in favour, motion carried.

Following a lengthy discussion and questions relating to the 2002-2003 budget

Motion from J. Ollerhead/seconded by M. Janowicz to have the Steering Committee revisit a revised budget and to produce a new draft budget, distribute to the members for a yes/no ballot with any other materials that are being forwarded to the membership.

All in favour, motion carried.

Motion from T. Chopin/seconded by C. Deacoff that the Steering Committee should reevaluate the new numbers and the working groups to provide an estimate of what they will be asking for the next year.

All in favour, motion carried.

The question of auditors was discussed. Acadia has been the auditor for the BoFEP accounts. The new Steering Committee will be asked to assess how we handle the auditing of funds.

Motion from B. Jones/seconded by J. Ollerhead that the BoFEP auditor for the upcoming year be Acadia University.

All in favor, motion carried.

10. Nominations and Election of Steering Committee

B. Jones reported on behalf of the nominating committee. All present members (20/24) are prepared to stay on the Steering Committee. The following individuals were elected to the Steering Committee: Davd Duggan, Rob Rangeley and Maria-Ines Buzeta. Justin Huston also volunteered to sit on the Steering Committee.

All members declared elected.

11. Date and location of the next AGM

Motion from B. Jones/seconded by P. Wells that the next AGM will be at the call of the chair and the location will be determined at a later date.

12. Other Business

The Gulf of Maine Council has invited the Minas Basin Working group to give a presentation in June.

Peter Wells reported that ~190 registrations have been received for the 5th Bay of Fundy Science Workshop. It appears to have been a huge success.

Peter also noted that the expenses for publications from Environment Canada were $7,500 and expects the extra costs for this year’s workshop, covered by Environment Canada, will be ~$10,500.

13. Adjournment

Motion to adjourn made by J. Ollerhead at 9:15 pm.

Participants List

Hugh Akagi
Passamaquoddy First Nations
48 Indian Pt.
St. Andrews, NB E5B 2R6
506-529-3402
506-529-9193
Akagih@Brunnet.net

Peter Amiro
Diadromous Fish Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 2N6
902-426-8104
902-426-6814
amirop@mar.dfo-mpo.gc.ca

Joe Arbour
Oceans and Coastal Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 2N6
902-426-7839
902-426-3855
arbourj@mar.dfo-mpo.gc.ca

Marieka Arnold
New Brunswick Federation of Naturalists
924 Prospect Street, Suite 2
Fredericton, NB E3B 2T9
506-459-4209
nbfn@nb.aibn.com

Peter Austin-Smith
6133 Shirley Street
Halifax, NS
902-425-8802
paustins@is2.dal.ca

Richard Bamberger
Marine Environmental Research Institute
PO Box 1652
Blue Hill, ME 04614 USA
207-374-2135
207-374-2931
meriedu@downeast.net

Myriam Barbeau
University of New Brunswick
PO Box 4400, 301 Charlotte Street
Fredericton, NB E3B 1L6
506-454-0824
mbarbeau@unb.ca

Angelika K. Bayer
University of Toronto
350 Atwood Lane
Oakville, ON L6H 5BG
416-419-5055
angelika.bayer@utoronto.ca

Karen Beazley
School for Resources and Environmental Studies
Dalhousie University
Halifax, NS B3H 3J5
902-494-1363
902-494-3728
kbeazley@is.dal.ca

Jody Berry
C-Ciarn Atlantic
1312 Robie Street
Halifax, NS B3H 3J5
902-422-2865
902-494-3728
jody_berry@hotmail.com

Kevin Blair
Environment Canada
45 Alderney Dr., Queen Square, 16th Floor
Dartmouth, NS B2Y 2N6
902-426-6892
902-426-8373
kevin.blair@ec.gc.ca

Gosh Bobba
Environment Canada
867 Lakeshore Road
Burlington, ON L7R 4A6
905-336-8911
905-336-4989
ghosh.bobba@cciw.ca

Angela Bond
ASU Box 6874
Wolfville, NS B0P 1Z1
902-545-3652
031337b@acadiau.ca

Beth Boon
Cape Chignecto
PO Box 581
Amherst, NS B4H 4H8
902-694-0535
902-251-2886
theboons@ns.sympatico.ca

Tony M. Bowron
Ecology Action Centre
1568 Argyle Street, Suite 31
Halifax, NS B3J 2B3
902-429-2202
902-422-6410
tbowron@is2.dal.ca

Rod Bradford
Diadromous Fish Division
Fisheries and Oceans Canada
PO Box 1006
Halifax, NS B2Y 2N6
902-426-4555
902-426-6814
bradfordr@mar.dfo-mpo.gc.ca

Christine Brown
Department of Geology
Acadia University
Wolfville, NS B4P 2R6
902-542-4450
03015b@acadiau.ca

John Brazner
PO Box 54
Knife River, MN 55609 USA
218-529-5207
218-529-5003
brazner.john@epa.gov

Monique Breau
Environment Canada
45 Alderney Drive, Queen Square
Dartmouth, NS B2Y 2N6
902-426-4178
902-426-8373
monique.breau@ec.gc.ca

Kate Bredin
Atlantic Canada Conservation Data Centre
PO Box 6416
Sackville, NB E4L 1G6
506-364-2660
506-364-2656
kbredin@mta.ca

Sean Brillant
Atlantic Coastal Action Program Saint John
PO Box 6878, Station A
Saint John, NB E2L 4S3
506-652-2227
506-633-2184
acapsj@fundy.net

Sadie Bryan
Bluenose Atlantic Coastal Action Program
PO Box 10
Mahone Bay, NS B0J 2E0
902-489-9818
902-624-9818
sadiebryan@hotmail.com

Michael Butler
Atlantic Coastal Zone Information Steering Committee Secretariat
1226 LeMarchant Street
Halifax, NS B3H 3P7
902-494-1977
902-494-1334
mbutler@is.dal.ca

Michael Brylinsky
Acadia Centre for Estaurine Research
Acadia University
Wolfville, NS B4P 2R6
902-585-1509
902-585-1054
mike.brylinsky@acadiau.ca

Maria-Ines Buzeta
Fisheries and Oceans Canada
St. Andrews Biological Station
531 Brandy Cove Road
St Andrews, NB E3B 2L9
508-529-8854
508-529-5862
buzetam@dfo-mpo.gc.ca

Stacie Carroll
Upper Bay Of Fundy Biosphere Initiative
RR#1
Economy, NS B0M 1J0
902-647-2811
902-647-2440
4.elements@ns.sympatico.ca

John Chardine
Canadian Wildlife Service
PO Box 6227
Sackville, NB E4L 1G6
506-364-5046
506-364-5062
john.chardine@ec.gc.ca

Tony Charles
Department of Finance and Management Studies
Saint Mary's University
Halifax, NS B3H 3C3
902-420-5732
902-496-8101
tony.charles@stmarys.ca

Chiu L Chou
Marine Chemistry Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-6277
902-426-7866
chouc@mar.dfo-mpo.gc.ca

Thierry Chopin
Department of Biology
University of New Brunswick
PO Box 5050
Saint John, NB E2L 4L5
506-648-5507
506-648-5811
tchopin@unbsj.ca

Gail Chmura
Department of Geography
McGill University
805 Sherbrooke St. W.
Montreal, PQ H3A 2K6
514-398-4958
514-398-7437
chmura@felix.geog.mcgill.ca

Ann Clarke
School for Resources and Environmental Studies
Dalhousie University
1312 Robie Street
Halifax, NS B3H 3J5
902-423-9558
calca@hotmail.com

Brenda Coldwell
PO Box 196
Wolfville, NS B0P 1X0
902-542-2171
brendac@ns.sympatica.ca

David Colville
Centre for Geographical Sciences
50 Elliott Road
Lawrencetown, NS B0S 1M0
902-584-2076
902-584-7211
david@cogs.ns.ca

Robert J. Conover
7415 McAllister Rd, RR #2
Bewdley, ON K0L 1E0
905-342-3546
905-342-2414
rconover@eagle.ca

Pam Comeau
Bay of Fundy Marine Resource Centre
PO Box 273
Cornwallis Park, NS BOS IHO
902-638-3044
902-638-3284
pconeau@bfmrs.ns.ca

Gail Corkum
GR Box AO-22, RR2
Wolfville, NS BOP 1XO
902-542-9708
tcfarms@ns.sympatico.ca

Mark Costello
Huntsman Marine Science Centre
1 Lower Campus Road
St. Andrews, NB E5B 2L7
506-529-1224
506-529-1212
costello@huntsman marine .ca

Francine Cottreau
Western Valley Development Authority
PO Box 278
Cornwallis Park, NS BOS 1H0
902-638-8100
902-638-8101
francinecottreau@wrdda.com

Chantal Couture
Oceans and Coastal Management Division
Fisheries and Oceans Canada
1 Challenger Drive, 5th Floor Polaris
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-4116
902-426-3855
couturech@mar.dfo-mpo.gc.ca

Brian Craig
Environment Canada
867 Lakeshore Road
Burlington, ON L7R 4A6
905-336-4431
905-336-4499
brian.craig@ec.gc.ca

Brad Crewe
Nova Scotia Department of Agriculture and Fisheries
PO Box 550
Truro, NS B2N 5E3
902-893-6578
902-893-0335
crewebc@ gov.ns.ca

Graham Daborn
Acadia Centre for Estuarine Research
Acadia University
Wolfville, NS B4P 2R6
902-585-1118
902-585-1054
graham.daborn@acadia.ca

John A. Dalziel
Marine Environmental Sciences Division
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-7272
902-426-6695
dalzielj@mar.dfo-mpo.gc.ca

Jaclyn Dann
Environment Canada-Atlantic Region
45 Alderney Drive
Dartmouth, NS B2Y 2N6
902-426-5378
902-426-6348
jaclyndann@ec.gc.ca

Ryan Debruyn
Applied Geomatics Research Group
50 Elliott Road
Lawrencetown, NS B0S 1M0
902-584-2076
902-584-7211

Cameron Deacoff
5681 Rhuland St., Apt 801
Halifax, NS B3H 4J6
902-422-3410
902-494-1001
cdeacoff@hotmail.com

Dan Deneau
Centre for Geographical Sciences
Box 1637
Middleton, NS B0S 1P0
902-825-9428
dan.daneau@hotmail.com

Andy Didyk
Faculty of Biology
University of New Brunswick
100 Arden Street
Moncton, NB E1C 4B7
506-869-6588
506-856-3356
adidyk@unb.ca

Elwood Lewis Dillman
Scotia Investments Ltd.
Box 393
Hantsport, NS BOP 1P0
902-684-1235
902-684-9045
edillman@scotiainvestments.ca

David Duggan
Oceans and Coastal Management Division
Fisheries and Oceans Canada
PO Box 1006, Mail Stn. B500
Dartmouth, NS B2Y 4A2
902-426-6183
902-426-3855
duggand@mar.dfo-mpo.gc.ca

Helene Maire Claire Dupuis
Policy and Program Planning
Fisheries and Oceans Canada
PO Box 5030
Moncton, NB E1C 9B6
506-851-3320
506-851-6579
dupuish@dfo-mpo.gc.ca

Peter Eaton
Environment Canada
45 Alderney Drive, Queen Square
Dartmouth, NS B2Y 2N6
902-426-4491
902-426-2062
peter.eaton@ec.gc.ca

Nestor Escara
1391 Henry Street, Apt. 1
Halifax, NS B3H 307
902-446-0794
nescara@is2.dal.ca

Kathy Faulkner
Baymount Outdoor Adventures Inc.
17 Elvin Jay Drive
Hillsborough, NB E4H 2S9
506-734-2660
506-734-1980
info@baymont&adventures.com

Sheri Faulkner Jackson
School of Resources and Environmental Management
Simon Fraser University
27 Christopher Court Apt. 12
Saint John, NB E2K 4L4
506-635-8068
fauljack@nbnet.nb.ca

James Ferguson
james.ferguson@hotmail.com

Cheryl Frail
Invertebrate Fisheries Division
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-5448
902-426-1862
frailc@mar.dfo-mpo.gc.ca

Jamie F. Gibson
Acadia Centre for Estuarine Research
Acadia University
PO Box 115
Wolfville, NS B4P 2R6
902-585-1311
902-585-1054
jamie.gibson@acadiau.ca

Jennifer Graham
Centre for Community Based Management
278 Water Street
St. Andrews, NB E5B 1C7
506-529-8357
grahamja@nb.sympatico.ca

David Greenberg
Oceans Sciences Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4AZ
902-426-2431
902-426-6927
GreenbergD@mar.dfo-mpo.gc.ca

Jennifer Ruth Hackett
Oceans and Coastal Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-1491
902-426-3855
hackettj@mar.dfo-mpo.gc.ca

Diana Hamilton
Department of Biology
University of New Brunswick
Bag Service 4511
Fredericton, NB E3B 6E1
506 453 4594
506-453-3583
dhamilton2@unb.ca

Anita Hamilton
Habitat Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-1642
902-426-1489
hamiltona@mar.dfo-mpo.gc.ca

Alan Hanson
Canadian Wildlife Service
PO Box 6227
Sackville, NB E4L 1B6
506-364-5061
506-364-5062
al.hanson@ec.gc.ca

Gareth C. H. Harding
Habitat Ecology Section
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-425-2692
902-426-6695
hardingg@mar.dfo-mgp.gc.ca

Tracy Hart
Maine Sea Grant
1084 School St., Apt.3
Veazie, ME 04401 USA
207-947-2783
hartycart@hotmail.com

Janice Harvey
Conservation Council of New Brunswick
45 Libbey Lane
Waweig, NB E3L 5Z1
506-466-4033
506-466-2911
ccnbharvey@nb.aibn.com

Stephen Hawboldt
Clean Annapolis River Project
PO Box 395
Annapolis Royal, NS B0S 1H0
902-532-2533
902-532-3038
C.A.R.P@ns.sympatico.ca

Jocelyne Hellou
Marine Chemistry Section
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-7451
902-426-6695
hellouj@mar.dfo-mpo.gc.

Elaine Hendricks
Irving Project
Acadia University
PO Box 48
Wolfville, NS B0P 1X0
902-585-1752
elaine.hendricks@acadiau.ca

Donald Hendricks
Irving Project
Acadia University
PO Box 48
Wolfville, NS B0P 1X0
902-585-1752
donald.hendricks@acadiau.ca

Peter Hicklin
Canadian Wildlife Service
PO Box 6227
Sackville, NB E4L 1G6
506-364-5042
506-314-5062
peter.hicklin @ec.gc.ca

Larry Hildebrand
Environment Canada
45 Alderney Drive, Queen Square, 16th Floor
Dartmouth, NS B2Y 2N6
902-426-2131
902-426-6348
larry.hildebrand@ec.gc.ca

Patricia Hinch
25 Hanover Court
Halifax, NS B3M 3K7
902-424-6345
902-424-0575
hinchpr@gov.ns.ca

Kelly Patrick Honeyman
J. D. Irving, Limited
300 Union Street
Saint John, NB E2L 4M3
506-632-4133
506-632-4421
honeyman.kelly@jdirving.com

Justin Huston
Nova Scotia Department Agriculture and Fisheries
PO Box 2223
Halifax, NS B3J 3C4
902-424-2996
902-424-1766
hustonje@gov.ns.ca

Sherri Jackson
Kings Community Economic Development Agency
28 Aberdeen Street, Suite 5
Kentville, NS B4N 2N1
902-678-2298
902-678-2324
sherri@kingsced.ns.ca

Marianne Janowicz
New Brunswick Department of Environment and Local Government
PO Box 6000
Fredericton, NB E3B 5H1
506-457-4923
506-457-7823
marianne.janowicz@gnb.ca

Isabel C. Johnson
Golder Associates Inc.
6241 NW 23rd Street, Suite 500
Gainesville, FL 32653 USA
352-336-5600
352-336-6603
ijohnson@golder.com

Barry Jones
626 Churchill Row
Fredericton, NB E3B 1P6
506-454-6108
barryj@nbnet.nb.ca

Denise Joy
New Brunswick Department of Environment and Local Government
8 Castle Street
Saint John, NB E2L 4Y9
506-643-6889
506-658-3046
denise.joy@gnb.ca

Gary Julien
Environment Canada
45 Alderney Drive, Queen Square
Dartmouth, NS B2Y 2N6
902-426-4486
902-426-8373
gary.julien@ec.gc.ca

Irena Kaczmarska-Ehrman
Biology Department
Mount Allison University
63B York Street
Sackville, NB E4L 1G7
506-364-2510
506-364-2505
iehrman@mta.ca

Martin Kaye
Bay of Fundy Marine Resource Centre
PO Box 273
Cornwallis Park, NS B0S IHO
902-638-3044
902-638-3284
martink@bfmrc.ns.ca

Brian Keating
Area Habitat Management
Fisheries and Oceans Canada
717 Main Street, Unit 3
Sussex, NB E4E 7H7
506-432-4152
506-432-5081
keatingb@mar.dfo-mpo.gc.ca

Sarah Kennedy
Environment Canada
351 St. Joseph Blvd
Place Vincent Massey, 12th Floor
Hull, PQ K1A 0H3
819-958-8155
819-953-0913
sarah.kennedy@ec.gc.ca

Joseph Kerekes
Canadian Wildlife Service
Environment Canada
45 Alderney Drive, 5th Floor
Dartmouth, NS B2Y 2N6
902-426-6356
joe.kerekes@ec.gc.ca

Paul D. Keizer
Marine Environmental Sciences Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-6138
902-426-6695
keizerp@mar.dfo-mpo.gc.ca

Marty King
World Wildlife Fund
Suite 504, 5251 Duke Street
Halifax, NS B3J 1P3
902-482-1105
902-482-1107
mking@wwfcanada.org

Andy Kirk
Town of Windsor
PO Box 158
Windsor, NS BON 2T0
902-798-4776
902-798-5679
agmkirk@ns.sympatico.ca

Karen Kittilsen
Hants Regional Development Authority
PO Box 2313
Windsor, NS B0N 2T0
902-798-8722
902-798-3254
Karen Kittilsen@hotmail.com

Zsofi Koller
Conservation Council of New Brunswick
180 St.John Street
Fredericton, NB E3B 4A9
506-458-8747
506-458-1047
zsofikoller@yahoo.ca

Hank Kolstee
Nova Scotia Department of Agriculture and Fisheries
PO Box 550
Truro, NS B2N 5E3
902-893-6569
902-893-0335
kolstehw@gov.ns.ca

Peter F. Larsen
Bigelow Laboratory for Ocean Sciences
Mckown Point
West Boothbay Harbor, ME 04575 USA
207-633-9600
207-633-9661
plarsen@bigelow.org

Peter Lawton
Fisheries and Oceans Canada
St. Andrews Biological Station
531 Brandy Cove Road
St. Andrews, NB E5B 2L9
506-529-5919
506-529-5862
lawtonp@mar.dfo-mpo.gc.ca

Charles LeBlanc
Environment Canada
Environment Science Centre
Moncton, NB E1A 6S8
506-851-7254
506-851-6608
charles leblanc@ec.gc.ca

Claudette LeBlanc
Atlantic Coastal Zone Information Steering Committee Secretariat
1226 LeMarchant Street
Halifax, NS B3H 3P7
902-494-1977
902-494-1334
leblancc@ca.inter.net

Heather Levy
Envirosphere Consultants Ltd.
PO Box 2906
Windsor, NS BON 2T0
902-798-4022
902-798-4022
enviroco@ns.sympaticao.ca

Allan Lines
Titanium Corporation
287 Lacewood Drive, Unit 103, Suite 432
Halifax, NS B3M 3Y7
902-443-7243
902-443-7243
alines@istar.ca

Gary Lines
Environment Canada
45 Alderney Drive, Queen Square, 16th Floor
Dartmouth, NS B2Y 2N6
902-426-5739
902-426-2248
gary.lines@ec.gc.ca

JohnLoch
52 Eaglewood drive
Bedford, NS B4A 2J6
902-832-0648
john.loch@ns.sympatico.ca

Heike Lotze
Department of Biology
Dalhousie University
Halifax, NS B3H 4J1
902-868-2885
902-794-3736
hlotze@is.dal.ca

Ron Loucks
RH Loucks Oceanology Ltd.
24 Clayton Park Dr.
Halifax, NS B3M 1L3
902-443-1113
ron.loucks@ns.sympatico.ca

Carl MacDonald
Fisherman & Scientists Research Society
PO Box 25125
Halifax, NS B3M 4H4
902-461-8119
902-461-0541

Colin MacKinnon
Canadian Wildlife Service
PO Box 6227
Sackville, NB E4L 1G6
506-364-5039
506-304-5062
colin.mackinnon@ec.gc.ca

Josette Maillet
Nature Conservancy of Canada-Atlantic Region
924 Prospect St., Suite 2
Fredericton, NB E3B 2T9
506-450-6010
506-450-6013
josette.maillet@natureconservancy.ca

Angela Martin
Huntsman Marine Science Centre
1 Lower Campus Road
St. Andrews, NB E5B 2L7
506-529-1213
509-529-1212
arc@mar.dfo-mpo.gc.ca

Amanda McGurire
Huntsman Marine Science Centre
1 Lower Campus Road
St. Andrews, NB E5B 2L7
506-529-1213
506-529-1212
arc@mar.dfo-mpo.gc.ca

Kyle McKenzie
C-CIARN Atlantic
1312 Robie Street
Halifax, NS B3H 3J5
902-494-6355
902-494-3728
kyle.mckenzie@dal.ca

Syliva Betty McKoy
Joggins Fossil Cliffs World Heritage Committee
PO Box 84
River Hebert, NS B0L 1G0
902-251-2446
902-251-2446
jfcliffs@creda.net

Heather McCracken
Applied Geomatics Research Group
50 Elliott Road
Lawrencetown, NS B0S 1M0
902-584-2076
902-584-7211
hmccrack@hotmail.com

Shayne McQuaid
Habitat Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-4612
902-426-1489
mcquaids@mar.dfo-mpo.gc.ca

Stephanie Mehlman
Clean Annapolis River Project
PO Box 395
Annapolis Royal, NS B0A 1S0
902-532-7533
902-532-3038
carp.climate@ns.sympatico.ca

Vincent Mercier
Environment Canada
PO Box 23005
Moncton, NB E1A G58
506-851-6244
506-851-6608
vincent.mercier2@ec.gc.ca

Inka Milewski
Conservation Council of New Brunswick
254 Douglasfield Road
Miramichi, NB E1N 4S5
506-622-2460
506-622-2438
milewski@nbnet.nb.ca

Alex Mosher
Applied Geomatics Research Group
RR#1
Bridgetown, NS B0S 1C0
902-584-3734
amosherpmd@hotmail.com

David J. Mossman
Department of Geography
Mount Allison University
144 Main Street
Sackville, NB E4L 1A7
506-364-2312
506-364-2625
dmossman@mta.ca

Sean Murphy
Parks Canada-Atlantic Service Centre
1869 Upper Water Street
Halifax, NS B3J 1S9
902-426-8172
902-426-6881
sean_murphy@pch.gc.ca

Steve Murray
7 Shannon Drive
Truro, NS B2W 3V5
902-895-8986
039141m@acadiau.ca

Kee Muschenheim
Acadia Centre for Estuarine Research
Acadia University
Wolfville, NS B4P 2R6
902-585-1113
kee@istar.ca

Robin Musselman
BOFEP
2497 Philip St.
Halifax, NS B3L 3H1
902-455-2202
902-455-1529
r.musselman@ns.sympatico.ca

Jason Naug
Oceans and Coastal Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-6046
902-426-3855
naugj@mar.dfo-mpo.gc.ca

Teresa Newcomb
RR#1 Barss Corner
Maplewood, NS B0R 1A0
902-644-2821
biomusic71@hotmail.com

Reg Newell
Nova Scotia Department of Natural Resources
136 Exhibition Street
Kentville, NS B4N 4E5
902-679-6145
902-679-6176
newellrb@gov.ns.ca

Charles O'Reilly
Canadian Hydrographic Services
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-5344
902-426-1893
oreillyc@mar.dfo-mpo.gc.ca

Jeff Ollerhead
Department of Geography
Mount Allison Unviersity
144 Main St.
Sackville, NB E4L 1A7
506-364-2428
506-364-2625
jollerhead@mta.ca

Jackie Olsen
Environment Canada
45 Alderney Drive, Queen Square, 16th Floor
Dartmouth, NS B2Y 2N6
902-426-0628
902-426-6348
jackie.olsen@ec.gc.ca

Roger Alan Outhouse
Island Consolidated School
PO Box 80
Freeport, NS B0V 1B0
902-839-6300
902-839-6303

Lisa Paon
Marine Chemistry Section
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-7866
902-426-7866
paonl@mar.dfo-mpo.gc.ca

Ed Parker
New Brunswick Department of Environment and Local Government
8 Castle Street
Saint John, NB E2L 4Y9
506-643-6889
506-658-3046
ed.parker@gnb.ca

Michael Parker
East Coast Aquatics
P.O. Box 129
Bridgetown, NS B4S 1L4
902-665-4682
msrparker@ns.sympatico.ca

Jon Percy
BOFEP
PO Box 42
Granville Ferry, NS BOS 1K0
902-532-5129
BOFEP@Auracom.com

Pamela Person
GPAC
479 Back Ridge Rd
Orland, ME 04472 USA
207-469-6770
207-246-6770
phppwp@aol.sm

Patricia Pocklington
Arenicola Marine
PO Box 1097
Wolfville, NS B0P 1X0
902-542-1903
902-542-1903
aremocp;@accesswave.ca

Gerhard Pohle
Huntsman Marine Science Centre
1 Lower Campus Road
St. Andrews, NB E5B 2L7
506-524-1203
506-529-1212
arc@dfo-mpo.gc.ca

Ivan Rafuse
Indian and Northern Affairs Canada
PO Box 160
Amherst, NS B4H 3Z3
902-661-6356
902-661-6237
rafusei@inac.gc.ca

Robert Rangeley
World Wildlife Fund
Suite 504, 5251 Duke Street
Halifax, NS B3J 1P3
902-482-1105
902-482-1107
rrangeley@wwfcanada.org

Munju Monique Ravindra
Parks Canada
Fundy National Park
Alma, NB E4A 1B4
902-426-3471
munju-ravindra@pch.gc.ca

Janice Raymond
Planning Division
Fisheries and Oceans Canada
PO Box 1035
Dartmouth, NS B2Y 4T3
902-426-6928
902-426-6767
RaymondJ@aar.dfo-mo.gc.ca

Trefor Reynoldson
Environment Canada
Acadia University
Wolfville, NS B4P 2R6
902-585-1638
902-585-1054
trefor.reynoldson@acadiau.ca

Joel Richardson
New Brunswick Department of Tourism and Parks
PO Box 6000
Fredericton, NB E3B 5H1
506-444-5171
506-444-2323
joel.richardson@gnb.ca

David Robichaud
Fisheries and Oceans Canada
531 Brandy Cove Rd
St. Andrews, NB E5B 2L9
506-529-8854
506-529-5850
robichaudd@mar.dfo-mpo.gc.ca

Denise Roy
Nature Conservancy of Canada-Atlantic Region
924 Prospect
Fredericton, NB E3B 2T9
506-872-3330
denise.roy@natureconservancy.ca

Kasia Rozalska
Applied Geomatics Research Group
PO Box 259
Lawrencetown, NS B0S 1M0
902-584-3203
rozalska@yahoo.com

Murray Rudd
Fisheries and Oceans Canada
PO Box 1035
Dartmouth, NS B2Y 4T3
902-426-4825
ruddm@mar.dfo-mpo.gc.ca

Bob Rutherford
Oceans and Coastal Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-8398
902-426-3855
RutherfordB@ mar.dfo-mpo.gc.ca

Donald Sam
Nova Scotia Nature Trust
PO Box 2202
Halifax, NS B3J 3C4
902-425-5263
902-429-5263

Shannon Scott
Fishermen and Scientists Research Society
PO Box 25125
Halifax, NS B3M 4H4
902-461-8119
902-461-0541
scottsl@mar.dfo-mpo.gc.ca

Glyn Sharp
Invertebrate Fisheries Division
Fisheries and Oceans Canada
1 Challenger Drive, B500
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-6042
902-426-1862

John Shaw
Geological Survey of Canada
Bedford Institute of Oceanography
Dartmouth, NS B2Y 4A2
902-426-6204
902-426-4104
shaw@aac.bio.ns.ca

Christine Anne Smith
26 Remington Ct.
Halifax, NS B2M 3Y6
902-443-9768
envSmith@chebucto.ns.ca

Melanie Smith
46 Millwood Drive
Lower Sackville, NS B4E 2V7
902-864-4270
smithml2@is2.dal.ca

Klaus Sonnenberg
Grand Manan Fishermen's Association
PO Box 907
Grand Manan, NB E5G 4M1
506-662-8481
506-662-8336
gmfa@nb.aibn.com

Herb Sooley
Health Canada
Suite 1625, 1505 Barrington Street
Halifax, NS B2W 5C2
902-426-5575
902-426-6675
herbert-sooley@nc.sc.gc.ca

Cliff Stanley
Department of Geology
Acadia University
Wolfville, NS B4P 2R6
902-585-1344
902-585-1816
cliff.stanley@acadiau.ca

Edward Peter Steenstra
US Fish and Wildlife Service
306 Hatchery Road
East Orland, ME 04431 USA
207-469-6701, x 215
207-469-6724
edward-steenstra@fws.gov

Airin Stephens
278 Water Street
St Andrews, NB E5B 1C7
506-529-8357
airinstephens@yahoo.com

Patrick Stewart
Envirosphere Consultants Ltd
PO Box 2906
Windsor, NS B0N 2T0
902-798-4022
902-798-4022
enviroco@ns.sympatico.ca

Peter Strain
Marine Environmental Sciences
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-3639
902-425-6695
strainp@mar.dfo-mpo.gc.ca

Michael Strong
Fisheries and Oceans Canada
531 Brandy Cove Road
St. Andrews, NB E5B 2L9
506-529-5939
506-529-5862
strongm@mar.dfo-mpo.gc.ca

Elsie Sunderland
School of Resource and Environmental Management
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6
604-291-5776
604-291-4968
ems@sfv.ca

Bill and Judith Swindell
PO Box 111
Advocate, NS B0U 1A0
902-392-2646

Brian Thompson
Habitat Management Division
Fisheries and Oceans Canada
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-1510
902-426-1850
thomsonb@mar.dfo-mpo.gc.cab

Sarah Townsend
8 Tache Street
Lower Sackville, NS B4C 1Y6
902-864-3569
sarahmerrill@netscape.net

Marsha Trites
Biology Department
Mount Allison University
63B York Street
Sackville, NB E4L 1G7
506-364-2510
506-364-2505
mjtrts@mta.ca

Megan Trites-Tolson
Environment Canada
45 Alderney Drive, Queen Square
Dartmouth, NS B2Y 2N6
902-426-3766
902-426-6348
megan.trites-tolson@ec.gc.ca

Danika Van Proosdij
Department of Geography
Saint Mary's University
923 Robie Street
Halifax, NS B3H 3C3
902-420-5738
902-496-8213
dvanproo@stmarys.ca

Bradley Walters
Geography Department
Mount Allison University
Sackville, NB E4L 1A7
506-536-1853
506-364-2625
bwalters@mta.ca

David Wartman
Environment Canada
45 Alderney Drive, Queen Square, 16th Floor
Dartmouth, NS B2Y 2N6
902-426-9132
902-490-0720
dave.wartman@ec.gc.ca

Tim Webster
COGS
50 Elliott Road
Lawrencetown, NS B0S 1M0
902-825-5475
tim@cogs.ns.ca

Darrell Wells
New Brunswick Department of Environment and Local Government
PO Box 6000
Fredericton, NB E3B 5H1
506-453-6633
506-453-2390
darrell.wells@gnb.ca

Peter Wells
Environment Canada
45 Alderney Drive, 7th Floor
Dartmouth, NS B2Y 2N6
902-426-1426
902-426-4457
peter.wells@ec.gc.ca

Maxine Westhead
Oceans and Coastal Management Division
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS B2Y 4A2
902-426-4215
902-426-3855
westheadm@mar.dfo-mpo.gc.ca

Bill Whitman
Nova Scotia Department of Agriculture and Fisheries
PO Box 280
Cornwallis, NS B0S 1H0
902-638-2390
902-638-2391
whitmanwe@gov.ns.ca

Jennifer Whitney
301 Charlotte Street
Fredericton, NB E3B 1L6
506-454-0824
u2ao@unb.ca

Peter Williams
School of Resource and Environmental Management
Simon Fraser University
1275 Mathers Ave.
West Vancouver, BC V1T 2G4
604-291-3074
604-291-4968
peter_williams@sfu.ca

Renee Wissink
Fundy National Park
PO Box 1001
Alma, NB E4H 3K1
506-887-6098
506-887-6011
reneee_wissink@pch.gc.ca

James Wolford
Federation of Nova Scotia Naturalists
Site 1, Comp. 61, RR 3
Wolfville, NS B0P 1X0
902-542-7650
902-585-1059
jww.driv@ns.sympatico.ca

Tom Young
Resource Management Associates
PO Box 818
Parrsboro, NS B0M 1S0
902-254-2772
902-254-2711
tmyoung@auracom.com

Colin Zwicker
Department of Geology
Acadia University
Wolfville, NS B4P 2R6
902-68409796
czwicker@acadiau.ca

Steve Zwicker
Environment Canada
45 Alderney Drive, Queen Square, 16th Floor
Dartmouth, NS B2Y 2N6
902-426-0992
902-426-8373
stephen.zwicker@ec.gc.ca

Index

Other reports in the Series:

Report No.

1. Atlantic Maritime Ecozone Research and Monitoring, Workshop Proceedings, March 1993 (out of print)

2. Ecological Monitoring and Research at Kejimkujik National Park, 1978-1992 (out of print)

3. Kejimkujik Watershed Studies: Monitoring and Research Five Years After "Kejimkujik '88"

4. Ecological Monitoring and Research in the Coastal Environment of the Atlantic Maritime Ecozone, Workshop Proceedings, Huntsman Marine Laboratory, March 9-11, 1994 (out of print)

5. Ecological Monitoring and Research in Atlantic Canada: A Focus on Agricultural Impacts in Prince Edward Island

6. Science and Policy Implications of Atmospheric Issues in Atlantic Canada, Workshop Proceedings, Halifax, NS, November 28-30, 1995

7. Canada Goose Studies in the Maritime Provinces 1950-1992, Compiled by Anthony Erskine, January 1997 (date of Pub. March 1997)

8. Bay of Fundy Issues: a scientific overview, Proceedings of a Workshop, Wolfville, NS, January 29 to February 1, 1996 (date of Pub. March 1997)

9. Climate Change and Climate Variability in Atlantic Canada, Proceedings of a Workshop, Halifax, NS, December 3-6, 1996 (date of Pub. March 1997)

10. Trends of Acid Precipitation Chemistry Variables in some Atlantic Canada National Parks (date of Pub. April 1997)

11. Using Environmental Prediction in Ecosystem Science in Atlantic Canada, Workshop Proceedings, Halifax, NS (date of Pub. March 1998)

12. Understanding Change in the Bay of Fundy Ecosystem, Workshop Proceedings, Sackville, NB (April 22-24, 1999)

13. Climate Change and Ecosystem Research in Canada's North, A report to the Northern Ecosystem Initiative Management Team, by Thomas A. Clair (March 2000, English/français)

14. Acid Precipitation Lake Monitoring Program in Canada's Atlantic Provinces (March 2000, Report in CDROM format)

15. Multi-disciplinary Study of Metal Cycling, Primarily Hg, in Aquatic and Terrestrial Environments, Workshop Proceedings, Sackville, NB (March 2000)

16. Environment Canada's Acid Precipitation Monitoring Networks in Atlantic Canada (March 2001, Report in CDROM format)

17. Opportunities and Challenges for Protecting, Restoring and Enhancing Coastal Habitats in the Bay of Fundy. Proceedings of the 4th Bay of Fundy Science Workshop, Saint John, NB, September 19-21, 2000

18. Cycling of mercury in Kejimkujik National Park. Toxic Substance Initiative Project/124 Summary, December 2001

19. Petitcodiac River/Estuary Modelling Workshop Summary, Moncton, New Brunswick, Canada, March 3 to 5, 2002

20. Atlantic Canada National Park Aquatic Resources Inventories, Kejimkujik, Gros Morne and Cape Breton Highlands. Republished from: J. Kerekes and P Schwinghamer