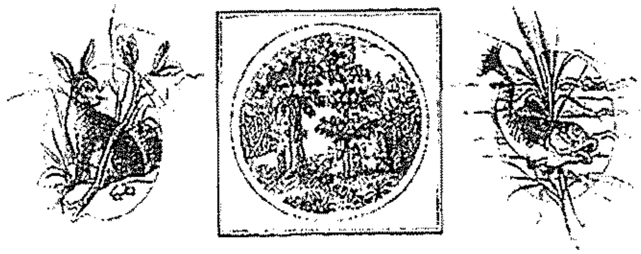

3rd Bay of Fundy Science Workshop

Understanding Change in the *Bay of Fundy* Ecosystem

Proceedings

EDITORS

J. Ollerhead, P.W. Hicklin, P.G. Wells and K. Ramsey

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BoFEP — Bay of Fundy Ecosystem Partnership

Mount Allison University

FMESP

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ACKNOWLEDGMENTS

We are pleased to acknowledge the support and assistance of many individuals and organizations who contributed to the success of the 3rd Bay of Fundy Science Workshop - *Understanding Change in the Bay of Fundy Ecosystem.*

First, special thanks to Environment Canada, Environmental Conservation Branch for financial support for this volume.

Second, the conference was made possible by contributions from Environment Canada, Mount Allison University, Bay of Fundy Ecosystem Partnership, Fundy Marine Ecosystem Science Project and Canadian Wildlife Service (Atlantic Region).

Third, thanks go those who helped the conference committee, namely Jon Percy (Consultant), Rebecca Rush and Andrew Langille (Student Assistants).

Finally, the greatest acknowledgment must go to the conference participants and presenters who made the workshop enjoyable and informative.

TRIBUTE TO DAVID E. GASKIN

P.G. **Wells,** Environment Canada

Dr. David (Dave) Gaskin passed away in September 1998. Dave was an internationally-known marine zoologist from the University of Guelph with a long interest and expertise in the biology, ecology and ecotoxicology (trace contaminants burdens) of cetaceans of the lower Bay of Fundy and Gulf of Maine. As such, Dave was known by many of us in the Maritime Provinces. The organizers of the 3rd Bay of Fundy Science Workshop dedicate this volume to his memory and to his outstanding legacy of Canadian marine science and undergraduate and graduate education.

Dave started his career at the National Institute of Oceanography, U.K., in 1961, continued in New Zealand at the Fisheries Research Division (1962-65) and Massey University (1965-68) and moved to Guelph in 1968, where he remained as a Professor in the Department of Zoology. His research interests were very broad - from Lepidopterans (butterflies), on which he was an international authority, to harbor porpoise (*Phocoena phocoena*) and the northern right whale (*Eubalaena glacialis)*, on which he concentrated his studies in the Bay of Fundy. He had 138 primary publications on these groups. He wrote "*The Ecology of Whales and Dolphins*" (1982), now in its second printing and countless book chapters and reports. He and his students were experts on the harbor porpoise, the north Atlantic right whale and other cetaceans of the north-west Atlantic. Many papers dealt with environmental pollution, dating back to the early 1970's, providing invaluable long-term data for trend analysis of contaminants in mammalian tissues. Dave had many graduate students and an outstanding record of theses and co-authored papers from their work. Over 27 years at Guelph, he taught 14 different undergraduate courses and 4 graduate courses, ranging from introductory biology to biometrics and fisheries biology. He taught Japanese in the Department of Languages. He was an exceptional teacher, with a rigorous, patient and friendly approach to what he preferred to call "training".

On a personal note, I knew Dave (albeit too briefly) through Guelph's Zoology Department, from 1970 to 1976, while studying as a Ph.D. candidate in Guelph and at the Huntsman Marine Laboratory in St Andrews, NB. David served on my thesis committee and always was most helpful, enthusiastic and knowledgeable. I took his fisheries biology course in which, to my surprise and lasting benefit, I helped with the water pollution lectures. I recall the broad smile, fast wit, acerbic humour and incredible energy radiated by the man, both in the classroom and in the field! After graduating, I sometimes saw Dave in his field boat near Deer and Campobello Islands in the summer months, shouting a friendly hello as he roared past our sailing boat, following porpoise or whales - always a picture of perpetual motion and dedication to his research!

"The University of Guelph's Department of Zoology has established the Gaskin Medal in Marine and Freshwater Biology to honour his contribution to both the Department and this field. The Medal will be presented annually at the June Convocation Ceremony to the student with the highest cumulative average in Guelph's Marine and Freshwater Biology major. David was aware of the establishment of this Medal and was very honoured to be recognized in this way"[1].

[1] From Dr. Paul D.N. Hebert, Professor and Chair, Department of Zoology. Contributions are needed to establish the endowment for the Medal and its annual award of $500. They should be directed to the Department of Zoology, University of Guelph, Guelph, ON, N1G 2W1, the cheque payable to the University of Guelph. A receipt for tax purposes will be issued.

FORWARD

Jeff **Ollerhead,** Mount Allison University

The 3rd Bay of Fundy Science Workshop was held in Sackville, New Brunswick on April 22-24, 1999. It followed successful meetings held in Wolfville, Nova Scotia (January 29-February 1, 1996) and St. Andrews, New Brunswick (November 14-15, 1997). The meeting was an activity of the Bay of Fundy Ecosystem Partnership which is dedicated to:

1. The ecological integrity, vitality, diversity and productivity of the Bay of Fundy ecosystem.
2. The effective communication and co-operation among groups and individuals interested in understanding sustainability using and conserving the resources, habitats and ecological processes of the Bay of Fundy.

The goal of the first workshop was to seek a consensus on further marine ecosystem research needed on the Bay's natural resources, to identify coastal management and conservation requirements for the Bay, and to map out a plan for timely, multi-partner, interdisciplinary research and coastal management initiatives. The proceedings of this workshop were published in Percy *et al.* (1997).

The goal of the second workshop was to consider the role of coastal monitoring and subsequent assessment in understanding the ecological processes and biota of coastal environments and the changes occurring in them. The proceedings of this Workshop were published in Burt and Wells (1998).

The goal of the third workshop was to consider a multitude of facets related to understanding change in the Bay of Fundy ecosystem. The central questions of the workshop were: how can we recognize change, what tools are needed to monitor change, and most importantly, how should we respond to change? These proceedings are the third in the series and additional copies may be obtained from:

Environmental Conservation Branch
Environment Canada - Atlantic Region
P.O. Box 6227, Sackville, NB
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The next Bay of Fundy Ecosystem Partnership meeting will be held in conjunction with the Coastal Zone Canada 2000 meeting which is scheduled to take place in St. John, New Brunswick on September 17-22, 2000. Further information about the Bay of Fundy Ecosystem Partnership may be obtained from:

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Further information about Coastal Zone Canada 2000 may be obtained from:

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czczcc2000@gov.nb.ca

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EXECUTIVE SUMMARY

Jeff **Ollerhead**, Mount Allison University

The third Bay of Fundy Science Workshop was held in Sackville, New Brunswick on April 22-24, 1999 at Mount Allison University. This workshop was held to foster effective communication and co-operation among all stakeholders interested in the Bay of Fundy ecosystem. The goal of the workshop was to consider a multitude of facets related to understanding change in the Bay of Fundy ecosystem. The central questions of the workshop were: how can we recognize change, what tools are needed to monitor change, and most importantly, how should we respond to change?

The three day meeting involved paper and poster sessions, a public lecture by author Harry Thurston, a panel discussion and several group discussions including a series of informal presentations by members of several non-governmental organizations (NGOs). The workshop was attended by 80 people including 10 students.

The most difficult issue tackled at the workshop was that of trying to identify all of the relevant changes which should be considered in any assessment of the 'health' of the Bay of Fundy ecosystem. There are numerous realms within which change may be occurring (biological, sedimentary, economic, social, cultural, etc.) and each must be considered in concert with the others. It is clear that no single group or organization can measure the 'pulse' of the Bay in isolation and then draw meaningful conclusions. A holistic approach to assessing change is more than desirable, it is essential.

Even defining change proved to be a challenge; the lack of good baseline data and/or long-term measurements were identified as a significant hurdle to identifying change in many cases. Methods of addressing these challenges were discussed including the use of key informants who may have witnessed change over the years or decades and the role that community groups might play in longer-term monitoring projects that other agencies either cannot or will not undertake.

As concern about the impact that changes of various types might have on this unique ecosystem and the people that live on and around it increases around the Bay, the need to identify and monitor change will likely grow in importance. A principal outcome of the meeting was an enhanced appreciation by many of the attendees that identifying, monitoring, and responding to change in all of its various facets, is a monumental task. It was concluded that the key to making headway is to act strategically and undertake projects that are manageable, meaningful, and which might attract broad support and input from all interested parties.

Sommaire Executif: Le troisième Atelier scientifique sur la baie de Fundy a eu lieu à Sackville (Nouveau-Brunswick) du 22 au 24 avril 1999, à l'Université Mount Allison. Cet atelier s'est tenu pour encourager la communication et la coopération efficaces entre toutes les personnes et organisations qui ont des enjeux dans l'écosystème de la baie de Fundy. Le but de l'atelier a été d'examiner une multitude de facettes de la compréhension des changements dans l'écosystème de la baie de Fundy. Les problèmes essentiels discutés dans le cadre de l'atelier ont été les suivants: comment reconnaître les changements, quels outils faut-il employer pour suivre ces changements, et, ce qui est le plus important, comment réagir à ces changements.

Cette réunion de trois jours a inclus des séances de présentations orales et de posters, une conférence publique donnée par l'auteur Harry Thurston, une discussion de panel et plusieurs discussions de groupes, lesquelles comprenaient une série de présentations libres faites par des membres de diverses organisations non gouvernementales (ONG*s*). L'atelier a réuni 80 participants, dont 10 étudiants.

Le problème le plus difficile abordé dans le cadre de l'atelier a été celui d'identifier tous les changements pertinents qu'il faut examiner dans toute évaluation de la « santé » de l'écosystème de la baie de Fundy. Ces changements peuvent se produire dans bien des domaines (biologique, sédimentaire, économique, social, culturel, etc.) et chacun de ces domaines doit être examiné de concert avec tous les autres. Il est clair qu'aucun groupe ou organisation ne peuvent, à eux seuls et isolément, prendre le « pouls » de la baie et en tirer des conclusions valables. Il est non seulement désirable, mais essentiel, d'aborder de manière intégrée l'évaluation des changements.

Même le problème de définir ces changements s'est révélé fort difficile ; l'atelier a reconnu que le manque de données de qualité sur les valeurs moyennes des paramètres, et/ou le manque de séries prolongées de mesures, constituent dans de nombreux cas des obstacles significatifs à l'identification des changements. L'atelier a discuté des méthodes à employer pour attaquer ces difficultés, entre autres le recours à des informateurs clés qui pourraient avoir été témoins de changements au long des années ou des décennies ; l'atelier a examiné le rôle que des groupes communautaires peuvent jouer dans des programmes de suivi prolongé, que d'autres organisations ne peuvent ou ne veulent pas entreprendre.

Les préoccupations au sujet de l'impact de divers types de changements sur cet écosystème unique vont aller croissant tout autour de la baie ; par conséquent, le besoin d'identifier et de suivre les changements va probablement s'accentuer. L'un des résultats principaux de la réunion est que de nombreux participants sont devenus plus conscients du fait que l'identification et le suivi des changements, et les réponses à ces changements, constituent des tâches monumentales. On a conclu que la clé des progrès dans ce domaine consiste à agir de manière stratégique et à entreprendre des programmes praticables, valables, et qui puissent attirer de larges appuis et contributions de la part de toutes les parties intéressées.

Introduction

OPENING REMARKS

Jeff **Ollerhead**, Mount Allison University

The third Bay of Fundy Science Workshop was opened by Jeff Ollerhead, the meeting Chair, on April 22, 1999 at Mount Allison University. After offering greetings on behalf of the Bay of Fundy Ecosystem Partnership (BoFEP), the workshop organizing committee and Mount Allison University, he attempted to set the tone for the workshop by suggesting that the goal for the meeting was to consider a multitude of facets related to understanding change in the Bay of Fundy ecosystem. He proposed that key questions for the workshop be: how can we recognize change, what tools are needed to monitor change, and most importantly, how should we respond to change?

He outlined the plan for the three day meeting and briefly described the scheduled paper and poster sessions, the theme of the public lecture by author Harry Thurston, and the nature of the planned panel and group discussions. He encouraged people to attend the informal presentations by members of several non-governmental organizations (NGOs) and to stay for the BoFEP general meeting on Saturday, April 24. He reminded people that the workshop was their opportunity to raise questions and explore the issues and concerns they saw as relevant to the meeting theme. Peter Wells of Environment Canada was then invited to present a short paper on the nature of change to get the workshop underway.

Understanding Change in the Bay of Fundy Ecosystem[2]

P.G. **Wells,** Environment Canada
Canadian Wildlife Service, Environment Conservation Branch
Environment Canada, Dartmouth NS B2Y 2N6

Abstract

This paper explores several questions related to understanding ecological change in the Bay of Fundy. Some challenges are noted for individuals, groups and institutions interested in and responsible for monitoring change in the Bay, a critical activity for ensuring long-term sustainability of its ecology, habitats and living resources.

Introduction

Several questions can be considered pertaining to the theme - "understanding change in the Bay of Fundy ecosystem" – at the outset of the workshop[2]. They are intended to set the context for the talks and discussions that follow. The questions are:

How do we define change and ecological change?
Why study change in the Bay of Fundy?
How do we measure change?
What is the evidence of natural change occurring in the Bay of Fundy?
What is the evidence of change in the Bay attributed to human activities?
Can the methods of detecting and interpreting change(s) be improved?
What challenges face us in our quest to understand change in a complex marine ecosystem - the Bay of Fundy?

These are suitable questions for initiating critical thinking about a highly complex topic. The challenge is to reliably distinguish natural change from human-induced change. Some of the latter could then be ameliorated if deemed socially and environmentally "important" (*e.g.* impacts of barriers on tidal rivers, loss of northern right whales, continued atmospheric inputs of mercury, pulp mill pollution, and others below).

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[2] This is the third workshop that BoFEP (Bay of Fundy Ecosystem Partnership – officially founded 1997) and FMESP (Fundy Marine Ecosystem Science Project – founded 1995, and now the science arm of BoFEP) have sponsored or co-sponsored on Bay of Fundy science. Earlier meetings were in Wolfville, NS in January 1996 (Percy *et al.* 1997) and St. Andrews, NB in November 1997 (Burt and Wells 1998). Also see Percy (1999).

How do we define change and ecological change?

The dictionary definition of change is: "making or becoming different; substitution of one for another, variety" (Sykes 1976). Change differs from "effects" or "impacts", as the latter denote an association between the cause(s) and the change. Change alone does not assume any understanding or knowledge of the causative factor(s). Change can be biological/ecological (the obvious emphasis of this meeting) and also social (*e.g.* economic, political, demographic); these are often linked. Ecological change has occurred when there is a significant alteration in the structure (the physical components) and/or function (energy flow between trophic components) of an ecosystem. It may or may not be irreversible. Much study is occurring now of ecosystems such as tropical rain forests, coral reefs (see Sapp 1999) and temperate coastal ecosystems to determine just when a system has been irrevocably changed. This research has produced some startling results. Some ecological changes are abrupt and one-way, *i.e.* the system will not return to the previous state (Rapport and Whitford 1999), such as may be the case with several Canadian fisheries stocks (*e.g.* northern cod, Atlantic salmon, some species of Pacific salmon). Usually, ecological change starts gradually and covers a gradient – there is minimum change (*e.g.* eutrophication – occurring gradually, reversible after the nutrients have been reduced, but not necessarily to the same biodiversity) to maximum change (*e.g.* loss of one or more species and significant changes in trophic structure – probably irreversible (Nettleship, pers. comm.)). Our concern, expressed as a working hypothesis, is that both types of change – minimum and reversible and maximal (often abrupt) and irreversible, are occurring locally or broadly in the Bay of Fundy, and even interacting where they co-occur, *i.e.* cumulative change occurs.

Why study change in the Bay of Fundy?

The Bay of Fundy is a north temperate, macrotidal embayment (Longhurst 1998) and the northeastern extension of the Gulf of Maine. It is a highly valued marine ecosystem, utilized by humans and wildlife (the term used in its broadest sense) for millennia. At the present time (circa 1990's), geological and biological events thought to be unusual are occurring in and around the Bay. These events are not fully understood. They include compositional changes in some mud flats, crustacean (amphipod) population fluctuations on the mudflats of the upper Bay, seabird "disappearances" in the outer Bay, and greatly diminished and threatened fisheries species (dealt with in greater detail below and in the individual papers). Many people around the Bay are concerned about these events and feel that the natural and anthropogenic change(s) and their possible interactions, should be studied and understood. This may indeed be possible. The Bay of Fundy is data and information rich due to the considerable research conducted over the past 100 years[3] (for example, Johnstone 1977, Gordon and Dadswell 1984, Plant 1985, Percy *et al.* 1997), and several

[3] 1999 is the 100th anniversary of the St. Andrews Biological Station and the 30th anniversary of the Huntsman Marine Science Centre, both in St. Andrews, N.B., illustrating the long history of fisheries and marine science in the Bay of Fundy and Gulf of Maine, and adjacent waters of the north-west Atlantic.

research laboratories and groups exist on both sides, from St. Andrews to Digby. Some research continues on parts of the Bay, especially focusing on aquaculture, fisheries for traditional and "underutilized species", effects of barriers on rivers and tidal rivers, and the ecology of the benthos and migratory wildlife. Considerable baseline data are available for a host of variables (from salinity and sea surface temperatures, to contaminants and distribution of algal, invertebrate and fish species). Hence the Bay of Fundy offers many opportunities for systematically studying and documenting change in a complex marine ecosystem, using modern techniques, and for making attempts to assess the Bay's "ecosystem health"[4] from a scientific perspective. Understanding how the ecosystem is changing and conducting periodic assessments of the whole system should assist our institutions (in the general sense) in choosing appropriate conservation and protection steps for the future.

How do we measure change?

Many scientifically-based observations are needed over time to build the case that a particular type of ecological change has occurred and to quantify the nature and direction of the change. Pivotal to detecting change is having the appropriate techniques and extensive knowledge of the previous "state" of the component of the ecosystem under study. Basic ecological concepts, some of them quite difficult to master, should be understood and applied. These include variability, stability, complexity, complex adaptive systems, non-linearity, time-lags, reliability and relevance[5], all in the context of selecting, monitoring and analyzing key environmental and ecological variables. Reliable techniques and experimental design and statistical rigor must be used. Sorting out the "signals" from the background "noise" in the system under study demands the very best application of current ecological theory and practice (see Levin 1999). To achieve this goal, it is necessary to ask clear questions and acquire reliable long-term (minimally, decadal) data sets using a wide range of indicators (NRC 1990, Spellerberg 1991, RSC 1995, amongst others).

What is the evidence of natural change occurring in the Bay of Fundy?

Natural change(s) are short or long-term fluctuations or oscillations in structure or function that usually occur in a dynamic ecological system and cannot be attributed, directly or indirectly, to human intervention. The demarcation line between natural and human-induced change(s) is not always easy to delineate (for example, see Sapp (1999) for coral reef ecology and Clarkson (1998) for methyl mercury toxicology). There are a number of indicators of natural change for the Bay of Fundy: climate and local weather patterns (warming and extreme events occurring more frequently,

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[4] See NRC (1985) and Wells (1991) for "early" definitions of environmental quality, marine environmental quality and marine ecosystem health, and most recently Valiela (1995), Rapport *et al.* (1998), Levin (1999) and Sapp (1999) for both the terminology and learned discussions of current ecological concepts.
[5] See Levin *et al.* (1989), Myers (1995), Valiela (1995), Rapport *et al.* (1998) and Levin (1999).

see Wartman below); coastal erosion and sedimentation (increasing in local areas, Milligan, pers. comm.); sea level rise (occurring throughout the Bay, Wartman below); sea surface temperatures (cooling?); marked shifts in population distribution and abundance of Northern Phalaropes, *Lobipes lobatus* , in the outer Bay, and their possible "disappearance" (Hicklin, pers. comm); a possibly wider distribution and longer feeding period of migrating shorebirds, such as Semipalmated Sandpipers, *Calidris pusilla*, on some of the mudflats of the upper Bay (CWS, unpubl. data). We collectively need to compile this list of natural changes, organized spatially and temporally with geographic information system (GIS) support, and confirm the signals through additional long-term field observation and analysis.

What is the evidence of change in the Bay attributed to human activities?

There are many examples of human-induced change(s) in and around the Bay of Fundy, some very old (the construction of dykelands) and some very recent (see Percy *et al.* 1997 for a description of 25 issues). Many of these changes are well documented in the literature; some are not, rather they are observational and anecdotal and in need of verification. Such change(s) includes: loss of critical habitat, *e.g.* a much diminished total area of salt marsh, spawning and feeding areas for fish such as salmon; construction of barriers on rivers, estuaries, shorelines, and their related effects (Wells 1999a, CCNB 1999); the wide-spread presence of trace contaminants, *i.e.* toxic substances and in some cases pollutants (Wells *et al.* 1997, Burgess, pers. comm., Tay, pers. comm.); imposex in marine snails attributed to organotins in harbours (Prouse, pers. comm.); increased numbers and types of industrial discharges, causing declines in water quality; occasional oil spills; increased numbers of shellfish closures due to high bacterial levels; increased Paralytic Shellfish Poison outbreaks (also naturally induced); diminished fisheries, *e.g.* salmon, alewives; and diminished wildlife, *e.g.* reduction in numbers of shorebirds and seaducks (Hicklin, pers. comm.), puffins, terns, others?) and northern right whales (see Mowat 1984 for documentation). One does not want to be polemic or "a false Cassandra or prophet of doom" (Sapp, 1999, p. 204). However, it appears that there has been and still is a concerted assault on the habitat, biodiversity and environmental quality of the Bay of Fundy, at different locations, since Europeans arrived and settled almost 400 years ago. Clearly, signals of deterioration or negative change linked to our activities abound. However, the recent evidence of significant human induced change needs to be sought, assembled and rigorously examined as a whole, in the manner being done for trace contaminants (Wells *et al.* 1997). False alarms are unacceptable and counterproductive to conserving and protecting coastal ecosystems. But if the single and collective signals indicate that significant change and indeed harm is occurring on an ecosystem-wide basis in the Bay, acting now would be judicious.

Can the methods of detecting and interpreting change(s) be improved?

The answer is yes. Methodologies are improving each year. Examples of how better methods can be attained are: employing new monitoring technology, *e.g.* biomarkers, sublethal assays and microscale ecotoxicology tests, in the case of trace toxic substances (Peakall 1992, Monette and Wells 1999, Wells *et al.* 1998; Wells 1999b); conducting power analyses on every technique employed to be certain of their ability to detect a signal; networking the techniques, *e.g.* satellite imagery plus GIS plus sampling and analysis, thereby establishing the capacity to monitor the whole system over the long term, at minimum decades; and above all, supporting the archival identification centres for marine species so that the marine biodiversity of the Bay is readily identified and well understood and losses and introductions (*i.e.* exotics) noted (Pilgrim *et al.* 1999; Pohle 1999).

What challenges face us in the quest to understand change in a complex marine ecosystem - the Bay of Fundy?

The challenges are many. As a society, we need to provide and increase long-term funding for marine ecological research and training so that a new cohort of expertise competently tackles the questions posed above. We need to think of novel ways of measuring change in the Bay of Fundy, *e.g.* utilizing new conservation and protection initiatives such as MPAs (Marine Protected Areas, under the new Oceans Act) for science and monitoring, and instituting broad monitoring initiatives under a comprehensive marine environmental quality framework (Chang, pers. comm.). We need new monitoring methods to detect subtle changes. Governments also need to become more innovative working with volunteer groups, to collect the data necessary to detect changes and respond accordingly. Facing these challenges, all oriented to understanding change in the Bay's ecosystem, will ensure a reliable information base upon which to manage the Bay of Fundy comprehensively and safeguard its environmental quality and health as the new millennium begins.

Acknowledgments

Many thanks are due to the organizers at Mount Allison University for their considerable efforts putting on this workshop and for giving me the opportunity to introduce this topic. I greatly thank Dr. Joe Kerekes of CWS for his critical review of this paper. It is dedicated to past, present and future generations of aquatic explorers[6] in the Bay of Fundy.

[6] Term adapted from Johnstone's marvelous tome on the history of the Fisheries Research Board of Canada (Johnstone 1977).

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Session One

Variation in the Bay's Ecosystem

Chair: Jeff Ollerhead, Mount Allison University

Climate Change and the Bay of Fundy

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Abstract

The Intergovernmental Panel on Climate Change states "the balance of evidence suggests a discernable human influence on global climate". This anthropogenic effect is especially important in Atlantic Canada, where ecosystems such as the Bay of Fundy exist in a delicate balance that is highly sensitive to changes in the climate system and where the economy is strongly based on natural resources.

An overview of the climate change issue is presented and a comparison of recent climate trends with global climate model projections is discussed. The regional sensitivities to a changing climate are examined, including those in the fisheries, agriculture, forestry, water resources and human health sectors. Particular emphasis is placed on those sensitivities of special relevance to the Bay of Fundy, such as the aquaculture industry. Potential changes in the frequency and intensity of winter storms and tropical cyclones are considered as well as the vulnerability of communities and habitats to accelerated sea level rise.

In addition to the absolute changes in climate, the rate of these changes are critical in determining the capability of ecosystems to adapt. The potential increased frequency of extreme events such as droughts, floods, and storms are also paramount in these early stages of assessing the impacts of climate change.

Spatial and Temporal Variation in Sediment Accumulation Rates Along the New Brunswick Coast, Bay of Fundy

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Abstract

We are measuring surface sediment deposition at seven marshes along the New Brunswick coast, from Bocabec at the mouth to Belliveau Village and Wood Point at the head of the Bay of Fundy. Vertical sediment accretion is determined by measuring the thickness of sediment accumulated over clay feldspar marker horizons. A cryogenic coring device allows us to subsample sediments of variable water content with minimal disturbance to the marsh surface. Marker horizons were established in the spring of 1997 along multiple elevational transects in each marsh. All marshes and all elevations showed measurable sediment deposition over the summer of 1997, but sediment thickness doubled at most plots during the winter of 1997-98, which was noticeably mild. In most marshes the thickness of sediment deposits decreased with elevation and distance from the mouth of the tidal creek. Amounts range from 45 mm in low marsh at Cape Enrage to a low of 2 mm in high marsh at Bocabec. An additional control is distance from sediment sources identified in the upper Bay. An interesting exception to this pattern is our site at Belliveau Village which is downstream of the Petticodiac barrage.

Sediment deposition over the historical period has been determined at two marshes on Point Lepreau, Chance Harbour and Dipper Harbour. Using the radionuclides cesium-137 and lead-210 and palynological techniques, we can compare sediment accumulation rates over time spans of 30, 100, and 200 years. Both marshes have accumulated sediment at the rate of 1.9 mm/yr over the last 30 yrs. Considering coring locations, this rate is within the range predicted from our marker horizon study. When calculated over a 100 yr period, rates of sediment accumulation decrease slightly. The greatest decrease is demonstrated when calculated over a 200-yr time span.

Suspended Sediment Circulation and Deposition over Single Tidal Cycles at Allen Creek Saltmarsh, Bay of Fundy

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Abstract

Relative sea level is rising in the upper Bay of Fundy at a rate of 0.3-0.4 m per century. Therefore, the saltmarshes in this area must grow up vertically if they are to survive. The marshes can grow vertically via the input of organic or inorganic materials where the inorganic materials, mostly coarse silts, are primarily contributed to the marsh surface by suspended sediments that settle out over high tide cycles. The purpose of this presentation is to explore suspended sediment circulation and deposition patterns over single tidal cycles at the Allen Creek saltmarsh near Sackville NB and to consider which variables appear to be necessary for the creation of a reasonable predictive model.

A field study was conducted during the summer of 1998 at the Allen Creek saltmarsh where net flow velocity, suspended sediment concentration, and sediment deposition were measured over thirteen individual tidal cycles. A vertical instrument array consisting of three electromagnetic flow meters and co-located OBS probes and a single pressure transducer was deployed in the low marsh region (van Proosdij *et al.*, 1999). Sediment deposition was measured using full-cycle sediment traps. The temporal distribution of sediment deposition was measured using sequential sediment traps exposed at different tidal stages.

The data collected suggest that sediment deposition on the marsh surface is primarily controlled by the interaction of water flow, marsh morphology and vegetation. The highest amounts of sediment were deposited during conditions of high suspended sediment concentration and low wave activity, especially when the relative roughness of the vegetation was high. Loss of suspended sediment from the water column was shown to be correlated with the sediment trap data; however, predictions of sediment deposition based on the variation in suspended sediment concentrations were found to be valid only for conditions with wave heights of less than 0.15 m.

The results clearly show that modelling the annual or even monthly amount of sediment accretion on the marsh surface using tide data and estimates of suspended sediment concentration alone is too simplistic as an approach. At a minimum, one would need to incorporate estimates of the relative roughness of any vegetation and the wave climate into such a model for it to be successful.

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Session Two

From Invertebrates to Fish

Chair: Peter Wells, Environment Canada

Horse Mussel Reef Project in the Inner Bay of Fundy

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Abstract

The purpose of the work begun in 1996 was to demonstrate the capability of acoustic methods, such as side-scan sonar, high resolution seismic reflecting systems and multibeam swath bathymetry, to spatially delimit the subtidal reefs of keystone horse mussels, *Modiolus modiolus*. We believe that the capability of acoustic methods to delimit the spatial limits of benthos and monitor temporal changes is worth investigating in much greater detail than has been done so far.

To date, we have shown that features identified by side-scan sonar and seismic reflectors are *M. modiolus* reefs by identifying them by colour video camera mounted on an ROV (Wildish *et al.* 1998a). Preliminary analysis of the side-scan sonar data obtained in 1997 suggests that there are 14 geological provinces (Wildish and Fader 1998; Wildish *et al.* 1998b). Of the provinces, only five commonly contain horse mussels: sand with bioherms, gravel/cobble, gravel/scallop bed, mottled gravel and glacio-marine mud. Horse mussel reefs can only be spatially determined from the first of these provinces, as all others have acoustic scattering due to other features, *e.g.* boulders that mask the mussel distribution. In all, 673 horse mussels were sampled from the five geological provinces and subjected to population and growth analyses (Wildish *et al.* 1998b). Results show that three population groups were present, each linked to particular geological provinces:

Group 1 - sand with bioherms	-fast growth
Group 2 - gravel/scallop bed	-intermediate growth
Group 3 - gravel/cobble, mottled gravel	-slow growth

Work still to be completed includes:

- multi-beam swath bathymetry survey of the inner Bay, scheduled for June 15-24, 1999
- digitization and work-up of side-scan data for 1997, inclusive of mapping the results
- experimental work to determine the mechanism of the horse mussel growth rate differences, particularly testing hypotheses that (a) fast flows inhibit growth, and (b) gravel/cobble substrates cause "skimming flows" which inhibits seston mixing within the benthic boundary layer.

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Habitat Requirements of Striped Bass (*Morone saxatilis*) in Eastern Canada With an Emphasis on the Shubenacadie-Stewiacke Rivers in the Inner Bay of Fundy, Nova Scotia

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Abstract

At least five spawning populations of striped bass once existed within eastern Canada: the St. Lawrence River, Quebec, the Miramichi and Saint John rivers in New Brunswick, and the Shubenacadie-Stewiacke and Annapolis rivers in Nova Scotia. The Miramichi and Shubenacadie-Stewiacke rivers are the only confirmed sites where striped bass now reproduce annually. These populations are genetically discrete and both differ from striped bass of American origin. Habitat loss is believed to have been the greatest contributing factor to past extirpations of striped bass from Canadian rivers and estuaries. The remaining populations are susceptible to alterations to essential spawning, rearing and wintering habitat through continuing human land-and sea-use practices. Within the Shubenacadie-Stewiacke system, alterations to essential habitat may have occurred as a consequence of the construction of an extensive networks of dykes and the wide-spread utilization of culverts, aboiteaus and causeways on tidal waterways. The consequences in terms of permanent losses of fish production and to population viability are largely unknown but are presently under investigation.

Reproductive Cycling in Mummichogs (*Fundulus heteroclitus*) in Bay of Fundy Estuaries Close to Saint John, NB

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Abstract

There is increasing evidence that environmental contaminants and pharmaceutical agents have sub-lethal toxic effects on the reproductive endocrine systems of fish. Previous work in our lab utilized caged mummichogs (*Fundulus heteroclitus)* throughout the Saint John Harbour (SJH). The SJH receives effluents from a number of major industries in addition to treated and untreated sewage. Our studies indicated that there are site-to-site differences in reproductive endocrine status that can be correlated to caging within particular waste water microenvironments. Hampering our interpretations of that work is our lack of information about the endogenous rhythms of the reproductive endocrine system of wild mummichogs living near SJH. During the summer of 1998, mummichogs were collected from four sites in the Bay of Fundy near the SJH. At each site, mummichogs were captured by dog food-baited minnow traps at approximately two-week intervals. Adult fish were weighed, measured, bled and the gonads removed and weighed. Plasma levels of the reproductive steroids [testosterone (T) and 11-ketotestosterone (11-KT) in males and T and 17β-estradiol (E_2) in females] were measured by radioimmunoassay. At all sites, 11-KT in males was high in May and decreased throughout the summer. Hormone and gonadal development patterns differed amongst the sites; T levels, however, always peaked prior to or during gonadal peaks. Males and females within each site showed similar patterns. The two sites furthest from the SJH were the most similar. However, it is too early to tell if site differences can be linked in any way to SJH pollution, natural variations amongst the populations, or differing habitats.

Session Three

Avian Ecology

Chair: Richard Elliot, CWS Sackville

The Loons of the Bay of Fundy

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Abstract

Common Loons (*Gavia immer*) and to a lesser extent Red-throated Loons (*Gavia stellata*) are year-round residents of the Bay of Fundy (Clay and Clay 1997a). Loons are seabirds that fly to inland lakes in the spring to breed. They return to the sea in the fall and the young remain at sea continuously until at least three years of age (McIntyre and Barr 1997).

It appears that all suitable and marginal freshwater lake habitats near the Bay of Fundy coast in New Brunswick and Nova Scotia in the summer are occupied by loons (*Gavia immer*) (Stocek 1989; Kerekes *et al.* 1994; Clay and Clay 1997b). It should be noted that in areas distant from the sea, (*e.g.* Ontario, Minnesota), many apparently suitable lakes are not occupied by loons in summer. In all likelihood, many young loons that are occupying lakes in the Bay of Fundy region are non-breeding birds. Studies with marked birds (*Gavia immer*) elsewhere, showed that loons do not breed until five years of age or older (Evers *et al.* 1999). Red-throated Loons breed north of the boreal forest.

It is not known where the loons of the Bay of Fundy breed. Recently some banding of breeding loons took place in the Bay of Fundy area and elsewhere in North America (Evers *et al.* 1999). Thus the first steps were undertaken to learn more about the migration patterns of loons in North America.

Recent studies showed that breeding loons in the Bay of Fundy area have among the greatest body burden of mercury in North America (Burgess *et al.* 1998). The possible source(s) of the high levels of mercury found in these loons are the subject of intensive investigations (Beauchamp *et al.* 1998).

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Survival of Common Eider Ducklings in the Southern Bay of Fundy and the Northern Gulf of Maine

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Abstract

The Great Black-backed Gull constitutes 25% of the large gull population in the southern Bay of Fundy and 35% in the Gulf of Maine and is becoming increasingly important in relation to the numbers of other species of birds breeding in these areas. Most studies of the impact of Great Black-backed Gull predation have focused on terns and alcids. However, an understanding of their impact on eiders is important given this species' current status and should predation rates increase such that management actions become desirable. We assessed the impact of gull depredation on eider duckling survival in relation to various levels of gull control in the southern Bay of Fundy and the northern Gulf of Maine: i) no control - The Wolves archipelago 1995, 1997, 1998; ii) limited control - The Wolves archipelago 1996; iii) total control - Petit Manan/Green Island 1998.

With the exception of two ducklings radio-tagged in 1996, all transmitters that were recovered from radio-tagged ducklings on The Wolves archipelago in 1995 (n=34), 1996 (n=46) and 1997 (n=16), had been depredated by Great Black-backed Gulls. Of the 30 ducklings radio-tagged on Green Island in 1997, 22 were depredated by Great Black-backed Gulls, 2 fledged in the immediate vicinity of Petit Manan Island, and 2 fledged in brood-rearing areas 6 km from their hatching island. Daily survival rate of radio-tagged ducklings did not differ from that of ducklings from broods of marked hens in 1995, 1996 and 1997 on The Wolves archipelago and in 1997 on Green Island. There was no difference in DSR of ducklings among years on The Wolves archipelago and Green Island. Daily survival rate of ducklings differed between The Wolves archipelago (DSR=0.3478) and Green Island (DSR=0.9237) ($X2=31.21$, $p<0.001$). The overall number of ducklings surviving to fledging was considerably higher in the Petit Manan/Green Island Archipelago, (21% of the breeding pairs in both 1997 and 1998), than on The Wolves archipelago in 1995, 1996 and 1997 (<5% of the breeding pairs in all years).

Aspects of Change for Wintering Razorbills (*Alca torda*) in the Lower Bay of Fundy

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Abstract

We present new findings from our seabird surveys supported by the Canadian Wildlife Service on wintering Razorbills (*Alca torda*) in the Grand Manan Island region during the winters of 1997/98 and 1998/99.

Surveys showed that the 'Old Proprietor Shoals', southeast of Grand Manan Island and the waters of 'Long Eddy', north of Grand Manan Island, supported very high numbers of wintering Razorbills, and to a lesser degree other auks (*alcidae*). We present research results on migration, movements and activity patterns, diet and small-scale distribution of these birds. Based on land-based counts of auks around northern Grand Manan Island the daily activity patterns and the influence of tide level and food items will be discussed. The results will be put in a larger ecological context. Comparisons with the summer diet and distribution of Razorbills from a breeding study on Machias Seal Island will also be presented.

With the financial help of ACWERN and the Canadian Wildlife Service (CWS), we were able to initiate and to carry out a two year project on a very exciting finding of wintering Razorbills (*Alca torda*) off Grand Manan Island (44.7 ° N, 66.8 ° W), Canada. This project was started with an email message from a local birder, Brian Dazell, on Grand Manan Island, New Brunswick, announcing the presence of approximately 30,000 flying Razorbills in Grand Manan. We were then able to put the observation into an overall population context and recognized the relevance of this finding for the northwest Atlantic population of this species. Wintering areas of Razorbills in the northwest Atlantic are poorly known. Small numbers breed at the mouth of the Bay of Fundy. Our two-year winter survey work showed that many Razorbills begin to appear in early winter off Grand Manan Island, certainly many more than can be accounted for locally-breeding birds. During the winter 1997/98, we conducted standardized surveys for seabirds on 26 days between November and March where up to 53,000 large auks (unidentified) were counted off Grand Manan. A distinct core zone of auk distribution was found around the shallow Old Proprietor Shoals. Extrapolation from the numbers of large auks identified to species suggest that ca. 52,000 Razorbills may have been encountered during a transect on 23 January (ca.74% of the North American population). This number dropped eight days later to 64 identified Razorbills, suggesting strong movement patterns of auks in the Gulf of Maine region (Figure 1).

For the winter season 1998/99, we did specific GPS-georeferenced surveys across the Old Proprietor Shoals to collect bird samples and to investigate the extent of Razorbill distribution patterns in offshore waters; simultaneous land-based counts, lasting half a day, were also carried out from four locations to analyse the migration and activity patterns of wintering auks. The boat survey data were added to the Canadian PIROP Database, (Programme intégré pour le recherche des oiseaux pélagiques) owned by the Canadian Wildlife Service, for future multivariate GIS-Analysis, such as influence of tides, moon stages and environmental data on Razorbill distribution. We presented how counting results from boat surveys for the Old Proprietor Shoals can be corrected to account for the whole wintering population within 17 km of southeast Grand Manan. This method would suggest that the numbers of wintering auks encountered during winter 1997/98 detected only 65 - 82 % of the overall Razorbill numbers. The surveys also indicated that some other, previously unknown, Razorbill concentration zones and travel corridors existed close to Grand Manan, such as western Grand Manan and particularly the waters of Long Eddy (Figure 2). Since no relevant Razorbill concentrations were reported from Passamaquoddy Bay (Head Harbour Passage), The Wolves archipelago or elsewhere in coastal Gulf of Maine, we conclude that Grand Manan is the core zone for wintering Razorbills. Almost all large auks encountered during the surveys in 1998/99 were Razorbills. These birds were moving during the morning and sitting on the water from noon on, with a smaller peak of movements in early afternoon. In December and early January, opportunistic feeding associations of Razorbills with feeding sea mammals, such as Finback whales (*Balaenoptera physalus*), Minke whales (*B. acutorostrata*) and Harbour Porpoises (*Phocoena phocoena*) were observed. Our results lead to questions on metabolism and nocturnal movements of wintering Razorbills. Since 21 Razorbill samples were collected, we present results from stomach content analysis, which suggested that the food chain is not complex. Crustacea ("krill"), rather than fish, constitute the main component of their food. Feeding data from breeding Razorbills on Machias Seal Island show that fish (especially herring *Clupea harengus*) is their main food item in the early summer. A more detailed analysis of food items and an investigation by stable isotope analysis of various tissues of the collected Razorbills during winter 1998/99, are currently in progress; (analysis of DNA and toxicology studies).We suggest that the protocols for morphometrical measurements of auks need to be standardized to help in detecting the presence of different populations. Our numerous surveys also allowed for a quantification of other wintering waterbirds of the Grand Manan archipelago.

Our findings advance the knowledge of winter ecology of Razorbills and put conservation issues for this species into a new perspective. Previously, it was believed that pelagic, offshore areas were relevant winter grounds for this species and that the coastal murre hunt (*Uria* spp.) off Newfoundland would present major threats to wintering Razorbills. Instead, we suggest more emphasis should be placed on threats to the wintering Razorbill population off Grand Manan, including intense oil traffic, pollution and small scale fisheries.

Winter 97/98 Off-Shore Vessel Transects, Grand Manan N.B.

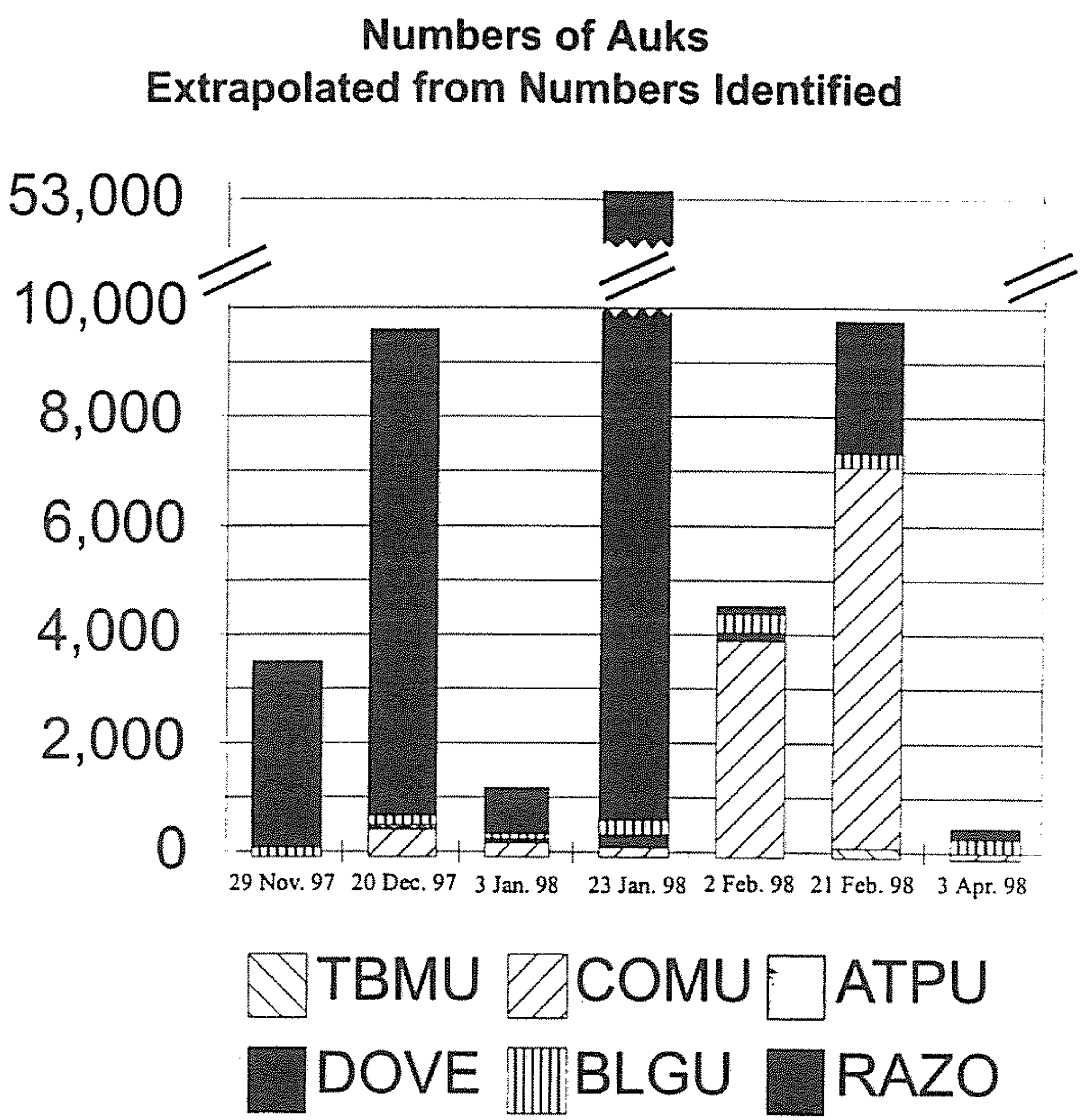

Figure 1

Razorbill Surveys Winter 1998/99
- land-based counts -

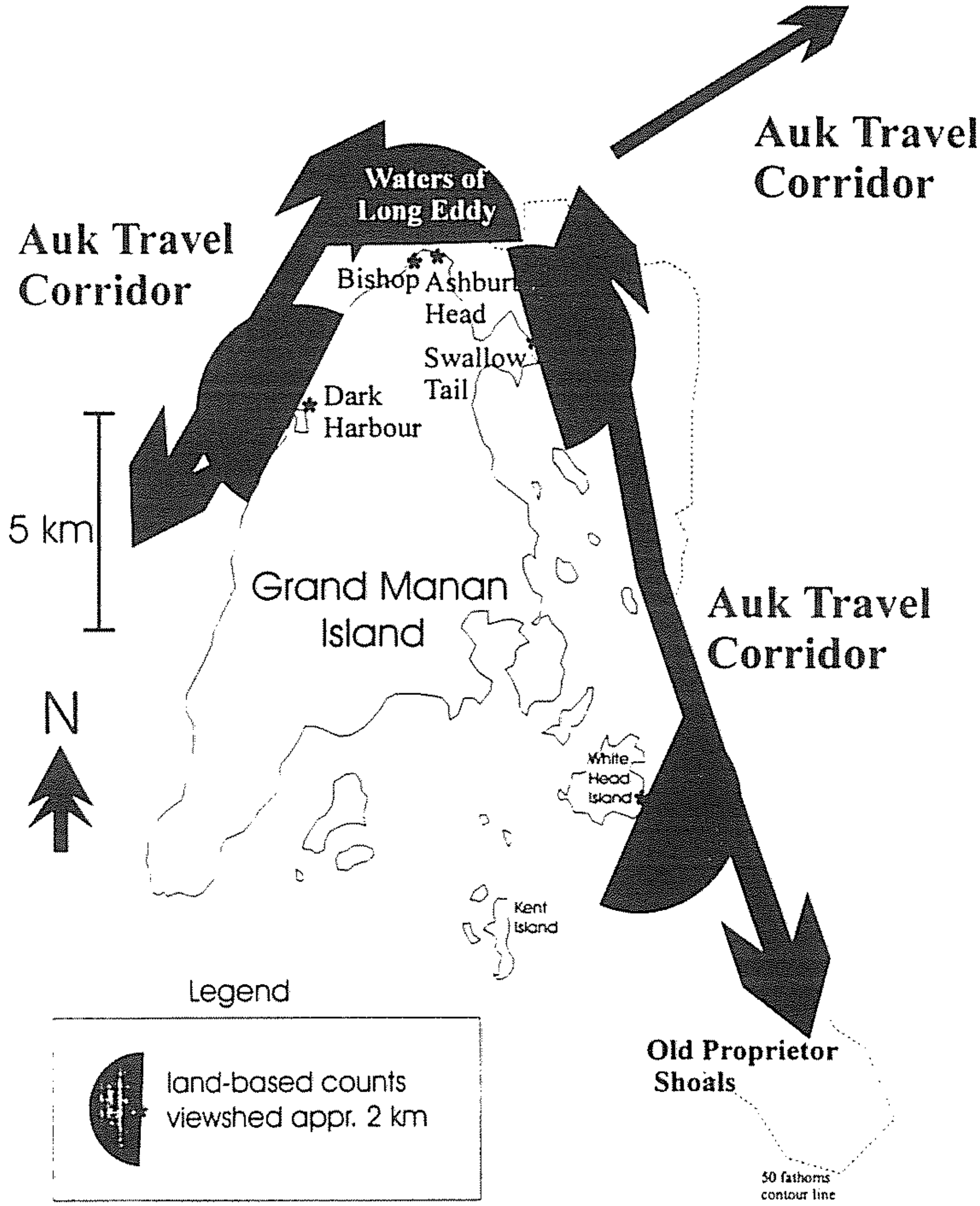

Figure 2

Time-Budget Flexibility and Behaviour of Breeding Arctic Terns *(Sterna paradisaea)*

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Abstract

In changing environmental conditions, seabirds will adjust their time-budgets to maintain reproduction and survival needs. In this way, Arctic Terns (*Sterna paradisaea*) will react sensitively to variations in food availability, weather conditions and tide. By quantifying the effect of these factors on time allocation, it may become possible to monitor changes in environmental conditions such as the abundance of fish stocks. Other factors such as chick age and sex of the adult can also affect behaviour, making it necessary to consider these in the overall time-budget analysis. Behavioural observations at the nest site and telemetry were used to measure Arctic Tern time-budgets and chick provisioning in 1997 and 1998 on Machias Seal Island, New Brunswick. Environmental conditions and nest history were monitored to assess their influence on time allocation while the use of radio-telemetry permitted a rare glimpse into nocturnal behaviour, roost attendance as well as dusk and dawn activities. This study of time-budgets will not only permit us to better understand the time and energy allocation of breeding Arctic Terns, but will help us assess the suitability of behaviour as an indicator for commercial fish stocks.

Trends in Organochlorine Contaminants in Seabird Eggs From the Bay of Fundy, 1972-1996

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Abstract

Organochlorine contaminants were measured in eggs of three seabird species from 1972 to 1996, in order to monitor marine environmental quality in the Bay of Fundy and assess possible implications for seabird health. Eggs were collected at four-year intervals from colonies of double-crested cormorant (*Phalacrocorax auritus*), Leach's storm-petrel (*Oceanodroma leucorhoa*), and Atlantic puffin (*Fratercula arctica*) at Manawagonish, Kent and Machias Seal Islands, New Brunswick, respectively. More limited collections were also made from herring gull (*Larus argentatus*) colonies. Organochlorine componds monitored include DDE, PCBs, hexachlorobenzene, dieldrin, oxychlordane, beta-hexachlorocyclohexane and mirex. Concentrations of all organochlorines have decreased since the 1970s in all species. DDE levels were higher in cormorants and storm-petrels and lower in puffins and gulls. PCB concentrations were more similar among all species. All organochlorines decreased exponentially over time in cormorants and puffins. However, organochlorine concentrations were steady in storm-petrel eggs during the 1980s and early 1990s. It appears that contaminant levels in cormorants and puffins reflect pollution inputs from coastal sources and rivers. In contrast, storm-petrels appear to be good indicators of long-range atmospheric pollution. Current levels of organochlorine contaminants do not appear to be causing significant impacts on seabird populations in the Bay of Fundy. The results suggest that long-range atmospheric transport is increasing in importance as a source of marine pollution to the Bay of Fundy, as coastal sources are reduced.

Session Four

Environmental Quality and Aquaculture

Chair: Jon Percy, CARP

Nutrification in the Bay of Fundy: Sustainable Integrated Aquaculture as one of the Bioremediation Tools

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Abstract

Nutrification of coastal waters as a result of anthropogenic activities is a worldwide phenomenon. In the Bay of Fundy, the salmon aquaculture industry is one of the contributors to significant nutrient loading. This monospecific type of aquaculture is presently at a crossroad, as its economic and environmental limitations are realized and its sustainability questioned. The development of integrated aquaculture practices appears more and more necessary and timely, in light of the several crises experienced by finfish aquaculture in recent years and rising concerns by the public over its impacts. The bioremediation role of seaweeds, acting as biological nutrient removal systems and the mutual benefits for co-cultured organisms are becoming better understood. Our results show that the productivity, and the phosphorus and nitrogen uptake of the red alga *Porphyra* are sufficiently high to make it an excellent choice for integrated aquaculture for bioremediation and economic diversification. Its regular harvesting amounts, on one hand, to constant removal of significant quantities of nutrients from coastal waters, and, on the other hand, to the production of marine crops of high added value. The development of integrated aquaculture will, however, only come about if there is a major change in social, economic, political, and funding reasoning by seeking sustainability, long-term profitability, and responsible management of the coastal zone through research for the development of innovative bio-engineering concepts and practices.

Salmonid Aquaculture Mortalities and a Bloom of *Mesodinium rubrum* in Passamaquoddy Bay in 1998

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Abstract

A red tide caused by the organism *Mesodinium rubrum* was observed in Passamaquoddy Bay in 1998 during the three weeks of late August through mid-September, 1998. Brick-red blooms of the planktonic ciliate have been observed in the past in many coastal regions throughout the world, including Passamaquoddy Bay. *M. rubrum* concentrations observed from water samples collected during the bloom period exceeded 1 million cells*L-1 in areas of water discolouration with dense concentrations observed to a depth of 10 m. The dominant organism in samples was *M. rubrum* and it represented up to 95% of the total algal population.

Although *M. rubrum* does not produce a toxin, it is possible for mortalities to occur through secondary effects, such as asphyxiation, as a result of oxygen depletion. During the bloom period, the red tide drifted through a number of salmonid aquaculture sites resulting in low level mortalities.

Discrete water samples collected for phytoplankton identification and enumeration revealed concentrations of *M. rubrum* greater than 1 million cells*L-1 at various locations in Passamaquoddy Bay. Sigma-t profiles indicate that the water column was stratified during August and well mixed during September.

Effects of Different Effluent Streams from a Bleached Kraft Pulp Mill on *Fundulus heteroclitus*

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Abstract

Reproductive dysfunction has been documented in wild fish populations exposed to bleached kraft pulp mill effluents in Canada and Scandinavia. Effects documented included decreased gonad size and fecundity, increased age to maturation, decreased reproductive steroid hormone levels, and altered expression of secondary sexual characteristics. The source of contaminants causing the dysfunction is unknown. The final effluent, which is discharged from a pulp mill, contains a complex mixture of contaminants arising from different stages in the pulping process (*i.e.*, condensate recycling, brownstock washing, bleach plant). In 1997, mesocosm studies commenced at a pulp mill in Saint John, New Brunswick to determine the effects of different effluents from the pulping process on the reproductive status of a fish species endemic to the St. John River estuary. Final effluent discharged from the mill decreased circulating reproductive steroid hormone levels in the mummichog. In 1998, the mill installed a reverse osmosis system to treat approximately 1100 USgal/min of clean condensate from the fifth effect evaporator that is recycled for brownstock washing. The reverse osmosis system had significant effects on final effluent quality resulting in approximately 2000 kg/d and 4000 kg/d reductions in biochemical and chemical oxygen demand, respectively. More importantly, the final effluent is non-acutely lethal to rainbow trout and the invertebrate *Daphnia magna*. In addition, sublethal toxicity levels (IC25s) of the final effluent, to three marine test species, are among the lowest when compared to mills that employ secondary effluent treatment. Plasma steroid hormone depressions are also no longer apparent in fish exposed to environmentally relevant (1%) concentrations of the final effluent. Installation of the reverse osmosis system has been an environmentally significant process change because, in the absence of secondary effluent treatment, it has significantly contributed to achieving compliance with environmental effluent regulations for acute lethality and has reduced sublethal reproductive effects in a native fish species. Further studies are underway in an attempt to reproduce the results of these studies.

A Review and Update of Aquaculture Impact Studies Carried Out on the Magaguadavic River, Southern Bay of Fundy, New Brunswick

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Abstract

The Magaguadavic River is located near the heart of the North American East Coast aquaculture industry, and monitoring work here provides the best data set for this region on the potential frequency of interaction between aquaculture and wild Atlantic salmon. Aquaculture fish may enter this river by escaping from hatcheries located within the watershed or after their escape from sea cage sites.

Wild salmon returns have steadily declined from 293 in 1992 to 31 fish in 1998. By contrast, escapees have composed from 34% to 90% of the annual salmon returns in this period. Only an estimated 13.5% (average 1992-1998) of the cultured salmon entering the river were classified as sexually mature, based on secondary sexual characteristics and/or hormonal assays. By contrast, all wild salmon were maturing and exhibited secondary sexual characteristics by mid August.

Juvenile salmon densities and relative abundance have been low at most sites examined. Higher numbers of parr caught near salmon hatcheries may have been due to juvenile escapees. Hatchery escapees dominated 1998 smolt samples.

Escaped adults caught in the fishway were transplanted to sites up to 48km away to see if they would home back to the river. In 1997, 1 of 78 fish returned. By contrast, in 1998, 31 of 146 fish (21%) made their way back. Homing to rivers by escapees has not been previously reported.

No pathogenic bacterial or viral organisms were found in wild and cultured salmon tested during 1992-1996. However, in 1997, 5 of 34 cultured salmon tested were suspect for hemorrhagic kidney syndrome (HKS). In 1998, 1 of 61 fish screened for viral and bacterial diseases tested positive for BKD. No positive tests for pathogenic virus have been reported.

Juvenile salmon densities and relative abundance have been low at most sites examined. Higher numbers of parr caught near salmon hatcheries may have been due to juvenile escapees. Escaped juveniles from hatcheries within the watershed dominated 1998 smolt samples.

INTRODUCTION

This review summarizes our most recent data on the interactions between wild and cultured Atlantic salmon (*Salmo salar*), in the Magaguadavic River, New Brunswick. The huge growth of the salmon aquaculture industry, and of escapees from the sea cages, could negatively affect wild salmon through genetic (foreign gene introductions) or ecological (competition, predation) swamping, and/or disease introductions. Our work aims to help provide a factual basis for planning and decision making.

The Magaguadavic River is situated near the center of the North American East Coast Atlantic salmon aquaculture industry (Figure 1), and large numbers of escaped cultured salmon from sea-cages have entered the river in recent years. Three commercial salmon hatcheries that together produce about two million smolts for the sea-cages are located within the drainage, and cultured juvenile salmon are escaping from those sites.

METHODS

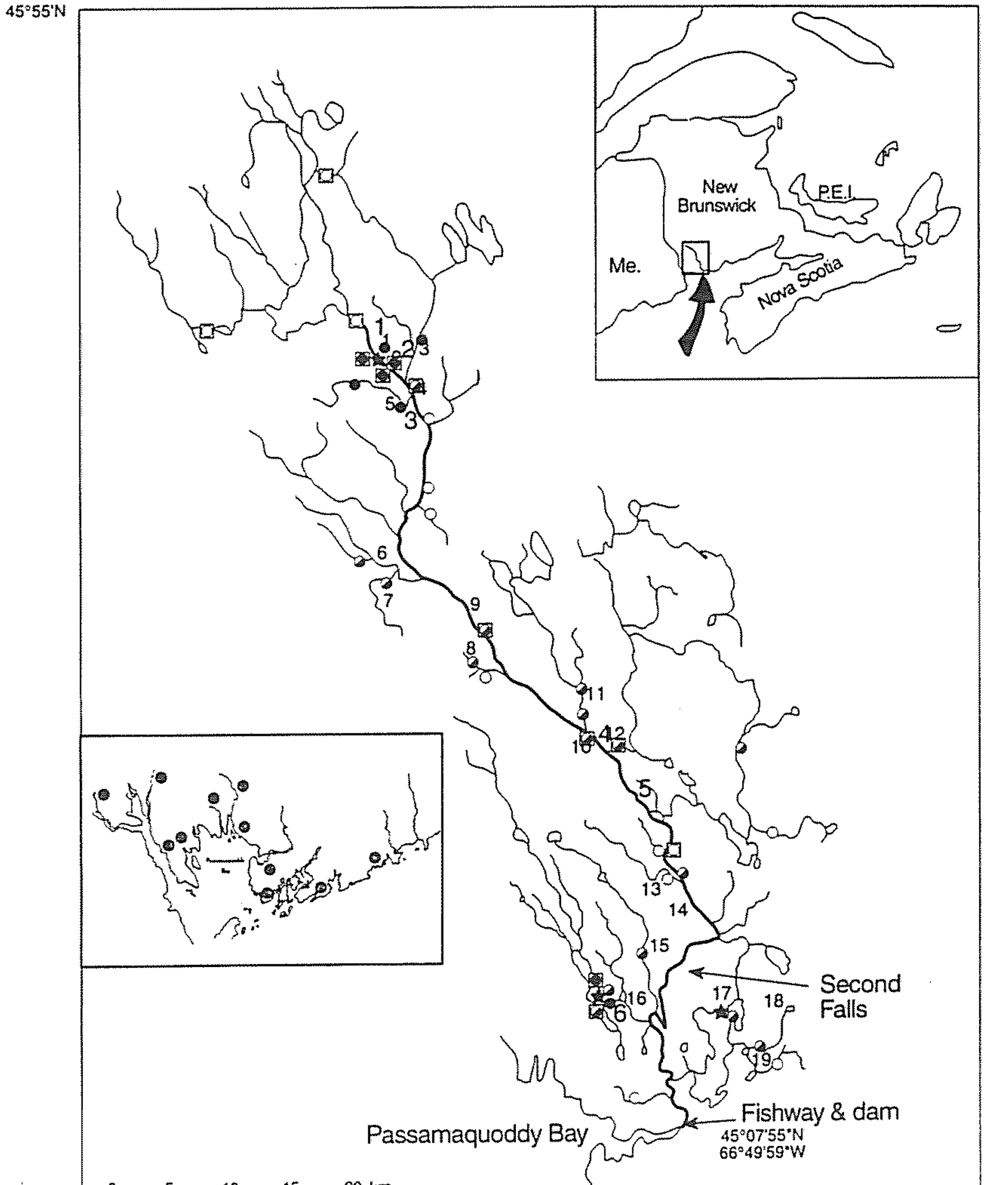
The study site

The Magaguadavic River is the sixth largest river in New Brunswick. It originates in the Magaguadavic Lake in the southwest part of the province and flows southeasterly 97 km to Passamaquoddy Bay (an offshoot of the Bay of Fundy) near St. George. There are 103 named tributaries and more than 55 lakes within a drainage area of 1812 km^2. A 13.4 m high dam (built in 1903) located at the head of the tide is equipped with Francis runner-type turbines which generate about 3.7 megawatts of power. A pool and weir fishway bypasses the dam for upstream fish passage. A sluiceway intended for downstream fish passage is situated adjacent to the penstock. Water storage reservoirs are located in Mill, Digdeguash, and Magaguadavic Lakes.

Sampling regimes

Details on the salmon of the Magaguadavic River and methods used for our work are found in Carr (1995), Carr *et al.* (1997) and Carr and Whoriskey (1998). Briefly, all salmon arriving at the Magaguadavic River from the ocean must past through a fish ladder which bypasses a head-of-tide dam built in 1903 (Figure 1). Complete counts of the river's salmon run have been made in the fish ladder's trap since 1992, and some historical counts are also available. Wild salmon ascend the river from June until early November. Spawning occurs from late October until mid November. Wild salmon spend 2 to 4 years in the river before they migrate to sea as smolt (Carr 1995). Fish captured in the fishway can be tagged, sexed, screened for sea lice or sampled for disease testing, and/or prepared for transplanting. Juvenile salmon were caught by electrofishing or in a fyke net during the smolt run.

Figure 1. Map of Magaguadavic River showing the locations of various sites and facilities



RESULTS

Wild and escapee returns

Counts of wild salmon have declined from 293 in 1992 to 31 in 1998 (Figure 2). Total wild returns in 1998 were only 27% of the average return of 115 fish in the 1993 to 1997 period. In the 1980s, wild returns were over 800 fish. The six year average (1992-1997) of repeat spawners in the wild salmon run was 7%. No wild repeat spawners returned in 1998.

Wild salmon entered the river from June through November and numbers generally peaked in July or August (from 1992-1998) (Figure 3). By contrast, cultured escapees entered the river later than wild fish in all years and their numbers peaked in either September or October (Figure 3).

The number of escapees entering the river have ranged from 119 (1997) to a peak of 1200 in 1994 (Figure 3). A Passamaquoddy Bay sea-cage failure in 1994 resulted in the escape of an estimated 20,000 fish. This probably accounts for the increased numbers of cultured salmon entering the Magaguadavic River in 1994 and 1995.

Spawning of escapees

In 1993, eggs were sampled from 20 redds, and analyzed for carotenoid pigments. Of these, 45% of the redds were made by wild females, 20% by escaped aquaculture females, and the remainder had pigments suggesting a possible aquaculture origin.

Two escaped MSW cultured salmon repeat spawners have been captured in the fishway: one male in 1992, and one female in 1994. It is not known if they had spawned in the Magaguadavic River, or elsewhere.

Since 1997, no aquaculture origin fish have been knowingly passed upstream through the fishway.

Transplants of escapees

In 1997 and 1998, 78 and 144 cultured salmon respectively were Floy-tagged and released at various sites in Passamaquoddy Bay (Figure 1) to determine whether they had entered the river at random or would home back to it if re-released.

In 1997, only one of the 78 fish (1.3%) was recaptured in the Magaguadavic fishway. This was a 73.8 cm male released in the river's estuary, at the site closest to the fish ladder. An unintended control was obtained when two male wild grilse were accidently classified as escapees and transplanted. Both returned to the fishway trap two and six days after release, from distances of 9.3 km (6 days later, 1.55 km/day) and 22 km (3 days later, 7.3 km/day).

Figure 2. The (a) total numbers and (b) percent of wild (shaded) and cultured (hatched bars) Atlantic salmon recorded in the fishway near the mouth of the Magaguadavic River from 1992-1998.

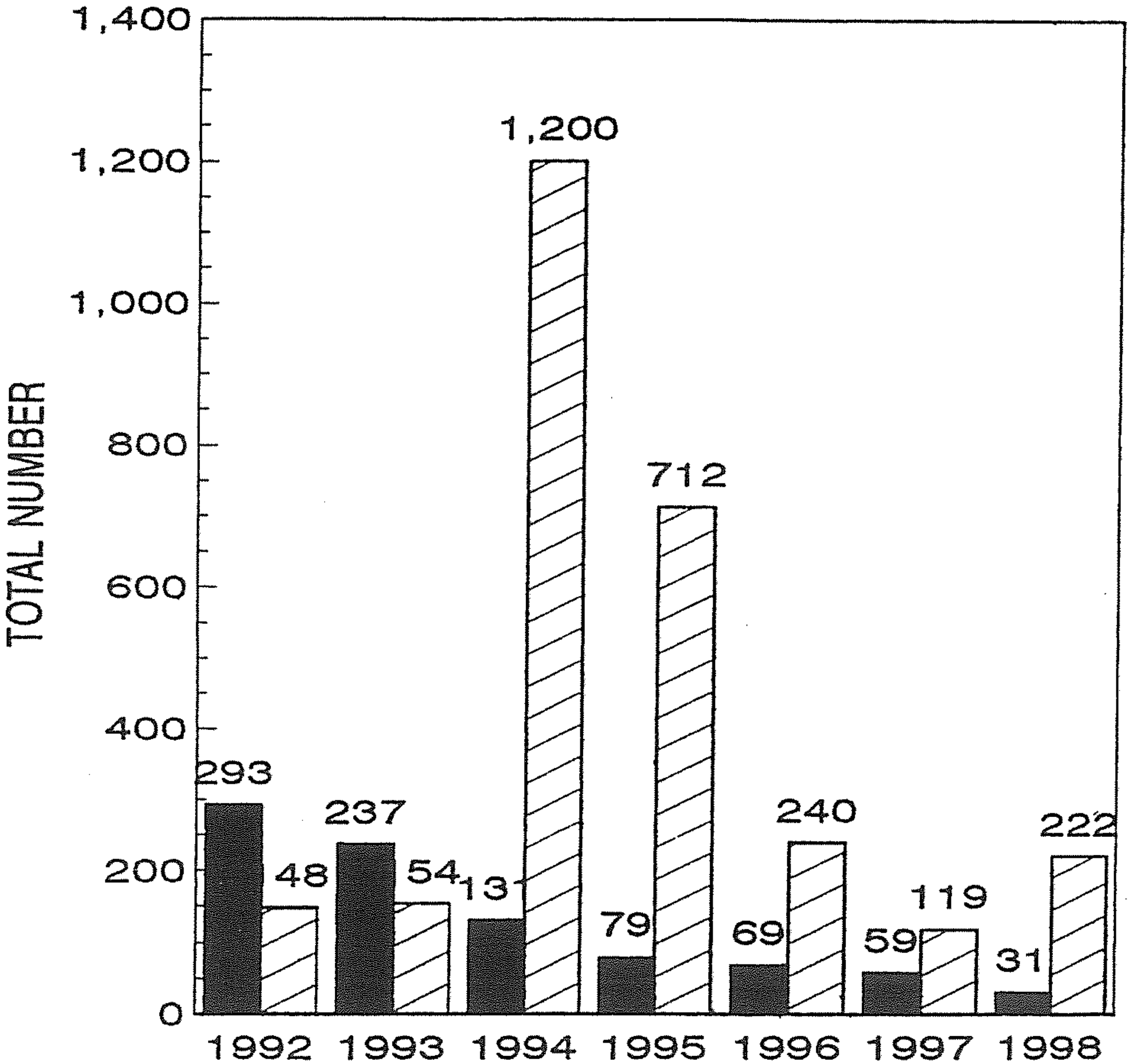
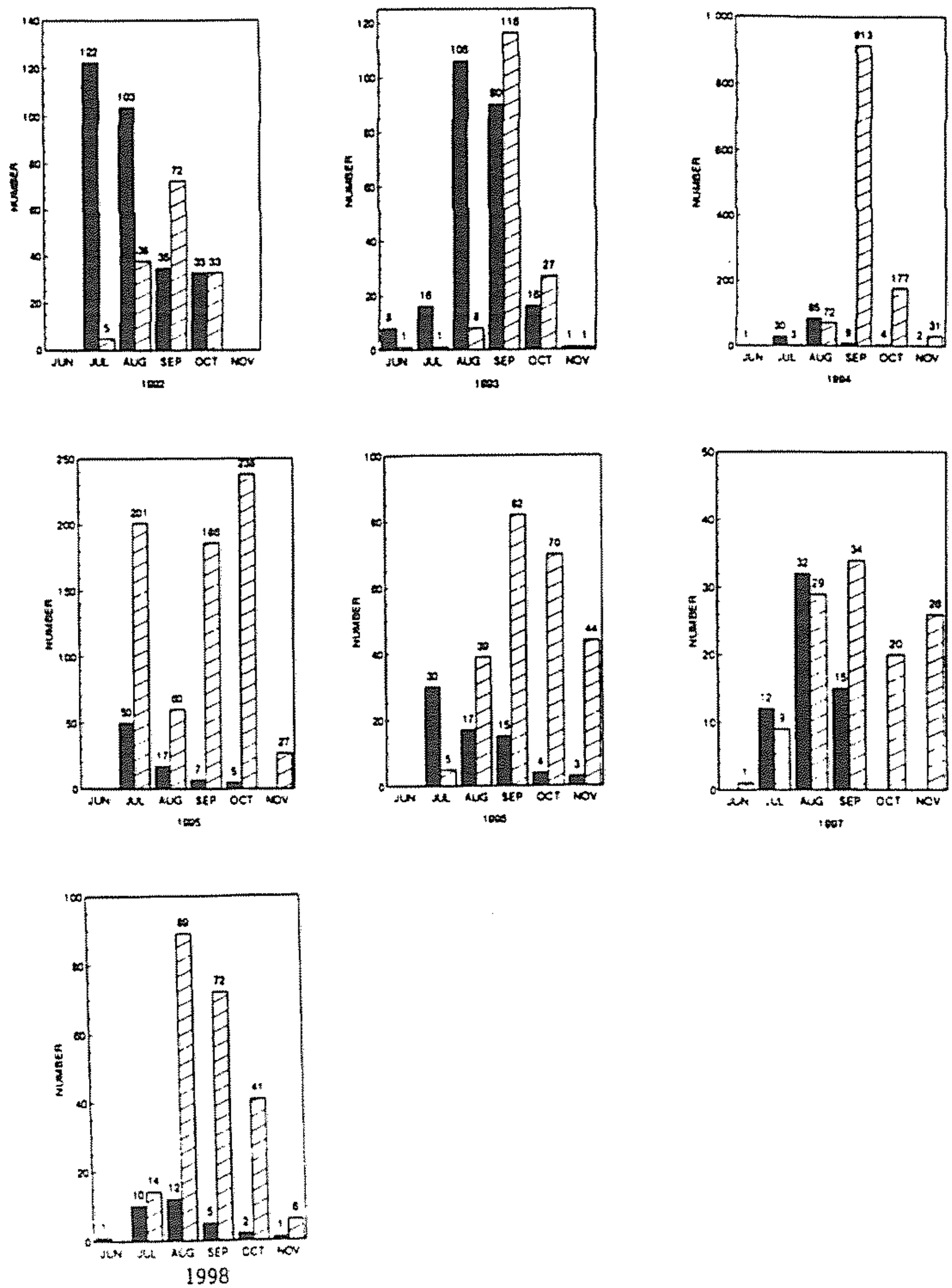


Figure 3. The monthly total numbers of wild (shaded) and cultured (hatched bars) Atlantic salmon recorded in the fishway near the mouth of the Magaguadavic River.



By contrast, in 1998, strong fractions of both the small (<=63 cm) and larger (>63 cm) salmon returned to the river following their initial transplantation. A significantly (X^2, $P < 0.05$) larger fraction of large (27%) than small (13%) salmon came back.

Pooling small and large salmon data, similar (X^2, $P > 0.25$) fractions of males (16.7%) and females (24%) returned after their first transplant.

Large and small salmon which had returned following a first transplantation were moved a second, and in some cases a third time. On each occasion, they were placed at a different site. For both the large and small fish that repeatedly returned to the Magaguadavic River fishway, rates of travel remained similar. However, while the number of fish returning fell after each transplant for both large and small salmon, in the small salmon category, the fraction of the fish returning increased with each transplant event. In addition, the returning fish tended to be the largest of the small fish. By contrast, for the large salmon, the fraction of fish returning did not increase with successive transplantation events and the sizes of returning fish did not trend upwards.

State of Maturity

On average, 11.1% of cultured salmon from the 1992-1998 period were classified as sexually mature (range 3.3% in 1994 to 46.2% in 1997) (see also Lacroix *et al.* 1997).

An increased frequency of escaped cultured postsmolts was observed in the river beginning in 1994, after the establishment of a brackish water rearing site near the mouth of the Magaguadavic River. Sexually precocious males comprised over 50% of the postsmolts in 1995 and 1997.

Disease Screening

Viruses and Bacteria

Deliberate killing of aquaculture escapees for disease screening was done in 1995, 1997 and 1998. Post mortem examinations/disease culturing were conducted either by the New Brunswick Department of Fisheries and Aquaculture (St. George), or the Department of Fisheries and Oceans (Moncton).

Tissue samples of kidney, spleen, gills, and pyloric caeca were extracted from 61 escapees in 1995, and sent to the Department of Fisheries and Oceans for virus screening. All tests were negative.

In 1997, 5 of 34 cultured salmon examined were suspect for HKS (Hemorrhagic Kidney Syndrome, now termed Infectious Salmon Anemia or ISA) based on visual inspection of pathologies in post mortem exams. Unfortunately, no viral cultures were done on these fish. No other pathologies were noted in post mortem exams or in cultures conducted on the other fish, including 19 sent to DFO for viral screening.

In 1998, 60 escapees were sent to the Department of Fisheries and Oceans for viral and bacterial screening. To date, one fish tested positive for a bacterial pathogen (BKD). No positive virus tests were recorded.

Occasional disease screening of incidental mortalities at the fishway was also done in the 1993 - 1996 period. Of seven wild mortalities, six showed no pathogens and one tested positive for *vibrio*. All escapees tested in the same period were clean (N=124).

Sea lice

No trends with time were evident in our sea lice counts. The majority of fish, both wild and escapees, had no or low levels of infestation with sea lice in all years. However, we do not know for how long the fish were resident in the river before they moved into the fish ladder trap. The lice may have dropped off before they could be counted.

JUVENILE SALMON ESCAPES

In 1998, 1185 smolts were captured, of which 82% were classified as hatchery escapees. An additional 15% were of Magaguadavic origin (including clipped fish from a satellite rearing program that used Magaguadavic River broodstock), and 2.6% were landlocked salmon that had been fin clipped and stocked in lakes in the system, and nevertheless were moving out to sea. Stokesbury and Lacroix (1997) also reported high numbers of escaped hatchery smolts from this river in 1996.

Electrofishing for parr have found them to generally be rare, with the largest catches being composed of hatchery escapees in the vicinity of the hatcheries (Carr and Whoriskey 1998).

CONCLUSIONS

1. The Atlantic salmon population of the Magaguadavic River, similar to that of other rivers draining into the Bay of Fundy, is in an extremely fragile state. Returning adults are providing a small fraction of the required egg depositions and wild juvenile numbers are low. This makes these rivers particularly vulnerable to the impacts of influxes of non-native fish.

2. Aquaculture escapees now far outnumber wild fish in Magaguadavic fish ladder counts, although their annual numbers vary greatly and unpredictably. In the past, these fish have spawned in the river and have probably mixed their genes with wild fish. Meanwhile, wild juveniles are also being swamped by fish escaping from hatcheries in the system. In European work, genetic and ecological swamping have been implicated in negative fitness effects on wild salmon populations (Fleming and Einum 1997, McGinnity *et al.* 1997). We have not had the resources to conduct similar work in the Bay of Fundy region.

3. In 1998, systematic disease screening suggested a low frequency of disease for the escapees. However, viral cultures are still being conducted. In 1997, five escapees had symptoms consistent

with ISA, but no viral cultures were done on the fish and the conclusion is uncertain. In all years, the great majority of escapees examined did not test positive for diseases. This suggests that aquaculture fish may pose a limited risk of carrying diseases to freshwater. Sea lice counts were also low on returning fish. However, none of our work can address the possibility that wild fish at sea might pick up and die from diseases which originate at cage sites. We are only screening the survivors.

4. In one of two years, transplanted aquaculture fish showed a degree of homing and returned to the Magaguadavic River. This had not been reported from other salmon farming areas. These fish may have been raised to the smolt stage in one of the hatcheries located in the system and hence have imprinted to it. The fact that many of them were not maturing shows that homing ability is decoupled from the reproductive cycle.

Given the fragile state of the wild fish of this river and of other rivers in the Fundy region, we must minimize interactions among wild and aquaculure fish.

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Location Names for Figure 1.

1. Magaguadavic River (Cook Hatchery, 2 sites)
2. Magaguadavic River (HWY 3 bridge, 2 sites)
3. North East Branch Magaguadavic River
4. Mouth of Davis Brook
5. Davis Brook (2 sites)
6. Lower Trout Brook
7. Deadwater Stream
8. Cox Stream
9. Magaguadavic River (Flume Bridge)
10. Magaguadavic River (Pomeroy Bridge)
11. Kedron Stream (2 sites)
12. Piskahegan Stream
13. Lake Stream
14. Magaguadavic River (Turnover Island)
15. Bonny River
16. Linton Stream (4 sites)
17. Mill Stream
18. McDougall Inlet
19. Colonel Stream
20. Dennis Stream
21. Waweig River
22. Bocabec River
23. Digdeguash River
24. St. Croix River release site
25. Chamcook release site
26. Ovenhead release site
27. Mascarene release site
28. Greens Point release site
29. Deadman's Harbour release site
30. Crow Harbour release site

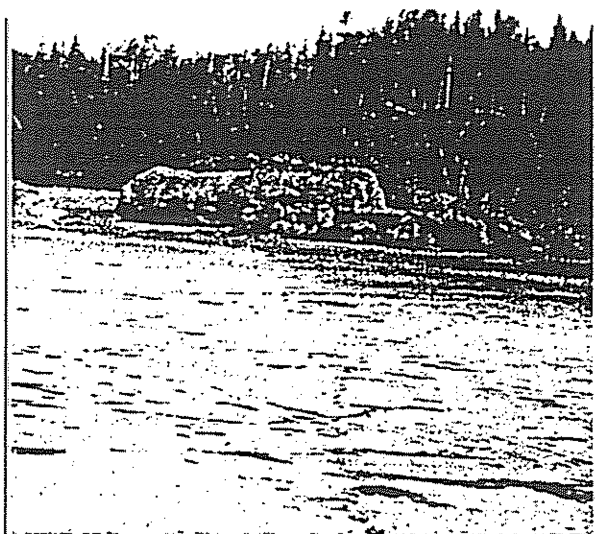
∫Commercial salmon hatcheries

Public Lecture

Harry Thurston

author

A long time contributor to both *Equinox* and *Harrowsmith* magazines, Harry is a well-respected environmental and natural-history writer and the recipient of awards from both the Canadian Science Writers' Association and the National Magazine Awards Foundation.



"Understanding Change in the Bay of Fundy Ecosystem: *A Personal Perspective*"

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Session Five
Monitoring and Management
Chair: Barry Jones, NB Dept. of Fisheries and Aquaculture

A 20-Year Environmental Monitoring Record of the Point Lepreau Nuclear Power Generating Station in the Bay of Fundy

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Abstract

The Point Lepreau Nuclear Generating Station is a 660 MW CANDU reactor located on the Bay of Fundy in New Brunswick which began operations in 1982. Radioactive substances are discharged both into the atmosphere and into cooling water that is subsequently released into the Bay of Fundy. The unique environmental constraints posed by the proximity of this reactor to the ocean and concerns with respect to the important commercial fishery in the Bay of Fundy, led to the establishment of the Point Lepreau Environmental Monitoring Program (PLEMP) in 1977 as an inter-departmental program, with DFO as the lead agency. The principle goals of PLEMP are to delineate the dispersion of artificial radioactivity in atmospheric, terrestrial and marine phases of the environment and to evaluate environmental impacts associated with reactor operations. Long-term monitoring records have been established for: levels of tritium in atmospheric water vapour and aerosols, levels of 137Cs in lichens, marine plants and animals, and levels of artificial radioactivity in seawater and sediments from the Bay of Fundy. These monitoring records illustrate the changes in marine environmental radioactivity levels associated with reactor releases and nuclear fallout and provide a baseline against which any future radioactivity releases to the marine environment can be compared. The primary environmental impact of the reactor has been an increase in tritium levels in atmospheric and terrestrial reservoirs proximal to Point Lepreau. PLEMP is also the primary Canadian vehicle for evaluating the long term impact on marine resources of radioactive releases from nuclear accidents. For example, during the Chernobyl accident in 1986 PLEMP monitoring was conducted continuously on samples from all major phases of the environment and the results permitted an immediate evaluation of the movement of Chernobyl radionuclides through the marine food web in eastern Canada. In addition, PLEMP has become a significant resource for assessing non-nuclear (*e.g.* metal contaminants) environmental changes in marine systems in the Bay of Fundy.

Implementation of the Global Program of Action for the Protection of the Marine Environment of the Gulf of Maine

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[3]Program Manager, Commission for Environmental Cooperation, Montreal QC

Abstract

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) was developed under the United Nations Environment Program in 1995, recognizing that approximately 80 percent of all marine pollution comes from human activities on land. The Commission for Environmental Cooperation (CEC) supports the implementation of international environmental agreements in North America. In 1996, the CEC initiated a program to support the implementation of the GPA. Two pilot project areas were identified, one covering waters shared by the US and Mexico referred to as the Bight of the Californias and the other covering waters shared by Canada and the US in the Gulf of Maine.

At the heart of the approach taken in the Gulf of Maine, is the reliance on a multi-stakeholder coalition that is inclusive of the various interests around this ecosystem. This coalition (called the Global Program of Action Coalition for the Gulf of Maine, (GPAC)) was pulled together drawing upon state, provincial and federal governments, First Nations and Founding Tribes, industry, non-governmental organizations (NGOs), community action groups and academia.

Experience gained in this effort has shown that the GPA is an excellent vehicle for focusing stakeholder attention on the land-based activities that lead to the degradation of the marine environment. The strategic approach which the GPA outlines is an excellent tool for establishing priorities and identifying strategies and actions to address these priorities. The coalition-based approach has provided the type of multi-stakeholder acceptance that is essential to initiating real action.

Although the real value of the GPA can only be assessed in the long-term, there have been a number of distinct short-term gains: establishment of a binational coalition of interests, identification of the priority issues in the Gulf of Maine, delineation of a number of key strategies, and the initiation of five projects that will advance the knowledge and capacity of the region to address the priority issues.

Introduction

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, usually abbreviated to the Global Programme of Action or (simply the GPA), was developed under the auspices of the United Nations Environment Programme (UNEP) and adopted by 108 nations on November 3, 1995 (UNEP, 1995). The GPA calls for actions by each signatory nation to preserve and protect the marine environment on a national, regional and international basis in order to reach the goal of "sustainable seas". It is internationally recognized that about eighty per cent of marine pollution is caused by human activities on land.

The GPA identifies (UNEP, 1995) a series of discrete steps that provide a strategic basis for addressing the impacts on the marine environment caused by land-based activities. These steps are:

1. identification and assessment of problems
2. establishment of priorities
3. setting management objectives for priority problems
4. identification, evaluation and selection of strategies and measures, including management approaches
5. criteria for evaluating the effectiveness of strategies and measures, including management approaches
6. program support elements

The GPA also targets contaminants and physical alteration of coastal habitat as its focus. The categories of contaminants that are addressed include: sewage, persistent organic pollutants, radioactive substances, heavy metals, oils (hydrocarbons), nutrients, sediment mobilization, and litter (UNEP, 1995).

In North America, the Commission for Environmental Cooperation (CEC) was created as a result of the North American Free Trade Agreement (NAFTA) negotiations to facilitate cooperation and public participation to foster conservation, protection and enhancement of the North American environment. In pursuing its mandate, the CEC decided to promote a series of pilot projects in North America to implement the GPA and selected the Gulf of Maine (GOM) as a candidate site for one of the projects. CEC brought together a diverse group of individuals with an interest in the GOM and the GPA to develop and implement a project of their own design, with some support from the CEC. The group, which has named itself the GPA Coalition for the Gulf of Maine (GPAC), has formulated an action plan to: 1) focus on regional problems and issues and 2) engage a broad, multi-sectoral support base to implement actions at the local and regional levels.

Setting: The Gulf of Maine

The Gulf of Maine is a semi-enclosed sea bounded to the southeast by tall underwater land forms called banks that rise up to form a barrier to the North Atlantic. It stretches from Cape Cod, MA to Cape Sable, NS and includes the three states of Massachusetts, New Hampshire and Maine and the provinces of Nova Scotia and New Brunswick.

The total land area of the Gulf of Maine watershed is 165,185 square kilometers (69,115 square miles), extending from eastern Quebec to central and southern Massachusetts. This land area far surpasses the 79,000 square kilometers (33,054 square miles) of the Gulf's water surface. One of the world's most biologically productive environments, the marine waters and shoreline habitats of the Gulf host about 2,000 species of plants and animals. The activities of every resident and visitor within this huge area ultimately influence the health of the streams and rivers that enter the Gulf of Maine and the health of the Gulf itself.

In 1989, the U.S. states of Massachusetts, New Hampshire and Maine along with the Canadian provinces of New Brunswick and Nova Scotia signed an agreement to protect the Gulf of Maine and formed the Gulf of Maine Council on the Marine Environment. This council provides an excellent mechanism for the coordination of various government activities addressing marine related issues in the Gulf. The Council has identified a number of priorities which it has described in its Action Plan, "Action Plan: 1996-2001" (Gulf of Maine Council on the Marine Environment, 1996).

Approach

The Gulf of Maine was selected as a pilot study for a number of reasons. It is a shared water body, bounded by the United States and Canada and complements the other pilot study which was selected, the Bight of the Californias, an area bounded by the United States and Mexico. The Gulf of Maine is also known for the collaboration that has been developed through the Gulf of Maine Council on the Marine Environment.

In approaching the region to initiate the project, the CEC made contact with the Council and other organizations within the Gulf of Maine to identify individuals to participate in an initial meeting to begin planning the approach to the GPA. This meeting was held in November 1996 in Durham, New Hampshire, USA. An initial scoping paper on issues was commissioned for this meeting to provide participants with an overview of issues in the Gulf.

This initial meeting brought together a wide variety of individuals from around the Gulf and from diverse backgrounds including government, NGOs, First Nations, and academia. The outcome of the meeting was an initial list of potential actions that could form part of the strategies and measures component of the GPA.

In a follow up meeting in July 1997, in Saint John, New Brunswick, Canada, the outcome of the Durham meeting was examined in detail. This session allowed a substantial airing of diverse and sometimes opposing opinions on the directions to take in implementing the project. The end result was a re-examination of the suggested activities in light of the overall intent of the GPA.

In the fall of 1997, a meeting was held in Danvers, Massachusetts, USA. The meeting successfully merged the intent of the GPA with the concerns and issues of the stakeholders in attendance. The result was the development of an action plan that would apply the GPA methodology to the issues of the Gulf of Maine over a 12-month period. At this meeting consensus was reached on the establishment of the coalition and its overall structure.

The Coalition

In developing the coalition, a key principle followed was that of inclusiveness and openness. Federal, provincial and state governments, native organizations, non-government organizations, community groups, industry and academia were invited to participate in the coalition. A major part of the success of the coalition was the excellent participation from a wide range of stakeholders. Individuals belonging to all of the groups referenced above participated fully in the activities of the coalition.

In establishing the coalition it was also recognized that the existing coordinating mechanisms in the Gulf of Maine would play a key role and should be well represented in the Coalition. Within the Gulf of Maine, the Gulf of Maine Council on the Marine Environment has provided an excellent coordination mechanism among the governments of the region. The coalition membership reflected this importance with five members selected from the Gulf of Maine Council Working Group, one from each province and state. In addition, two liaisons were identified by the Council, one from Canada and one from the United States.

Development of an Action Plan

In November of 1997, the coalition identified a five step action plan that followed the process and philosophy described in the GPA (GPAC, 1998a). The key steps in that action plan were:

1. Strategic assessment of pollutants and habitats in the Gulf of Maine
2. Establishment of priority pollutants and critical habitats
3. Identification of management objectives for priority problems
4. Identification, evaluation and selection of strategies and measures, including management approaches
5. Adoption of criteria for evaluating the effectiveness of proposed strategies and programs

The development and implementation of the GPAC action plan was also targeted towards:

- strategic identification, synthesis and integration of existing work in the Gulf of Maine to reduce overlap and needless repetition of effort
- cross-sectoral, multi-disciplinary consensus on the identification and ranking of significant habitat issues and toxic contaminants in the region
- integrated, collaborative partnering with existing institutions, organisations, communities and the private sector that are already at work in environmental management in the region, or can be encouraged to participate
- the ultimate integration of GPAC activities and resources into existing, more permanent organizations once the Action plan to advance the GPA is in place

Implementation of the Action Plan

Strategic assessment of pollutants and habitats in the Gulf of Maine. The first step in the implementation of the Action plan was taken through the development of two issue scoping papers. The papers were designed to address the two areas, contaminants in the Gulf of Maine and habitat disturbance in the Gulf of Maine. These scoping papers reviewed existing literature, issues scans and priority setting exercises undertaken in the area. The authors developed an initial ranking of issues that could be used in the next phase of the action plan. These background papers were distributed in advance of the following priority-setting workshop.

Establishment of priority pollutants and critical habitats. At a binational workshop in Saint John, New Brunswick on April 27 to 29, 1998, over 100 participants developed a consensus list of priority contaminants and physical alterations upon which an action plan to reduce or eliminate their impacts would be developed. The participants included industry, First Nations, community groups, municipalities, scientific institutions, provincial governments and the federal government.

Within the Gulf of Maine the following strategic issues have been identified through the scoping papers as the most prominent concerns affecting the marine environment. The issues fall into two broad categories, contaminants and habitat disturbance (Horsley and Witten, Inc., 1998). The contaminants of concern are:

1. bacteria and viruses
2. pesticides, PCBs, dioxins
3. arsenic, cadmium, chromium, copper, lead, mercury, tin, zinc
4. oils, polycyclic aromatic hydrocarbons (PAHs)
5. nitrogen, phosphorous

The other category deals with habitat disturbance (Percy,1998). The issues identified are:

1. Development on and adjacent to sensitive marine habitats
2. Sewage and eutrophication in coastal waters
3. Dams: loss of fish habitat and alterations in freshwater flow
4. Mobile fishing gear use in estuaries and coastal embayments
5. Salt marsh habitat restoration
6. Tidal flow restrictions in estuaries and coastal inlets
7. Aquaculture impacts on benthic habitats
8. Rockweed harvesting

From this broad range of issues the following priority issues were identified (GPAC,1998b):

- the discharge of pathogens (bacteria and viruses)
- the release of biocides through activities like aquaculture
- discharges of dioxins/furans

- release of mercury into the environment
- discharges of polycyclic aromatic hydrocarbons (PAHs)
- chronic spills of petroleum hydrocarbons
- inputs of nitrogen
- development adjacent to and disruptive of coastal habitats
- sewage and eutrophication in coastal waters
- use of mobile fishing gear in coastal embayments
- protection and restoration of salt marsh
- tidal and freshwater hydraulic obstructions
- impacts of aquaculture on habitats
- harvesting of low trophic level species and habitat
- absence of "No-Take" reserves

Identification of management objectives for priority problems. In order to deal with them more effectively, GPAC grouped the issues identified into five broader categories: coastal development, physical alterations, resource use, sewage and eutrophication and toxics. Scoping papers were commissioned to examine the various approaches, actions and in particular targets that were being utilized currently to address these issues.

Identification, evaluation and selection of strategies and measures, including management approaches. On November 15-17, under the sponsorship of the Global Programme of Action Coalition for the Gulf of Maine (GPAC), over 140 stakeholders from the region reviewed existing activities, identified gaps in current environmental protection and land-use programs, and developed an action package to reduce pollutants and protect and manage habitats. Fifteen top strategies were proposed at the Portland workshop to reduce priority regional pollutants and other human impacts on critical marine habitat.

The second workshop at Portland identified 15 top strategies which addressed the following (GPAC, 1999):

Coastal Development

- Communication/Education Strategy in Support of Gulf of Maine Goals for the Protection of the Marine Environment from land based Activities
- Shared Principles for Integrated Land Use Planning
- Communities United for the Gulf Of Maine

Physical Alterations

- Developing and Applying Standards and Criteria for Restoration of Tidal Wetlands
- Loss Of Salt Marsh
- Protecting and Restoring of Salt Marsh Areas (Demonstration Project).
- Identifying and Prioritising Restoration Sites

Resource Use

- Low Trophic-Level Harvesting: Resource and Policy Development Conference
- Identifying and Establishing Marine Protected Areas with Minimal Human Activity
- Workshop on the Impacts of Mobile Fishing Gear in Coastal Embayments

Sewage and Eutrophication

- Gulf Wide Coastal and Estuarine Eutrophication and Pathogen Monitoring
- Gulf of Maine Bilateral Agreement on Environmental Quality
- Gulf of Maine Watershed Management Plans for Pathogens and Nutrients

Toxics

- Workshop on Models For Bilateral Agreements and Arrangements for Toxic Chemicals
- Status Report on Toxic Chemicals in the Gulf of Maine
- "50 Things You Can Do To Save the Gulf Of Maine" Booklet

Measures. Based on the strategies identified in the second workshop GPAC identified five measures that it would recommend the CEC support during 1999 to advance the application of the GPA in the Gulf of Maine. These five measures address eleven of the strategies identified in the second workshop.

- Workshop: "Exploring the Options: Bilateral Arrangements for Management of The Gulf of Maine Ecosystem"
- Salt Marsh Restoration
- Communities United for the Gulf of Maine
- Education Materials on Land-Based Sources of Marine Pollution
- Low Trophic-Level Resource Harvesting and Policy Development Conference

1999 Workshop: "Exploring the Options: Bilateral Arrangements for Management of the Gulf of Maine Ecosystem". This conference will address the need to examine institutional arrangements that are or can be applied to the Gulf of Maine. The purpose is to enhance the ability of stakeholders to effectively address issues of regional concern, including i) the management of sewage-borne contaminants and other toxic chemicals, which will require sharing technical knowledge and establishing common standards for assessing environmental quality between agencies and communities and ii) the development of shared values, goals and targets to create integrated and sustainable coastal land and marine resources management.

Salt Marsh Restoration. Building on existing work in the state and provincial jurisdictions, this initiative will develop a regional database of restoration opportunities and standardized, regionally applicable criteria and protocols for evaluating the success of restoration projects in reconstructing the structure and functions of natural systems. It will establish a regional network of sites, consolidate existing coastal databases and update them for regional use as required. A salt marsh restoration site in Canada will be identified to educate local communities on the value of salt marshes and to apply the evaluation protocols to demonstrate successful restoration techniques.

Communities United for the Gulf Of Maine. This capacity building approach is intended to expand the capabilities of community-based organizations to monitor environmental quality and ultimately improve the management of coastal resources throughout the Gulf of Maine. This will be coordinated through the Coastal Network, an existing binational network that is monitoring environmental indicators such as water quality.

Education Materials on Land-Based Sources of Marine Pollution. A fundamental element to addressing the issues is the availability of effective materials to inform a general audience and school children about the impacts of their activities on the marine environment. Materials developed in this project will include a booklet about activities that cause pollution and habitat destruction and what can be done to help restore the health of the marine environment. Supporting materials will include items such as posters and fact sheets. An inventory will be done of existing materials within the state and provincial departments of education to avoid duplication of effort and survey the need for the kinds of materials and specific topics to guide their design.

Low Trophic-Level Resource Harvesting and Policy Development Conference. A conference will be held in 1999 to develop a research program and make policy recommendations for managing the harvesting of low trophic-level species such as rockweed and krill. Participants will examine how to sustain low trophic level species and their important function within the Gulf of Maine ecosystem. Within each of the measures undertaken, specific criteria for evaluating their success have been identified. These range from the increase in the number of volunteer water quality monitoring groups to influencing institutional arrangements in the Gulf of Maine.

Conclusions

The GPA has proven to be a valuable tool in promoting and advancing the protection of the Gulf of Maine ecosystem. It has added value to the existing collaborative efforts that are important to the health of the Gulf. The protocol introduced by the GPA with its very strategic approach to assessing problems and identifying actions enabled the Coalition to develop an implementation plan that will contribute in significant ways to addressing the issues in the Gulf. This has all been accomplished in an open and participatory approach that bridges jurisdiction, interest and geography.

As a pilot study in North America, this project has established that the GPA is of value even in areas with relatively mature regulatory and resource management frameworks. Both Canada and the United States have extensive legislation covering human activities that can affect the marine environment and existing arrangements for regional collaboration. The philosophy of the GPA and the approach that it promotes brings the many diverse interests of stakeholders from around the Gulf together. In this pilot project the result has been the development of a sense of ownership in the process, a clear understanding of issues and a clear list of specific activities that can be launched to address the issues raised.

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An Ecological Classification of the Marine Environment: Framework for Management

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Abstract

Addressing the gaps in our knowledge about marine species, habitats, and processes and the growing conservation imperative for the marine environment, require achieving a balance between fine-scale, detailed information gathering exercises and coarse-scale planning that can operate in shorter time frames while still delivering protection to a significant proportion of Canada's native biodiversity. A marine classification framework has been developed through the collaborative efforts of World Wildlife Fund Canada, consultants and various academic and government agencies to assist in striking this balance for marine protected areas in planning. The classification framework utilizes the enduring and recurrent oceanographic and physiographic features of the marine environment. The framework is a natural hierarchical classification of marine environments which leads to the delineation of marine representative units (MRUs). A cast study demonstrating the application of the framework to the Scotian Shelf/Bay of Fundy area will be discussed.

Marine Protected Areas in the Bay of Fundy – An Update

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Abstract

A new vision for the management of our oceans came into effect in January 1997 with the passage of the *Oceans Act*. Part II of the *Oceans Act* identifies three complementary initiatives by the Department of Fisheries and Oceans as part of a national strategy for managing Canada's oceans: integrated management plans in coastal and marine waters, the establishment of marine environmental quality guidelines and the designation of marine protected areas.

DFO has developed both a national policy and regional framework for establishing marine protected areas (MPAs) under the *Oceans Act*. As part of a 'learn by doing' approach, DFO is currently involved in identifying potential sites or Areas of Interest (AOI) in order to test the process for evaluating and designating MPAs in the Maritimes. This paper provides an update on the progress of DFO in gathering input into the MPA Program and on specific projects underway in the Bay of Fundy. Particular focus will be on the proposal for a MPA in the Musquash estuary. A committee has been established and meets on a regular basis to further develop the proposal for *Musquash Estuary Pilot Study* in order to evaluate the benefits and requirements of a MPA in the area. The paper concludes with a discussion on further work and collaborative efforts in the Musquash area and in the Bay of Fundy as a whole.

Semipermeable Membrane Devices for Environmental Monitoring of Polycyclic Aromatic Hydrocarbons

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Abstract

Investigation into the sources of polycyclic aromatic hydrocarbons (PAHs) was identified as a priority by ACAP Saint John in the 1997 Comprehensive Environmental Management Plan for the Saint John Harbour. Polycyclic aromatic hydrocarbons (PAHs) are naturally occurring compounds which can also be produced through anthropogenic activities. Identified sources of PAHs include incomplete combustion, petroleum products, urban run-off and sewage. Some PAHs have been identified as carcinogenic compounds and therefore, are of particular concern.

In 1996, ACAP Saint John discovered extensive creosote contamination in Marsh Creek, a tributary of the Saint John Harbour. The extensive contamination originated from an historic creosote treatment plant located on the land currently owned by the Canada Post Corporation. ACAP Saint John has done a number of studies investigating the extent and effects of this creosote.

Given the variety of potential sources of PAHs in the Saint John Harbour (Marsh Creek, urban run-off, untreated municipal sewage), ACAP Saint John was interested in developing a technique to monitor PAHs. In addition to providing reliable data, several other criteria were required. First, as PAHs are hydrophobic and have a low solubility in water, the monitoring technique needed to be sensitive to low concentrations. Second, the monitoring mechanism was required to be integrative, sampling through intermittent storm cycles without missing sudden events. Third, the technique had to be simple and robust; able to survive the harsh conditions of some of the sampling sites with little or no maintenance. Finally, the technique had to be cost-effective in production and analysis.

The method chosen was to develop semipermeable membrane devices (SPMDs). These devices consist of a hexane-filled dialysis tube enclosed in a protective cage. During their approximately 30 day deployment, hydrophobic PAHs in the water column are passively drawn through the semipermeable tube and accumulated in the hexane. The hexane can then be retrieved from the tube and tested directly, with little laboratory clean-up. As a result of the fluorescent characteristics of PAHs, preliminary screening of the UV and fluorescence spectra of the hexane samples allowed high values to be identified for more detailed analyses at a later date. Phase I of the pilot project consisted of field testing a limited number of SPMDs. Results from UV spectrophotometry were consistent with water samples taken at the same locations. This supported the use of the technique as an accurate and cost-efficient method of monitoring PAHs. A test was also performed to measure the rate of PAH uptake in the dialysis tubes. After a re-design of the SPMDs, Phase II, the PAH survey, began.

Phase II consisted of deploying 36 SPMDs at various locations throughout Saint John, including storm and municipal sewers, shopping mall parking lots, and several creeks and rivers that empty

into the Saint John Harbour. The SPMDs were deployed for at least a 30 day period. After being collected, the UV and fluorescence spectra of the samples were analyzed. These data are currently being compiled.

Poster Presentations

Quality of Bay of Fundy Sediments: Further Insights Using the Microtox® Solid Phase Assay

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Abstract

The Microtox^{R} Solid Phase Test (SPT) was used to describe the toxicity of Bay of Fundy sediments at three sites. The first objective of the study addressed the toxicity and its relationship to site, level, particle size, organic carbon (OC), and moisture content. Previous studies showed that the sediments were of low toxicity (~5,000-10,000 mg/L), with the IC50's correlated with level on the beach, particle size and OC content. The present experiment found IC50's ranging from 2,500-25,000 mg/L, with a mean of 7,700 mg/L. The mean IC50's varied with site, level, particle size and moisture content.

A second objective was to investigate the possible loss of bacteria in the assay and the effect of washing the sediment on this loss and the resulting IC50. The toxicity of autoclaved sediments (axenic particles) and autoclaved/washed sediments (axenic, stripped particles) was determined. At the same time, microbiological experiments determined the bacterial loss at two concentrations and the control sample after the filtration stage of the SPT. At the maximum concentration, the mean bacterial loss ± standard deviation (sd) was 48%±27%, while at the IC50 concentration the bacterial loss was 30%±24%, both significantly different from 0 ($p<0.001$). The difference between the bacterial losses at the two concentrations (18%± 23%) was also significantly different from 0. Bacterial losses and the difference did not vary significantly with washing or toxicity, nor with site, level on the beach, particle size, organic carbon, or moisture content.

The Microtox^{R} SPT continues to be evaluated for accuracy, influencing factors and practicality in the context of sediment quality issues in the Bay of Fundy. The reasons for the bacterial losses, and effect of the bacterial loss on the accuracy of the IC50, require further investigation.

Assessing Benthic Impacts from Marine Aquaculture

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Abstract

The rapid development of salmonid aquaculture in the Bay of Fundy requires assessment of environmental impacts of this new industry. Analyses of sediment geochemical and benthic macrofauna community variables were carried out using diver-collected cores and grabs at 22 salmon farm sites in the Western Isles region of the Bay of Fundy and at 47 subtidal locations in Annapolis Basin to evaluate changes associated with salmon aquaculture. An imaging technique with a sediment-water interface camera allowed vertical gradients in sulfide accumulation in surface sediment layers to be determined. Total sulfide, redox (Eh) potentials, benthic oxygen uptake and carbon dioxide release were the most sensitive indicators of organic enrichment under fish pens compared with reference locations >500 m away. Variability between replicate measurements under cages reflected spatial patchiness in sedimentation and accumulation of fecal waste and food pellets. Total biomass of macrofauna was not increased with organic enrichment but biomass of deposit feeders was enhanced. Temporal observations at a site with low to moderate currents in the Western Isles region showed that effects of organic enrichment persisted for 1-2 years following removal of fish pens.

Toxic Contaminants In *Mytilus edulis* From the Gulf of Maine

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Abstract

The Environmental Quality Monitoring Committee of the Gulf of Maine Council on the Marine Environment has used blue mussels (*Mytilus edulis*) for the past seven years as a sentinel species for habitat exposure to bioaccumulative, toxic contaminants in the Gulf of Maine/Bay of Fundy. Mussels were collected at 59 sites in the five jurisdictions boarding on the Gulf for spatial and temporal analysis. Tissue was analysed for PAHs and PCBs, pesticides, dioxins and furans, and trace metals and for measurements of growth and condition index. Results show a southward trend of increasing concentrations for organic contaminants and both silver and lead, reflecting major local and regional pollution sources while other trace metals showed relatively uniform geographical distribution. In the southern Gulf, concentrations were elevated at sites previously assumed to be uncontaminated and other areas have been identified that appear to be hot spots. While very few sites have mussel tissue contaminant concentrations that exceed US or Canadian seafood human health tolerances, some sites in the Gulf do exceed USEPA screening values for triggering more in-depth assessment of human health risk and several sites exceed a preliminary Environmental Canada tissue reference concentration considered harmful to avian and mammalian species. Gulfwatch has been useful to managers in a variety of ways and it provides unique Gulf-wide information that helps focus efforts to reduce contaminant loadings to the Gulf.

Evaluating Measures of Sub-Lethal Stress in *Mytilus* spp. for Contaminant Monitoring in the Gulf of Maine and Bay of Fundy Ecosystem

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Abstract

The Gulf of Maine Council on the Marine Environment's Gulfwatch program currently uses *Mytilus* spp. body burdens and tissue concentrations of contaminants (polynuclear aromatic hydrocarbons, polychlorinated biphenyls, chlorinated pesticides and trace metals) as indicators of marine habitat exposure. Such data from mussels are intended to reflect the ambient contaminant concentrations and the overall health of the Gulf of Maine and Bay of Fundy ecosystem. In addition to contaminant measures, Gulfwatch also employs biological endpoints or measures; for example, mussel shell growth, condition index and gonad index. To enhance this biomonitoring program and better demonstrate an ecotoxicological connection, practical measures of sub-lethal stress in *Mytilus* could be added to the current monitoring approach. This project, still underway, evaluates promising biochemical (mixed function oxygenase activity, metallothionein induction), cytological (lysosomal membrane stability, condition of haemolymph cells) and physiological biomarkers (embryo-larval development, immune system health, filtration rate, scope for growth, condition index) in terms of their potential relevance, ease of use by community group volunteers, and practicality within the Gulfwatch monitoring framework. This poster summarizes the evaluation of MFO activity, MT induction, lysosomal membrane stability, condition index and filtration rate. By expanding the Gulfwatch monitoring approach to include additional endpoints with mussels and eventually other species, an assessment of both exposure (tissue burdens and concentrations) and effects (measures of sub-lethal stress) could be used in risk management within the Gulf of Maine and Bay of Fundy ecosystem. This will also contribute to the broader goal of maintaining and enhancing coastal ecosystem health.

Seasonal Changes in Contaminant Levels in Nearctic Shorebirds: Effects of Migration

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Abstract

We measured concentrations of contaminants in tissues of four Nearctic shorebird species, collected during five stages of their annual cycle: breeding (Cape Churchill MB), fall migration (Bay of Fundy NB), early and late overwintering in Venezuela, and spring migration (Delaware Bay NJ). Mean levels were below those associated with toxic effects. Semipalmated Plovers tended to be most contaminated followed by Lesser Yellowlegs, with Short-billed Dowitchers and Semipalmated Sandpipers being the least contaminated. Significant interspecific differences were found only for DDT compounds, total PCBs and renal cadmium. Significant effects of the stage of migration were found for DDT compounds, dieldrin, mirex, HCH, chlordane compounds, total PCBs and liver mercury. The highest levels of most compounds were found at Churchill MB, whereas dieldrin and DDD+DDT were highest at Delaware Bay NJ. Concentrations of chlordane compounds and total PCBs were highest on arrival in Venezuela in the autumn, but these compounds, like other organochlorines, declined while overwintering in Latin America. Seasonal patterns suggest exposure to North American sources during migration.

The Bay of Fundy Ecosystem Partnership (BoFEP) and the Fundy Marine Ecosystem Science Project (FMESP)

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Abstract

The Bay of Fundy is a dynamic, productive and diverse coastal ecosystem with an abundance of renewable resources. However, there are disturbing signs that all is not well with the Bay. Many marine species and habitats are at risk and the sustainability of some living resources may be compromised. Scientists are questioning the adequacy of their understanding of the Bay's oceanographic and ecological processes underlying a number of pressing environmental issues. There is a growing recognition that ensuring a healthy ecosystem in the Bay requires the participation and commitment of a wide range of stakeholders including scientists, resource managers, industrialists, resource users and residents of communities all around the Bay. Forging bonds between all interested stakeholders was the impetus for the formation of the Bay of Fundy Ecosystem Partnership. BoFEP is a "Virtual Institute", with no bricks and mortar, open to all interested citizens and groups who share its vision. Its principal objective is to foster wise conservation and management of the Bay's resources and habitats. It promotes this by disseminating information, monitoring the state of the ecosystem and encouraging communication and co-operation among its members and others. The Fundy Marine Ecosystem Science Project is a distinct but integral partner in BoFEP. FMESP is largely comprised of scientists and environmental managers and is chiefly dedicated to fostering information exchange and co-operative research among scientists of all research disciplines working in the Bay. It disseminates scientific information among all BoFEP partners by means of periodic publications and workshops.

The Quoddy EMAN Site: Coastal and Atmospheric Monitoring and Assessment

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Abstract

The Quoddy EMAN Site (QES) is one of five Ecological Monitoring and Assessment (EMAN) sites in the Atlantic Ecozone. It is located at the Huntsman Marine Science Centre in St. Andrews NB. It focuses on coastal and atmospheric issues and their land, freshwater and sea linkages in Passamaquoddy Bay and adjacent coastal areas. An interdisciplinary Management Committee encourages cooperation among agencies involved in the use and management of natural resources and the environment, and collaboration in research and monitoring projects among local scientists and with the other EMAN sites. The overall research objective is the understanding of environmental stressors and their cumulative effects on cold temperate marine and coastal ecosystems. Current activities include i) the development and use of marine biodiversity monitoring protocols, ii) assessment of biodiversity with a focus on the Bay of Fundy, iii) monitoring of long range/transboundary atmospheric pollution, especially mercury, iv) quantifying presence, loadings and effects of toxic substances in fog and v) studying seabird ecology of the outer Bay of Fundy. The Quoddy Site also runs workshops and produces assessment reports to exchange data and information amongst scientists, managers and public stakeholders.

Community-Based Management Reveals the Need for Local Ecosystem Research: A Bay of Fundy Case Study

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Abstract

A group of independent fishermen conducting community-based management (CBM) determined the necessity of local ecosystem research to the management of their fisheries. The Southwest New Brunswick Fixed Gear Groundfish Board, a group of fisher representatives, work together to design, implement, and enforce fisheries management rules in their local communities. In the process of decision-making, the board members discovered that they needed detailed ecological information in order to make sensible conservation-minded rules. The desired information included predator-prey relationships, migration patterns, and local stock structure. Much of this information either had never been documented or was in scientific debate. Consequently, the group began conducting their own local-level research utilising both TEK (traditional ecological knowledge) and joint fisher-scientist research. The subject of the first project was a local run of very large cod. Initially, open-ended interviews were conducted with active and retired fishers to examine the possibility that this fish run is distinct from the larger regional stock. In the course of the qualitative phase of this research a variety of information emerged including the cod's relationship to feed species, migration patterns, the effects of pollution and oceanographic factors. The depth and breadth of the information gathered is of great interest and has led to several other research projects. This qualitative data served as a basis for scientific data collection, jointly conducted between the DFO and the local fishers. However, the interviews provided more than a focus for scientific study as the documented TEK gives valuable insight into the functioning of the larger ecosystem.

Patterns of Flow and Suspended Sediment Concentration in a Macrotidal Saltmarsh Tidal Creek, Bay of Fundy, Canada

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Abstract

Measurements of velocity and suspended sediment concentration were carried out in a saltmarsh tidal creek network in the Cumberland Basin, Bay of Fundy, Canada. The study area was located on the north-west shore of the basin in part of an undyked marsh that is about 200 m wide with a simple reticulate creek network. The area is macrotidal with spring tides greater than 12 m and suspended sediment concentrations in the basin characteristically range from 150-300 $mg \cdot l^{-1}$. The purpose of the study was to determine vertical and along channel variations in these two parameters over individual tidal cycles and to use these data to assess the role of the tidal creeks in the import and export of water and sediment from the marsh surface. Measurements using a vertical array of co-located electromagnetic current meters and OBS probes for measuring suspended sediment concentration were carried out over 4 spring tides at a cross-section in the lower part of Middle Creek. Six sets of measurements were carried out at four locations along the length of the creek, a distance of about 200 m, over 6 tides ranging from spring to neap. Maximum mean velocities measured over sampling times of eight minutes did not exceed 0.1 $m \cdot sec^{-1}$ in Middle Creek and 0.15 $m \cdot sec^{-1}$ in Main Creek. Transient high velocities associated with the overbank flows were weakly developed as a result of the absence of significant levees or embankments on the marsh surface. Suspended sediment concentrations in the creek generally decreased steadily over the period of inundation. Flow across the marsh margin occurred simultaneously with the achievement of bankfull conditions and the creeks themselves appear to play a relatively minor role in the movement of water and sediment onto and out of the marsh. Despite the fact that the marsh surface is still low in the tidal frame and active sedimentation is still occurring, the low flow velocities and observations in the field suggest that the tidal creek network is unable to flush itself and that it is contracting.

Health of the Oceans Monitoring

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Information

During the Bay of Fundy workshop, I briefly described a discussion paper on Canadian ocean monitoring requirements relevant to health of the oceans (HOTO) issues, because I thought it would be of potential interest to a number of the participants. This discussion paper has been produced as part of the work of a DFO *ad hoc* working group tasked with examining Canadian ocean monitoring requirements. The mandate for this group is to identify requirements and to develop a detailed implementation plan for ocean monitoring to meet Canadian needs first, but also to satisfy Canada's commitments to the Global Ocean Observing System (GOOS) and other international commitments. Over time, it is intended that this discussion paper will evolve into a set of detailed specifications for a HOTO monitoring program. This preliminary paper has been distributed to solicit input on potential threats to HOTO, the priorities we have assigned to threats, identify suitable means for monitoring high priority threats, and to foster discussion on how the details of a monitoring program might be specified.

Anyone who is interested in this paper, or who wishes to comment on it, is welcome to a copy. Please contact Peter Strain at the following email address: strainp@mar.dfo-mpo.gc.ca

The Bay of Fundy From the Perspective of Underwater Naturalists

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Department of Fisheries and Oceans
St. Andrews NB E0G2X0

Abstract

This photographic display is a work in progress; there will be further contributions by six more UW Naturalists. When finalized, the display will tour communities, museums, art galleries and educational facilities around the Bay of Fundy. This preliminary viewing is meant to provide an opportunity for organizations to contact us if interested in hosting the display for a period of time.

For underwater naturalists, each dive offers the thrill of exploring new communities, identifying the diversity of marine species, and the challenge of capturing these images on film. For those that do not dive, we hope that this display will serve as a dry and warm underwater nature trail. Beyond simply exhibiting the obvious beauty found below, we hope to convey a strong awareness of the fragility of this ecosystem and of how poorly it is understood. This display provides a snapshot, through the lenses of UW photographers, of the underwater world of the Bay of Fundy.

This project is a joint venture of The Department of Fisheries and Oceans, Oceans Sector and Sundbury Shores Arts and Nature Centre. For further information on this display, please contact the Curators: Mike Strong (506) 529-5939 strongm@mar.dfo-mpo.gc.ca or Tom Moffatt (506) 529-3386 sunshore@nbnet.nb.ca. For further information on Marine Protected Areas in the Bay of Fundy, please contact: Maria-Ines Buzeta (506) 529-8854 buzetam@mar.dfo-mpo.gc.ca

Historical Patterns of Mercury Loading in the Bay of Fundy Region

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Abstract

We have compiled an inventory of historical mercury emissions in Maritime Canada that extends from 1800-1995. Preliminary analysis of marsh sediment cores taken from the New Brunswick coastline of the Bay of Fundy provides an indication of historical emissions in this region. Deposition of mercury recorded in dated sediment cores provides useful information on 1) "natural" levels of mercury in the Fundy region, and 2) the relative significance of local and long range sources of mercury to the Fundy region. We will present our preliminary results as well as future research plans.

Historical Patterns of Mercury Loading in the Bay of Fundy Region: From the Past to the Future

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HISTORICAL EMISSIONS

Throughout history mercury has been used in many industrial and consumer applications. Mercury is released to the environment during manufacture, application and disposal of mercury containing goods. In addition, other human activities such as fossil fuel combustion and smelting of base metal ores result in inadvertent emissions of mercury.

In a country such as Canada there is great variability between regions. Thus it is especially important to compile local and regional scale emissions inventories to assemble more accurate information on mercury releases. Historical information on mercury releases indicates how various sources have changed in magnitude and relative importance over time and helps to illustrate the relative success of various management strategies aimed at reducing the amount of mercury in the environment.

Source	Time Period of Significance	Max. Releases to Atmosphere (kg/yr)	Max. Total Releases (kg/yr)	Approximate Year Max. reached
Petroleum Combustion	[illegible]	[illegible]	[illegible]	[illegible]
Coal Combustion	[illegible]	[illegible]	[illegible]	[illegible]
Wood Combustion	[illegible]	[illegible]	[illegible]	[illegible]
Gold Amalgamation	[illegible]	[illegible]	[illegible]	[illegible]
Metal Smelting	[illegible]	[illegible]	[illegible]	[illegible]
Chlor-alkali Facilities	[illegible]	[illegible]	[illegible]	[illegible]
Agricultural Compounds	[illegible]	[illegible]	[illegible]	[illegible]
Pulp & Paper Slimicides	[illegible]	[illegible]	[illegible]	[illegible]
Pharmaceutical	[illegible]	[illegible]	[illegible]	[illegible]
Dental Uses	[illegible]	[illegible]	[illegible]	[illegible]
Paint Applications	[illegible]	[illegible]	[illegible]	[illegible]
Waste Incineration	[illegible]	[illegible]	[illegible]	[illegible]
Electrical Goods	[illegible]	[illegible]	[illegible]	[illegible]
Hospital Uses	[illegible]	[illegible]	[illegible]	[illegible]

Table 1. Major sources of mercury in Maritime Canada and their relative importance over time.

Total releases of mercury as effluents, solid waste, and atmospheric emissions in Maritime Canada have been estimated using point source data where available, and emission factors which describe an amount of mercury released per unit of activity or good consumed.

Major sources of mercury in Maritime Canada have been divided into three major categories, illustrated in Figure 3. These are:

1) Miscellaneous sources which include solid waste incineration, paint application, dental uses, hospital uses, electrical goods and pharmaceutical compounds.
2) Industrial sources which includes pulp and paper slimicide use, the chlor-alkali industry, agricultural compound uses, gold mining, and base metal smelting.
3) Emissions resulting from energy generation which includes all fuel combustion of wood, coal and refined petroleum products.

Figure 1. Mercury emissions in Maritime Canada rose steadily until the 1970's and have declined in more recent years.

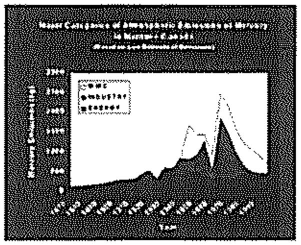


Figure 2. Inadvertent mercury emissions from fuel combustion in Maritime Canada have been significant sources of contamination throughout history.

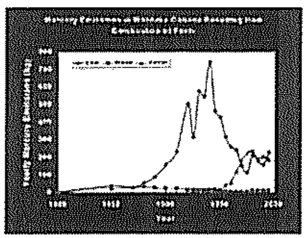
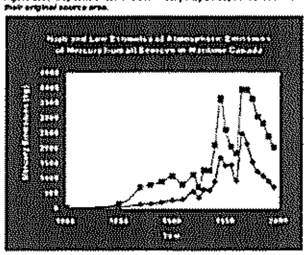


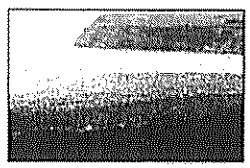
Figure 3. Atmospheric emissions of mercury may be deposited far from their original source area.



INTRODUCTION

Mercury is a highly volatile element and has an atmospheric lifetime of several days to many months. These properties make it a pollutant of not only local but global significance. Unlike many other naturally occurring elements the "toxic threshold" of mercury lies very close to levels that occur naturally in the environment. Thus, small amounts of anthropogenic mercury pollution may have a major impact on the natural biogeochemical cycling of this element and observed mercury levels in the aquatic food chain.

We have compiled an inventory of mercury emissions in Maritime Canada that extends from 1800-1995. Preliminary analyses of marsh sediment cores taken from salt marshes along the New Brunswick coast of the Bay of Fundy provides an indication of historical loading patterns in this region. A comparison of historical mercury emissions in this region with loading patterns recorded in dated sediment cores can provide useful information on 1) "natural" levels of mercury in the Fundy region, and 2) the relative significance of local and long range pollutant sources in this area.



SEDIMENT MERCURY RECORDS

Salt-marsh cores can provide useful records of atmospherically-derived contaminants. Salt marsh cores are less susceptible to biological disturbance than some other sediments, their pH is regulated by their saline condition and the dense roots of surface vegetation protect roots from post-depositional disturbance.

A comparison of documented local sources of mercury release with reliable sediment records of loading provides information on the natural levels of mercury in the environment and the significance of various contaminant sources. However, before this can be done with confidence, the salt marsh data must be established as a reliable historical record.

Two marsh cores were extruded from Dipper Harbour salt marsh, first in 1994 (Core A) and the second in 1996 (Core B). An additional core was extruded from Bocabec marsh. Cores were sub-sectioned at 0.5-1.0 cm depths and freeze-dried prior to analysis. Dipper Harbour cores were dated using pollen, Pb-210 and Cs-137. All sub-samples were analyzed for metals. Iron (Fe) and Manganese (Mn) provide an indication of the redox profile within the sediment core. This is important for determining the extent of diagenetic processes that may affect the post-depositional mobility of mercury within the sediment core, disturbing the historical record of pollution.

Figure 4. The Dipper Harbour marsh core shows an overall increase in mercury deposition since pre-industrial times.

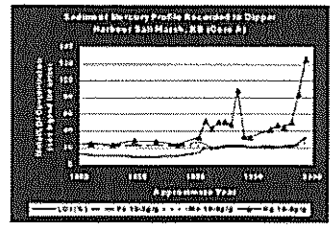


Figure 5. This core illustrates the importance of analytical precision for mercury analysis. In this case, 0.5 cm sub-samples from Dipper Harbour salt marsh Core B were analyzed in separate batches, and the variability between 0.5 cm sub-sections can largely be attributed to analytical variability.

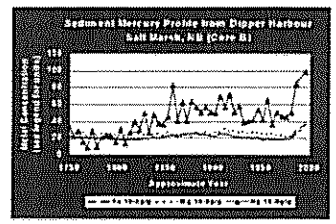
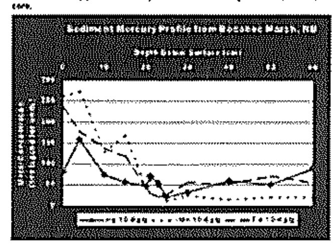


Figure 6. In the Bocabec marsh core the redox profile is indicated by the Fe and Mn concentrations. It is apparent from these profiles that diagenetic processes strongly influence the pattern of historical Hg accumulation in this core.



PRELIMINARY SAMPLING

Preliminary sampling of three sediment cores along the New Brunswick coast indicates that in overall mercury deposition in this area has increased since pre-industrial times, which is in accordance with other sediment core studies in the region (e.g. Lucotte et al. 1997). It is apparent that the diagenetic processes, variability in organic matter accumulation, and measurement precision are all issues that need to be addressed in future sampling methodologies. Such factors can all alter the historical record of mercury accumulation, making it difficult to conclude with confidence that observed peaks are the result of local or long-range pollution signals. In addition, tidal contributions and exports of mercury from the marsh ecosystem need to be considered. Constructing a simple mass-balance for mercury accumulation with the marsh sediment would indicate the relative significance of these processes.

FUTURE RESEARCH

Future research will focus on the Passamaquoddy Bay region. Additional sampling will be used to determine the historical profile of mercury deposition in this region, accounting for variations in local sources, and dominant wind patterns. *In situ* measurements of sediment pH and redox potential will be compiled prior to additional core extrusion in order to minimize the effects of diagenetic processes seen in the preliminary samples. Historical data on atmospheric deposition rates will provide useful inputs into the mass balance mercury model being developed for Passamaquoddy Bay. Increases in mercury above the "natural" level recorded during pre-industrial times in sediment cores will provide an estimate of anthropogenic mercury contamination in the Fundy region. The patterns of anthropogenic contamination will be compared to local and regional emissions inventories in order to assess the significance of these contaminant sources. The current trajectory of atmospheric loading in the Passamaquoddy Bay region will be provided by the marsh sediment profiles. This information can also be input into the mass-balance mercury cycling model for Passamaquoddy Bay in order to assess how future increases in loading may affect tissue concentrations of mercury in the food-web.

ACKNOWLEDGEMENTS

The Impact of Mercury Contamination on a Coastal Ecosystem: Development of a Multimedia Mercury Cycling Model for Passamaquoddy Bay, NB

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Abstract

Mercury is a known neurotoxin and can cause developmental and reproductive problems in exposed organisms. The accumulation of this contaminant in the tissues of aquatic organisms poses a serious threat to the long-term health of ecosystems. In the Bay of Fundy region, mercury contamination is a long-standing regulatory concern. Mercury levels in loons and seabirds in this area are among the highest in North America, while high levels of contamination have also been recorded in the tissues of porpoises, seals, fish and lobster. As managers, we attempt to control the risks associated with elevated levels of mercury in the environment. The principle objectives of this study are i) to develop a tool for managers concerned about mercury contamination issues, with a particular emphasis on coastal ecosystems ii) to clarify current and historical loading of mercury to the Fundy region from both local and long range sources and iii) to elucidate the link between anthropogenic emissions of mercury in the Maritime environment and contaminant concentrations in benthic organisms, fish and seabirds. A mass balance multimedia model is developed to forecast the mercury concentrations in biota resulting from a given "dose" or amount of contaminant input into the ecosystem. The model includes three main sub-components: 1. A chemical speciation model, 2. an environmental fate model and 3. a food-web bioaccumulation model. Physical and hydrological data from Passamaquoddy Bay are used to parameterize the model. The model will be tested using observed data collected in the region and applied to a number of relevant management questions within the region.

The Impact of Mercury Contamination on a Coastal Ecosystem:
Development of a Multimedia Mercury Cycling Model for Passamaquoddy Bay, NB

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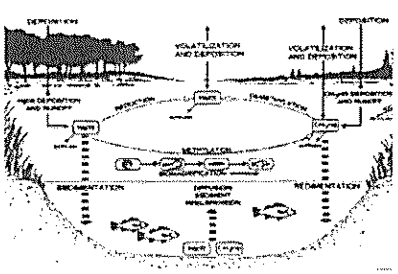
INTRODUCTION

Figure 1. Location of Passamaquoddy Bay in the Bay of Fundy

Coastal areas are resource rich and provide habitat for a diverse range of plant and animal species. These areas also tend to be heavily populated and are thus highly susceptible to anthropogenic change. Atmospherically derived contaminants such as mercury are brought into the region with prevailing winds from the more highly industrialized Northeast States and Central Canada.

Mercury is a longstanding regulatory concern in the Bay of Fundy. Gaskin et al. (1973,1979), first noted high levels of contamination in harbour porpoises in the early 1970's. Dietary intake advisories for the consumption of freshwater and sportfish have been issued throughout the Northeast States and Eastern Canada (NESCAUM et al. 1998). High levels of mercury contamination have also been observed in loons and seabirds from the region (Elliott et al. 1992, Evers et al. 1998) and are thought to be affecting the reproductive success of affected species (Burgess 1998). The majority of research in the field of mercury contamination has focused on freshwater regions. However it is also important to consider the effects of mercury contamination on coastal and marine ecosystems.

Figure 2. An Overview of the Aquatic Mercury Cycle



OBJECTIVES

The principle objectives of this study are:

1) To assess the risks to ecosystem health posed by local and long-range sources of mercury contamination in Passamaquoddy Bay, NB.

2) To elucidate the link between anthropogenic emissions of mercury to the Maritime environment and contaminant concentrations in benthic organisms, fish and seabirds from Passamaquoddy Bay.

3) To develop a mass balance modelling framework that can be used to link mercury inputs to mercury concentrations in marine biota in coastal ecosystems.

MODEL DEVELOPMENT

Multimedia environmental models are useful tools for managers interested in the link between emissions of chemical to the environment and their ultimate effect on organisms in the food web. A mechanistic mercury cycling model is used to characterize the cycling of mercury in Passamaquoddy Bay. This model consists of three major sub-components 1) a chemical speciation sub-model, 2) an environmental fate sub-model, and 3) a food web bioaccumulation sub-model. A complementary empirical model is also being developed from observed measurements of mercury concentrations and fluxes in the water, sediment and biota of Passamaquoddy Bay. The empirical model will be used to test the forecasts produced by the mechanistic model.

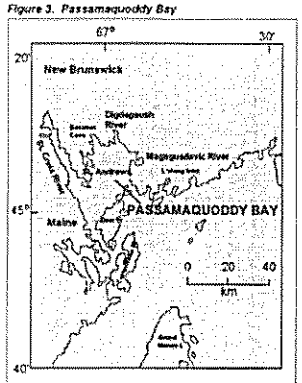
PHYSICAL AND HYDROLOGICAL PARAMETERS

Physical Characteristics of Passamaquoddy Bay
- Area = 84.8 km^2
- Perimeter = 73.7 km
- Volume = 1733 x 10^6 m^3
- Maximum Depth = 47.7 m
- Flushing Time = 44.8 hr
- Tidal Range: = 6-8 m
- Tidal/Freshwater - Volume Ratio = 377.33

(From Gregory et al. 1993)

Physical and hydrological data from Passamaquoddy Bay are used to parameterize both the mechanistic and empirical models. These data have been collected by a number of agencies in Maritime Canada.

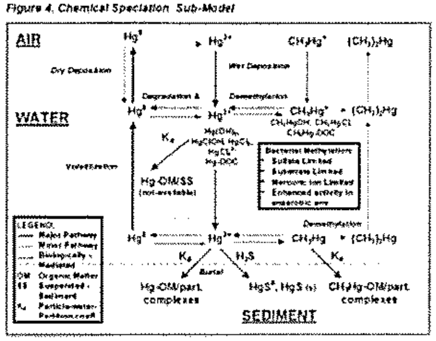
Figure 3. Passamaquoddy Bay



CHEMICAL SPECIATION

The mechanistic mercury cycling model includes a chemical speciation sub-model. This model is based on both thermodynamic and empirical data that describe the speciation of mercury in water and sediment. This sub-model is used to predict the "freely dissolved" or bioavailable concentrations of inorganic and organic mercury in Passamaquoddy Bay.

Figure 4. Chemical Speciation Sub-Model



EMPIRICAL DATA:

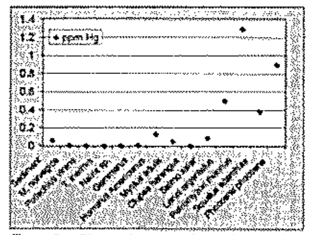


Figure 6. Observed mercury levels in organisms residing in Passamaquoddy Bay and surrounding Bay regions. (Data from Loring 1981, Braune 1987, Cdn. Health Inspection Agency, Musselwatch 1997)

In order to build an empirical model, data are needed that quantify the magnitudes and fluxes of mercury in water and sediments, as well as the concentrations of mercury in various trophic levels of the food-web. Examples of food-chain mercury concentration data are given in Figure 6. By comparing observed data to model forecasts we can establish the reliability of the proposed model.

ENVIRONMENTAL FATE

The environmental fate sub-model, is used to describe the flux of mercury between water and sediments. It includes processes such as sediment burial and chemical degradation, which affect the duration and concentrations of mercury to which organisms in the system are exposed. The processes depicted in Figure 5, will be measured directly for construction of the empirical model. In the mechanistic model, the environmental fate sub-model will be closely integrated with the chemical speciation sub-model.

Figure 5. Environmental Fate Sub-Model

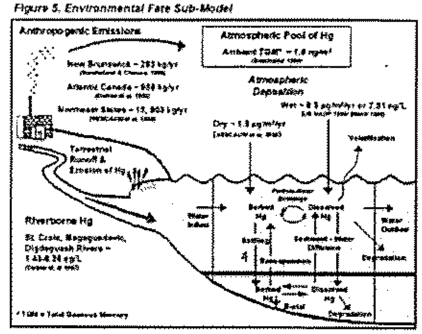


Figure 7. Mechanisms of chemical uptake and excretion represented in the fish bioaccumulation model.

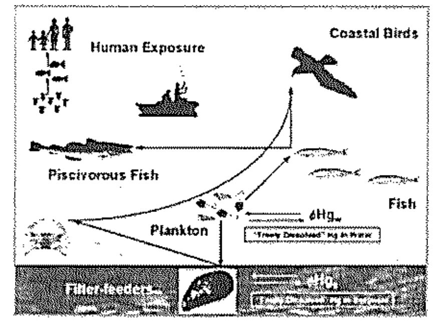


Figure 8. Food-Web Bioaccumulation Sub-Model

FOOD-WEB BIOACCUMULATION

This sub-model simulated mercury dynamics in food-webs. The food-web bioaccumulation model is based on biological and physical uptake and excretion parameters specific to the species of interest.
In Figure 7, k_1 = dietary uptake, k_1 = gill uptake, k_2 = gill elimination, k_E = fecal elimination, k_M = metabolic transformation. Dietary uptake is thought to be the major mechanism of mercury accumulation in organisms, while gill uptake, elimination and metabolic transformation are thought to be negligible in fish.

MODEL APPLICATION

Mercury is a highly volatile element with a propensity for long-range transport and deposition (e.g. Mason et al. 1994). As a result, one of the key questions in this field is the significance of local and long-range mercury sources. This information is critical for managers developing emissions reduction strategies and working to reduce the levels of mercury in biota and the ambient environment. The mercury cycling model helps elucidate the link between anthropogenic emissions of mercury and observed concentrations in the food chain. Thus, it can be applied to address a number of issues. These include whether 1) present levels of Hg in fish and filter-feeders can be linked to historical atmospheric deposition rates, and 2) future increases in atmospheric deposition will be sufficient to push mercury tissue levels above acceptable concentrations specified by management guidelines. The mercury cycling model will also be manipulated to look at the significance of other sources of mercury input in the Fundy ecosystem such as deposition of atmospheric mercury from fog.

REFERENCES

[illegible]

ACKNOWLEDGEMENTS

- Fundy Marine Ecosystem Science Project
- Bay of Fundy Ecosystem Science Project
- Environmental Conservation Branch, DOE Atlantic Region
- Mountain Equipment Coop
- NSERC

Where are all Those Harbour Seals?

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Abstract

Semi-monthly aerial and shipboard surveys of hauled-out harbour seals (*Phoca vitulina*) were conducted along the New Brunswick coast of the Bay of Fundy (excluding The Wolves archipelago and Grand Manan Islands) during the fall and early winter of 1998. The maximum number of seals observed (1032) and the rate of population decline over the survey period (6.7 per day) were essentially unchanged from similar surveys in 1984 and 1987. Harbour seal populations in Maine have been increasing by 8 % per year since 1983 so we had expected that the counts would be considerably higher. Anecdotal evidence suggests that direct harassment of the seals has occurred. The distribution of the seals has not changed in the last decade. It appears that harbour seals are neither attracted to, nor repelled from, areas containing aquaculture sites.

Corophium volutator - Understanding a Keystone Species in Mudflat Ecology

P.G.**Wells** [1], C.M.**Hawkins** [2], J.**Grant** [3], P.**Hicklin** [4] and V.**Partridge** [5]
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[2]Triton Environmental Consultants, Dartmouth NS
[3]Department of Oceanography, Dalhousie University, Halifax NS
[4] Canadian Wildlife Service, Environment Canada, Sackville NB
[5]Acadia Center for Estuarine Research, Acadia University, Wolfville NS

Abstract

The amphipod *Corophium volutator* inhabits the mudflats of the upper Bay of Fundy and plays an important role in their ecology. Researchers joined together in 1997 to form a *Corophium* Working Group, under the auspices of the Bay of Fundy Ecosystems Partnerships and its science component, the Fundy Marine Ecosystem Science Project. The objectives of the Group are: i) to meet periodically and exchange information on research projects and new findings, ii) to summarize and assess existing knowledge on *Corophium*, maintaining an active electronic bibliography and preparing appropriate papers and fact sheets, iii) to identify new key research questions and approaches, especially utilizing models and iv) to facilitate research opportunities and mechanisms for cooperative research, especially for young researchers. Current work of members falls into four categories: ecological modelling, interactive role, habitat factors and biological issues.

Activities are described and the linkages between them are illustrated, emphasizing the holistic nature of *Corophium* ecology and the role of *Corophium* as a keystone species. The working group encourages all interested persons to join and participate in the group. For information, please email fundy@fundy.acadiau.ca or peter.wells@ec.gc.ca.

Fundy Forum

Maxine **Westhead**
Bedford Institute of Oceanography, Dartmouth NS

Abstract

The Fundy Forum is an internet-based communications service open to all. The Fundy Forum encourages dialogue, information sharing, partnering opportunities and activities that benefit the health of the Bay of Fundy and its coastal communities.

This interactive web site and discussion listserver supports all those who wish to exchange information or discuss issues related to the health and sustainable use of the Bay of Fundy ecosystem. You are invited to use the Fundy Forum to connect with others interested in the Bay by: joining the discussion listserver, asking the questions about issues that concern you, sharing your previous experiences, lessons learned, techniques and more, looking for information on current activities, issues and research around the Bay. Benefits of participation include: easy access to a wide variety of perspectives and opinions, greater availability of information, expansion of your current information base, awareness of the Bay of Fundy coastal communities, keeping yourself 'up to date' on Fundy related issues and activities, an enhanced understanding of the state of the health of the Bay of Fundy, and cost-effectiveness by using the Fundy Forum as a 'messenger' *via* the discussion listserver and bulletin boards.

'Surf on in' and ride the tide to keep the Bay of Fundy waters and communities healthy! Visit the web site, join the discussion and get involved!

Intertidal Invertebrate Population Density and Diversity: Does Salmon Aquaculture Play a Role?

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Department of Biology, Mount Allison University, Sackville NB

Abstract

Due to its location on the Bay of Fundy, Passamaquoddy Bay is subject to some of the largest tidal ranges in the world. During low tide, vertical zonation can be easily observed in the rocky shore intertidal zone. Both physical and biological factors play a role in determining zonation and intertidal invertebrate population dynamics. However, external factors such as pollution may also play a role. One such factor, salmon aquaculture, is prevalent in Passamoquoddy Bay. While it is well known that aquaculture activities produce a large amount of organic and inorganic waste, no studies have investigated the effect of this waste on the near-shore environment. The purpose of this project was to determine whether the proximity to salmon cages plays a role in intertidal invertebrate population dynamics. I used stratified random sampling to compare intertidal invertebrate diversities and densities at sites near (=<500 m) and away (=>500 m) from salmon cages. Diversity was highest at away sites in core samples only, which may indicate that infaunal invertebrates are more sensitive to aquaculture activity than substrate invertebrates. Density of both core and substrate organisms showed little relationship to distance from salmon cages. Some inconsistent significant differences were found between location, site, and time and may be due to abiotic factors such as wave force, shore slope, rock type, or sediment composition.

Introduction

The importance of salmon aquaculture in the Bay of Fundy has grown dramatically since the late 1970s when the first experimental site was set up in Lord's Cove, Deer Island (Cook 1990; Milewski *et al.* 1997). Salmon aquaculture in New Brunswick is presently a $100 million industry. It is concentrated in Passamaquoddy Bay, southwestern New Brunswick around Deer Island and Campobello Island.

Growing salmon in sea cages has similarities to growing beef in feedlots (Buerkle 1993). Like feedlots, a cage operation produces large quantities of waste. Workers (both scientists and practitioners) in the aquaculture industry are divided on the impacts of salmon aquaculture waste. Critics argue that aquaculture is now one of the more important pollutants of the aquatic environment (Pillay 1992). However, many proponents of aquaculture claim that the aquatic environment can absorb aquaculture wastes with minimal effects (Goldburg and Triplett 1997). Moreover, they argue that salmon aquaculture is generally beneficial as it alleviates fishing pressure and increases the supply of fresh fish to the market (Baldwin 1990).

Intensive salmon cultivation generates large amounts of inorganic and organic waste. The primary sources of the inorganic contaminants are construction materials (Zitko 1984). Antioxidants, commonly used in plastics based on polypropylene, accumulate and are toxic to aquatic fauna.

Antistatic additives, flame retardants (organophosphates), fungicides and detergents are all used in cage operations and have been found to have adverse effects on aquatic fauna (Zitko1984).

The cage operations produce a large quantity of organic waste in the forms of excess feed and excretory products (Goldburg and Triplett 1997). The production of the major polluting agents (organic carbon, nitrogen, and phosphorous based compounds) can stimulate algal blooms. When these blooms die, their degradation can drastically lower oxygen levels in the water, increasing stress and/or death in fish and other organisms (Goldburg and Triplett 1997). In addition to oxygen depletion, toxic algal blooms may produce toxins which cause high mortality rates of organisms (Goldburg and Triplett 1997). Uneaten food creates a large amount of waste which may accumulate under cages or in areas some distance away, depending on local current patterns. The natural sediments are affected by increased oxygen consumption, generation of anaerobic layers, increased carbon, sulfide and nitrogen compounds, and the creation of volatile gases such as methane (Getchell 1988). Although little is known about currents in the Fundy Isles area, studies show that wastes will be transported inshore (Hunter and Associates, 1982 *In* Buerkle 1993).

Aquaculture research has placed its attention on improving existing technologies and developing new ones for increased production. Environmental studies are mainly limited to determining optimum conditions for growth required in the farms. The impact of farming on the external environment is rarely evaluated (Pillay 1992). More specifically, while it is understood that nutrification and pollution increases with the presence of salmon cages, the effect of salmon aquaculture on nearby rock shore organisms is unknown (Buerkle 1993). Intertidal marine invertebrates may be a good indicator of pollution due to their ease in identification and large density and diversity on rocky shores. The purpose of this study was to determine if proximity to salmon cages effects diversity and population densities of intertidal marine invertebrates. It was hypothesized that, due to increased sedimentation from aquaculture activity, invertebrate diversity and population densities will be highest at sites away from salmon cages than at sites near salmon cages.

Methods

Green's Point (45° 04'N; 66° 89'W) and Kilmarnock Head (45° 02'N; 67° 14'W), both in the Quoddy region, were the designated study locations. These locations were chosen due to their accessibility and proximity to salmon cages. Two sampling sites were established at each location; one was placed 'near' the salmon cages (≤500 m) and the other 'away' from the salmon cages (≥500 m). Permanent transect lines which were perpendicular and parallel to the shoreline were placed at all sites to enable random sampling. The size of the sample area varied at each site and differed depending on the physical characteristics of each shore. Green's Point Near is 50 m along-shore x 50 m across-shore, Green's Point Away is 27 m x 50 m, Kilmarnock Head Near is 55 m x 50 m, and Kilmarnock Head Away is 50 m x 50 m. Stratified random sampling was used to ensure an accurate representation of the sampling areas. 1 m^2 quadrats were used to sample invertebrate epifauna. Core samples (214 cm^3) were used to investigate invertebrate infauna.

Statistical Analysis

All invertebrates in each replicate were identified and counted (Wong 1999). The invertebrate epifauna were identified to species, while several invertebrate infauna were assigned numbers. These included three species of oligochaetes, two species of polychaetes, while nematodes were identified only to phylum. Epifaunal and infaunal species diversity was calculated for each sample using Simpson's diversity index (Lande 1996). Species diversity and population density of intertidal invertebrates were analysed using ANOVAs. There were 0 to 4 replicate quadrats for epifauna and 0 to 2 replicates for infauna from each stratum at each sampling date. Homogeneity of variances was tested using Cochran's C Test (Underwood 1997). When variances were not homogeneous, data were transformed by taking the square root or Log_{10} (datum + 0.01) (Underwood, 1997). For epifauna, a 3-way ANOVA with location, site, and sampling time as fixed factors was used. For infauna, a random block ANOVA with location and site as fixed factors and sampling time as the blocking factor was used. *Post hoc* comparisons were done using Tukey's Test.

Results

Fifty species were found over the entire sampling area. Of the nine phyla found, Mollusca and Arthropoda contained the majority of species (Table 1).

Diversity

Species diversity of invertebrate epifauna was significantly higher at Green's Point Near than all other sites ($F_{1,163}$=16.434, $p<0.001$; Figure 1a). Green's Point Away had the lowest diversity, while both Kilmarnock Head Near and Kilmarnock Head Away had intermediate values. At both locations, the diversity at the Near site was higher than that at the Away site.

Species diversity of invertebrate infauna was significantly higher at sites away from salmon cages than at sites near salmon cages ($F_{1,163}$=4.259, $p<0.05$; Figure 1b).

Density

Four patterns of densities are shown by invertebrate epifauna (Wong 1999), and are illustrated by the four examples in Figure 2. *Carcinus maenas* (Green Crab) displayed the first pattern: that of significant difference in density over time (Figure 2a). *C. maenas* had highest densities at both Away sites during sampling time 7 (October 10-12, 1998) ($F_{6,137}$=2.432, $p<0.05$). A second pattern, shown by the density of *Littorina littorea* (Common Periwinkle), was the significant difference between one site and all others (Figure 2b). The density of *L. littorea* at Kilmarnock Head Away was higher than all other sites ($F_{1,137}$=12.845, $p<0.001$). Northern rock barnacle *Balanus balanoides* densities showed a third pattern in which there was significant difference between Green's Point and Kilmarnock Head (Figure 1c). The density of *B. balanoides* was significantly higher at Kilmarnock Head than at Green's Point ($F_{1,137}$=14.774, $p<0.001$). The last pattern shown by invertebrate epifauna

Table 1 - Number of invertebrate epifauna and infauna species found in nine different phyla. n=220.

Phylum	Number of Species
Porifera	1
Cnidaria	4
Bryozoa	1
Mollusca	18
Echinodermata	3
Arthropoda	11
Annelida	7
Nematoda	1
Nemertea	3

Figure 1

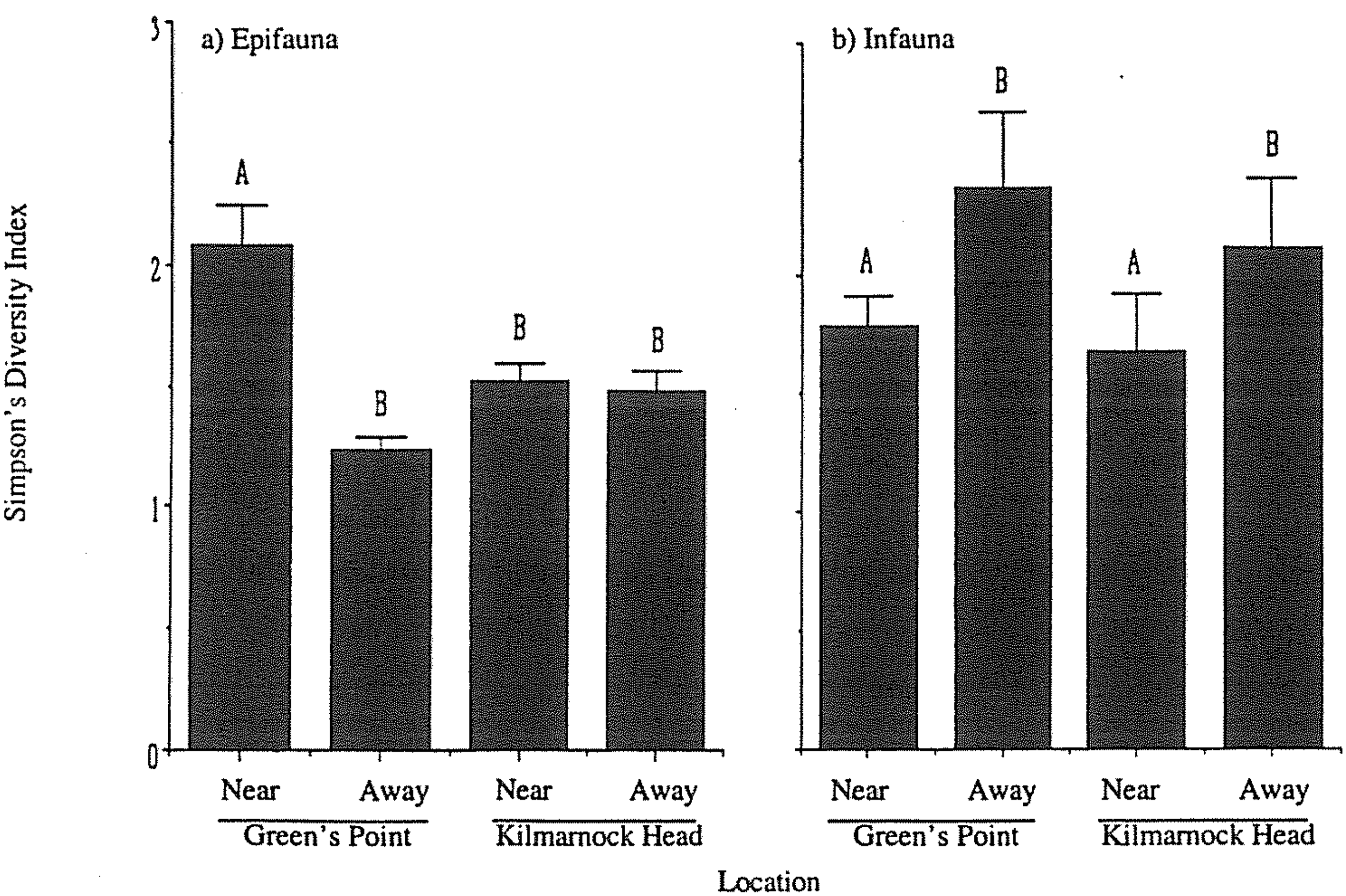


Figure 2

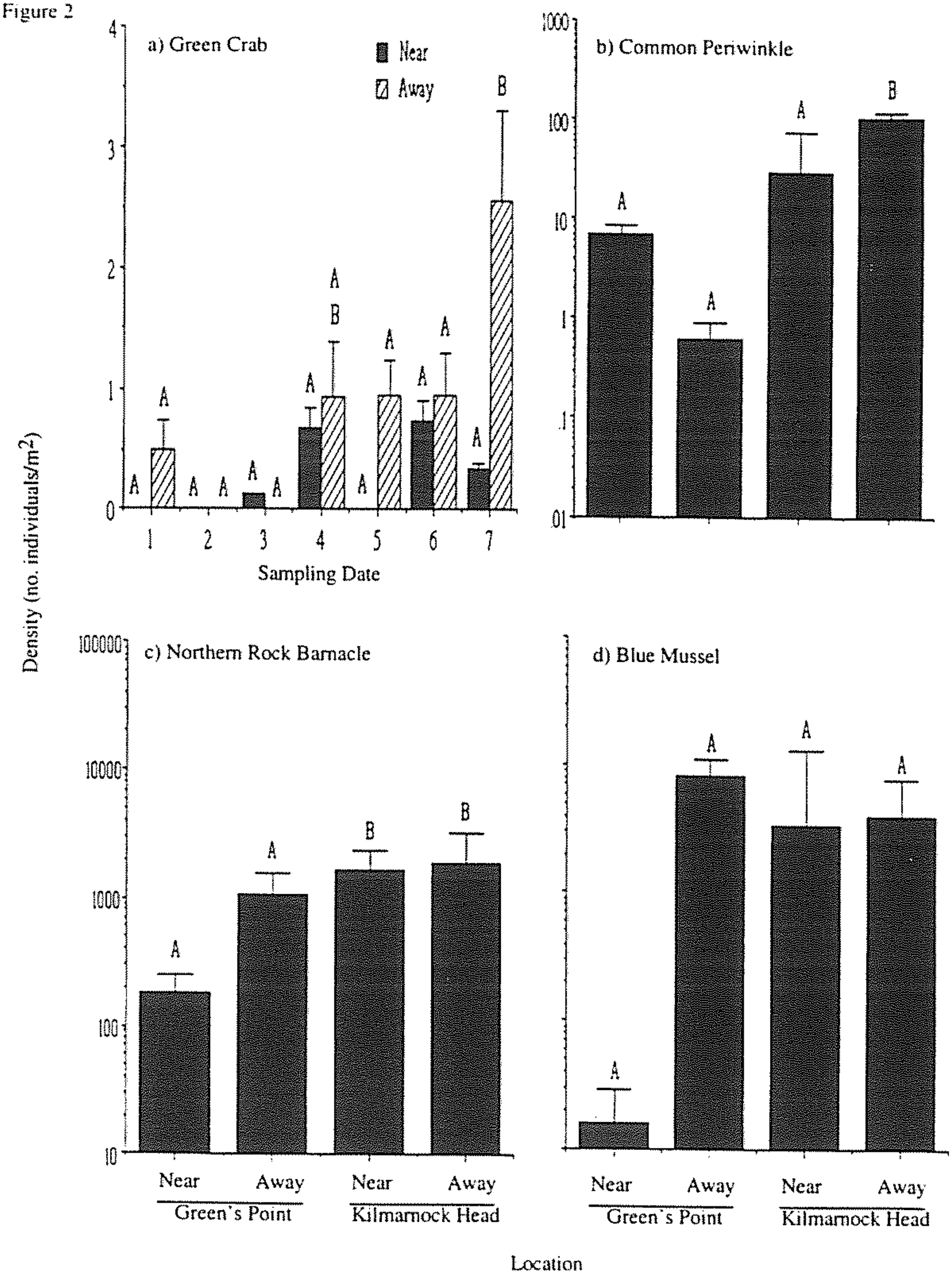
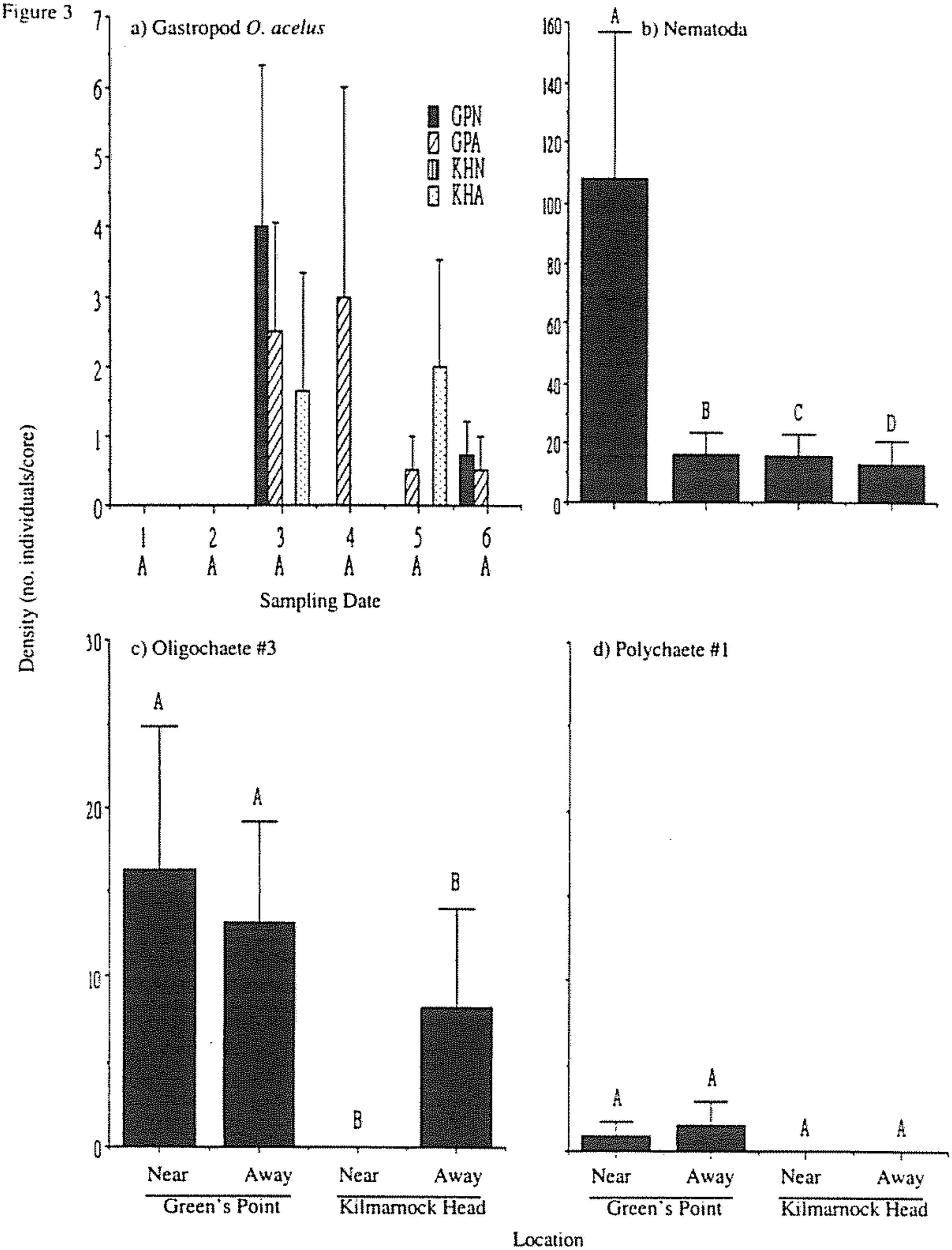

a) Green Crab
Near
Away
Sampling Date
b) Common Periwinkle
c) Northern Rock Barnacle
d) Blue Mussel
Density (no. individuals/m2)
Near
Away
Near
Away
Green's Point
Kilmarnock Head
Location

Figure 3


a) Gastropod *O. acelus*
b) Nematoda
c) Oligochaete #3
d) Polychaete #1
GPN
GPA
KHN
KHA
Density (no. individuals/core)
Sampling Date
Near
Away
Green's Point
Kilmarnock Head
Location

density was no significance in density with any factor (location, site or time). The Blue Mussel *Mytilus edulis* displayed this pattern ($p>0.40$; figure 2d).

The four patterns of population densities shown by invertebrate epifauna were also shown by invertebrate infauna. The gastropod *Onoba aculeus* showed the first pattern of significant difference in densities over time ($F_{5,43}=3.240$, $p<0.05$; Figure 3a). No pattern was displayed between the sites except one of possible patchy distribution. *Post hoc* comparisons could not detect where the significant difference lay. Nematoda displayed the second pattern of significance between sites. Densities at Green's Point Near were higher than at the other sites which displayed densities similar to each other ($F_{1,43}=10.433$, $p<0.01$; Figure 3b). The third pattern of significance between locations was shown by Oligochaete #3 (Figure 3c). Oligochaete #3 had higher densities at Green Point than at Kilmarnock Head ($F_{1,43}=5.0283$, $p<0.05$). The last pattern shown by invertebrate infauna was that of no significance in any factor (location, site or time). This is shown by Polychaete #1 ($p>0.20$; Figure 3d).

Discussion

Aquaculture activity can create a large amount of waste from excess feed and faeces as well as waste generated from construction materials and maintenance (Goldburg and Triplett 1997; Getchell 1998). However, the effect of this waste on the near shore environment is unknown. We examined the relationship between proximity to salmon cages and intertidal invertebrate diversity and population densities. While several statistical patterns were shown, only invertebrate infauna diversity supported our hypothesis that aquaculture activity would cause density and diversity of invertebrates to be highest at sites away from cages than at sites near cages.

Species diversity

Diversity of invertebrate epifauna was highest at Green's Point Near. This may have resulted due to the type of sediment found there. In addition to the large boulders and stones present, Green's Point Near sediment was primarily composed of fine mud. This sediment type, possibly a result of increased sedimentation from the nearby salmon cage, provides numerous additional microhabitats for invertebrates as it holds water for longer periods of time than rocky sediment (Steele 1983). This fine sediment also reflects the wave energy the site is exposed to. Because sediment suspended in the water column has been allowed to settle, this site can be considered sheltered (Steele 1983). This characteristic may also account for the largest number of species found at this site.

Diversity of invertebrate infauna supported the hypothesis that diversity would be highest at Away sites than at Near sites. This may indicate that invertebrate infauna are more sensitive to aquaculture activity than invertebrate epifauna, a possible direct result of increased sedimentation. Aquaculture waste accumulation can cause a reduction in redox potential, an increase in sedimentary carbon and nitrogen, generation of H_2S and CH_4, and a decrease in dissolved O_2 (Nunes and Parsons 1998). Aquaculture waste is known to cause an increase in sulphur bacteria and a reduction in macrofauna biomass directly beneath the fish cage (Nunes and Parsons 1998; Stewart 1997; Chang and Thonney

1992; Getchell 1988; Phillay 1992); however, the impact may also be significant in areas not in the immediate vicinity of the cage site (Nunes and Parsons 1998). This impact may be illustrated by the diversity indices of intertidal invertebrate infauna found in this study.

Population Density

While invertebrate epifauna displayed four patterns of significant differences in densities between locations, sites, and/or times, their densities were not significantly higher at sites farther away from salmon cages than sites near salmon cages. The first statistical pattern, in which significant differences in densities occurred over time, was displayed by *C. maenas*. The significance between sites and times, in which the Away site on October 10, 1998 was significantly different from all others, is most likely not due to aquaculture. Instead, this pattern may be explained by the life cycle of this organism. *C. maenas* normally copulate in July-September, eggs are carried in January-April, zoeae appear April-June, megalopae in June-July, and young crabs settle in July-August (Crothers 1966). Due to the small size of the juvenile instars (3-9 mm) (Gosner 1978), the highest population densities were found at the end of the season when the crabs were largest and easy to find.

L. littorea illustrated the second statistical pattern of significant differences in densities between one sampling site and all others. Large densities of *L. littorea* were found at each site possibly due to its ability in tolerating a large range of conditions (Fish 1972). The largest significant difference in densities at Kilmarnock Head Away site can be explained by the large algal cover which can support this herbivorous population.

The third statistical pattern, in which significant differences in densities were found between locations, was shown by *B. balanoides*. The large numbers of *B. balanoides* at each site occur most likely because this organism is highly adapted to an intertidal existence (Foster 1971). Through development of opercular plates which resist desiccation and the entry of freshwater, the barnacle is able to withstand harsh intertidal conditions (Foster 1971). The barnacle is also known to increase in abundance with an increase in wave exposure (Thomas *et al.* 1983). Significantly higher densities at Kilmarnock Head than Green's Point may indicate that Kilmarnock Head experiences a higher degree of wave exposure.

The last statistical pattern of no significant differences in densities between any factor is illustrated by *M. edulis*, an invertebrate known to dominate many rocky shore communities (Suchanek 1986). Their attachment mechanism, byssal threads, allows the mussel to exploit *M. edulis* and it is able to exist at high population densities at all four sites.

Due to a lack of research in intertidal invertebrate infauna, most of the statistical patterns shown cannot be explained. However, a few general comments can be made.

The presence of gastropods in the sediments is indicative of juveniles in the sediment. *O. aculeus* displays high abundances, indicating its preference for an infaunal habitat. This gastropod is commonly found in surface sediments in this region (Smith 1964).

High abundances of nematodes were found at all sites, with abundance being highest at Green's Point Near. Nematoda includes the most numerous and widespread organisms of all multicellular animals (Barnes 1987). For this reason, identification is difficult and these animals in this paper are classified only to phylum. Free-living marine nematodes are known to occur in large densities in a variety of habitats and especially favour shores high in organic muds (Pearse *et al.* 1989). The sediment type of clay/silt at Green's Point Near, possibly due to low water currents and increased sedimentation from aquaculture activity, provides an optimum habitat for this organism. Patchiness in distribution may account for significant difference in density between all sites.

Marine oligochaetes are shallow burrowers which live beneath intertidal rocks or in algal patches (Barnes 1987). The large number of oligochaete #3 found is most likely due to its ability to tolerate wide ranges of ecological conditions (Brinkhurst 1973). Highest abundances are displayed at Green's Point Near. This may have occurred due to the general preference oligochaetes have for rich organic sediments (Brinkhurst 1982).

Although polychaetes are known to be an indicator of pollution, the species found showed no preference for sites away from salmon cages. This may be due to the fact that burrowing and tubicolous polychaetes are generally not limited by available resources (Barnes 1987).

In conclusion, proximity to salmon cages affected only invertebrate infauna diversity. Possibly due to the direct impact of increased sedimentation on invertebrate infauna habitat, diversity was highest at sites located away from the salmon cages. Proximity to salmon cages did not play a role in invertebrate epifauna diversity or invertebrate epifauna and infauna population densities. This may have resulted for two reasons. First, aquaculture sites chosen may be young and/or classified as cages with low environment impact (as according to Chang and Thonney 1992). Large amounts of wastes may not yet have accumulated beneath the cage site or have been transported to near shore environments. Secondly, abiotic factors may play a more dominant role in invertebrate population dynamics. These factors, requiring further study, include wave exposure, current patterns, shore slope, rock type, and sediment composition.

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Figure Captions

Figure 1 - Mean species diversity (± SE) per quadrat or core sample for (a) invertebrate epifauna and (b) invertebrate infauna. Letters above the bars indicate the results of *post hoc* comparisons: bars sharing a common letters do not differ significantly. For invertebrate epifauna, n=38-47; for invertebrate infauna, n=10-19.

Figure 2 - Mean densities of invertebrate epifauna (± SE): (a) *Carcinus maenas* (Green Crab) showing significant difference in density between date and site, (b) *Littorina littorea* (Common Periwinkle), (c) *balanus balanoides* (Northern rock barnacle) and (d) *Mytilus edulis* (Blue Mussel). For (a), the sampling dates are: 1=June 3,4/98, 2=June 18,19/98, 3=July 3,4/98, 4=July 18,19,20/98, 5=July31/98, August 1,2/98, 6=August 18,19,20/98, 7=October 10,11,12/98. Letters above the bars indicate the results of *post hoc* comparisons: bars sharing a common letter do not differ significantly. For (a) n=4-15; (b) n=38-47; (c) n=38-47; (d) n=38-47.

Figure 3 - Mean densities of invertebrate infauna (± SE): (a) *Onoba acelus* showing significance between location, site and time, (b) Nematoda, (c) Oligochaete #3, and (d) Polychaete #1. Core

volume=214 cm^3. Sampling dates in (a) are as in Figure 2 (a). GPN=Green's Point Near, GPA=Green's Point Away, KHN=Kilmarnock Head Near, KHA=Kilmarnock Head Away. Letters above or below the bars indicate the results of *post hoc* comparisons: bars sharing a common letter do not differ significantly. For (a) n=0-2; (b) n=10-19; (c) n=10-19; (d) n=10-19.

Panel Discussion

Chair: Peter Hicklin, CWS

Panel Discussion

Understanding Change in the Bay of Fundy

Chair: Peter Hicklin, Canadian Wildlife Service

Panelists

Peter Hicklin, Canadian Wildlife Service, Sackville
Graham Daborn, Acadia University
John Kearney, St. Francis Xavier University
Rodney Bradford, Department of Fisheries and Oceans

The panelists chosen for this discussion group brought expertise which represented an array of biological components of the Bay of Fundy which underwent various levels of change in recent years. John Kearney has long been involved in the fishery in the Bay of Fundy and represented the interests of the fishers but also, as a former fisher and presently a social anthropologist at a small maritime university, understands the many changes which have taken place in the fishery, and associated communities, over the past few years. Rodney Bradford focused specifically on known changes in fish populations and Peter Hicklin, speaking on behalf of Tony Diamond who was unable to attend, discussed changes in bird populations. Graham Daborn outlined oceanographic changes (i.e. "everything else") in the Bay of Fundy which, in one way or another, could have affected many of the changes described by the other participants above. Each panelist focused on changes noted within his area of special interest in the Bay of Fundy with the objective of initiating further discussion from the audience.

Peter Hicklin first described the most significant change in bird abundances in the Bay of Fundy as being the complete disappearance of two species of phalaropes (marine shorebirds), during their fall migration, which once numbered between one and two million birds. In 1982, Mercier and Gaskin (1985) estimated that over 1 million Red-necked Phalaropes *Phalaropus lobatus* staged in the Quoddy region in Eastport and Lubec on the coast of Maine and Deer island and Campobello Island in New Brunswick during the birds' southward migration from mid-July to mid-September. And, at the same time of year but on the other side of the bay in Nova Scotia, approximately 20,000 Red Phalaropes *Phalaropus fulicarius* concentrated near Brier Island. But starting in 1986 and ending around 1990, both species disappeared from that portion of the Bay of Fundy in late summer and no explanation has been available to explain why both species have so suddenly disappeared from the mouth of the Bay of Fundy at the time of their post-breeding migration.

The distribution of other species of migrant nearctic shorebirds underwent some changes in their distributions and abundances in the Bay of Fundy during their southward migration and the reasons for this remain unclear. In the late 1980s, bait harvesters came to the bay to harvest polychaetes from the Bay's mudflats during low tide, causing considerable disturbance on some mudflats where birds foraged. Harvesting of the polychaetes reduced their densities and caused considerable disturbance to foraging sandpipers. At about the same time, Peregrine Falcons *Falco peregrinus*, an endangered species in Canada and one which favours shorebirds as a main prey, was reintroduced to nesting sites in Chignecto Bay. They've bred there successfully ever since. These falcons' activities in Chignecto Bay caused considerable disturbance to the birds. Consequently, since 1976 when the first aerial surveys of shorebirds in the Bay of Fundy were conducted, Semipalmated Sandpipers *Calidris pusilla* are now significantly more abundant in Minas Basin than in Chignecto Bay, opposite of what was described 20 years previously.

Other changes in the avifauna in the Bay of Fundy include the arrival of a new breeding species in the bay: the Black-legged Kittiwake *Rissa tridactyla* which started as a small colony (15 birds) in 1980 on South Wolf Island in The Wolves archipelago in Passamaquoddy Bay and presently numbers >100 pairs. Furthermore, in 1998, another small colony (4-5 pairs) of Black-legged Kittiwakes got established on Whitehorse Island (off Campobello Island). A new colony of Razorbills *Alca torda* also started breeding on South Wolf Island in 1995. And the breeding numbers of Razorbills on Machias Seal Island (south of Grand Manan) increased almost twofold since 1994.

Around the Bay of Fundy, the numbers of breeding Herring Gulls *Larus argentatus* over the last 20 years declined by 50% while the numbers of Great Black-backed Gulls *L. marinus* increased by about 150% along the coast of New Brunswick between Saint John and Grand Manan.

With regards to other species of seabirds, a substantial increase in the numbers of Common Terns *Sterna hirundo* breeding on Machias Seal Island has occurred since the early 1990s. And similarly, the numbers of breeding Common Eider *Somateria mollissima* increased since 1995 from 40 pairs to > 100 pairs.

Over a longer time scale, 17th century accounts by explorers show that Gannets *Morus bassanus*, Puffins *Fratercula arctica* and Terns *Sterna* spp. used to nest on The Wolves archipelago. None of those species now breed within 50 km (Puffins and Terns) or several hundred km (Gannets) of The Wolves archipelago today.

In the fishery, John Kearney indicated that the most striking changes to the fishery have been that caused by deregulation of the fishery and the consequent privatization of the resource. The transfer of quota has proven not to help conservation. One major consequence of change has been the de-population of many coastal communities which once depended on the fishery. With cutbacks in the Department of Fisheries and Oceans, science now has less influence in the management of the fishery. Management boards have been created which maximize the benefits to the community rather than individuals. These management boards have come together to adopt an "ecosystem approach" to speak for industry and the bay. Although management is now community-based, these same communities need scientists to work with them. Management of the fishery requires a strong scientific oversight function in the interest of all Canadians. Hence, fisheries management now needs function not only with respect to natural sciences but also the social sciences.

With respect to fish populations, Rodney Bradford began by noting that no one person can fully appreciate the 'pulse' of all the changes which have taken place. Where we perceive a change in the population of fish, we must eliminate the direct human element. This must be looked at first and once it can be eliminated as a significant factor, focus on the ecosystem. There are now fewer personnel at the Department of Fisheries and Oceans (DFO) and, consequently, fish species of lesser economic value are poorly studied and changes in fish distributions are poorly understood. The ocean is a complex ecosystem and more scientists are required to better understand it and to identify the gaps in our knowledge.

Graham Daborn pointed out that oceanographic changes are only noted "from a distance": indicators such as fish and birds and changes in sediment distributions and concentrations all indicate that some broader changes are taking place. But, as indicated by Bradford, we must separate the human and natural components which are involved in these changes. We must consider long-term cycles, like the 18-year tidal cycle in the Bay of Fundy, which can play a major role in some of the changes we observe in the bay over time.

There are various natural changes taking place in the bay like sedimentary changes which appear to be due primarily to anthropogenic influences such as barriers in tidal rivers. We must not forget the potential cumulative changes that can take place in the bay as a result of numerous small changes over time. And the effect of these cumulative changes cannot be assessed at this time. The potential impacts of small cumulative changes in the Bay of Fundy have not been addressed before. Do we have information and long-term data to use to make predictions? In the formal scientific sense, no such useful data is available. Furthermore, we face major difficulties in tackling these problems in light of the decline in scientific personnel in order to undertake the necessary research that needs to be done to fill these gaps.

Because of the biological connections between the Bay of Fundy and other parts of the world (migratory birds and fish for example) we have an international responsibility to better understand the changes that are going on in the bay. There are now examples in Atlantic Canada, such as the ACAP program in place in many parts of Atlantic Canada, which can show how governments, universities and communities can work closely together to understand changes in rivers and coastal areas and communities for example, and act upon them.

What needs to be done at this time is for members of this group to put together a list of all known and recognized changes going on in the bay and "mine" all the data that is available on these subjects. Following this effort, the gaps that need to be filled could be identified and short and long-term research needs listed and prioritized so that funding needs can be clearly identified.

Following these presentations, an interesting and lively debate ensued.

Group Discussion

Chair: Jeff Ollerhead, Mount Allison University

Group Discussion
Research Needs into the Next Millennium
Chair: Jeff Ollerhead, Mount Allison University

David Coon asked Bay of Fundy stakeholders to: "Think Strategically and Act Opportunistically". Let us now ask ourselves: what are our research needs and goals for the next millennium? How can we as scientists better understand change into the 21st century?

Key Points Discussed

Change

- How do we approach an understanding of change? How do we measure change?
- How do we account for the spatial and temporal scales of change?
- In order to measure change, we need a baseline, but where do we start?
- From a geologist's point of view, change has occurred over thousands of years; which temporal scale(s) matter?
- Changes are never neutral. They either are positive or negative.
- Understanding thresholds (of acceptability or harm) is a key part of understanding change.

The Bay of Fundy ecosystem

- Is the Bay of Fundy in acute crisis? Could we detect each (and every) crisis? If yes, what is our role? If no, how many years away is the crisis? Will there be a crisis? Are we prepared?
- Some crises have already arisen (*e.g.* depletion of wild salmon, wide-spread closures of shellfish beds).
- As a whole, our ecological system is robust. It will evolve and survive. However, its evolution may not suit human needs/desires, and major change(s) may be unavoidable.

Long-term monitoring

- Our scientific community needs long-term monitoring programs, measuring consistently key variables.
- Politicians work on a short-term basis. This difference can create problems when setting policy and/or research objectives.
- Do Canadians value long-term monitoring? We need to convince our local politicians that time-series observations are crucial to understanding the well-being of our ecosystems.
- We need to think about new ways to support longer-term research projects. Could we consider third party foundations? Endowment funds? Corporate sponsors? Atlantic lottery?

The need to be inclusive

- There are many community groups are out there. BoFEP needs a working group to develop strategies to build collaborative research efforts with as many community groups as possible.
- There is a need to gather groups of people with similar interests (*e.g.* the *Corophium* working group). Perhaps other working groups could be established through BoFEP?

Communication

- We are still missing a strong scientific community around the Bay of Fundy.
- We as scientists need to set up a communications system. For example: an exceptional marine data bank where observations can be made readily available.
- The role of the scientist is to gather information, then communicate that information. Scientists are not very good lobbyists. Lobbyists have no time to be scientists.
- One resource we have lost is a voice. The science community lacks a high profile representative for the Bay of Fundy.

We have an opportunity as a scientific group to offer solutions addressing the lack of time-series observations:

- the research stations are in place
- we have university honours students willing to do research
- we should be suggesting hypotheses that deal with impacts and begin long-term monitoring
- we need regular sampling programs across the Bay of Fundy. We should use Falk Huettmann's study of seabirds from the Saint John-Digby ferry as an example

Research and strategy ideas

- Create some new BoFEP working groups to encourage collaboration on specific issues.
- Build better resource inventories.
- Use BoFEP as a mechanism to improve communications with other groups.
- Collect better migratory fish data.
- Give more attention to the sub-tidal environment.
- Should we advocate a trial saltmarsh restoration in the upper Bay of Fundy? How would such a project be monitored?

Liaison with the NGOs

Chair: Jeff Ollerhead, Mount Allison University

Liaison with the NGO's
Current Initiatives
Chair: Jeff **Ollerhead**, Mount Allison University

The Conservation Council of New Brunswick

The Conservation Council of New Brunswick is a province-wide, membership-based environmental organization. CCNB was founded in 1969 by concerned citizens to promote public policies that recognize the importance of a healthy environment.

CCNB is a non-profit organization with charitable status. Its core funding is provided by donations from its members and supporters, and income earned from special events. A Board of Directors, consisting of 24 volunteers from across New Brunswick, oversee the organization's work. CCNB has an office based in Fredericton, a permanent staff of three, and project staff as its programming permits.

In 1990 the Conservation Council was appointed to the United Nations Global 500 Roll of Honour in recognition of its outstanding contribution to the improvement and protection of the environment. CCNB was one of the founders of both Friends of the Earth Canada and the Canadian Environmental Network. It continues to be a member of the Canadian Environmental Network and the Environmental Liaison Centre International.

Priorities for Action:

1. Promotion of ecological approaches to fishing, farming and forestry.
2. Establishment of more community control over resource management and economic development.
3. Decontamination of our atmosphere, waterways and food chain.
4. Restoration and protection of marine habitat.

Resources:

Conserver House houses CCNB's offices and an extensive environmental resource centre for use by the public.

Tula Farm, located on Keswick Ridge, is 29 acres of land held in trust by CCNB to promote sustainable agriculture. It includes an interpretive trail and self-guided tour.

CCNB produces videos and publishes books and booklets on a wide variety of environmental topics.

CCNB Addresses Current Issues:

Ecological deterioration and the decline of biodiversity in the Acadian forest.
Depleted fish stocks and habitat destruction.
Toxic chemical pollution.
Environmental enforcement.
Endangered spaces and endangered species.
The Conservation Council is an active participant in the Canadian Climate.
Action Network and the World Wildlife Fund's Endangered Spaces.
Campaign and a member of CEN's toxics, biotechnology and forest caucuses.

Fisheries

In May 1993, CCNB took the initiative and commissioned a paper by fisheries consultant and social anthropologist John Kearney entitled "Restoring the Common Wealth of the Oceans" (Kearney 1993). This provided an analytical framework for consideration by Canadian environmental groups and fishing organizations. The paper was circulated throughout Canada via the Canadian Environmental Network (CEN), and by the time of the first session of the United Nations Convention on Straddling Stocks and Highly Migratory Fish in July of that year, nearly 80 groups had endorsed the paper. Dr. Kearney and CCNB Vice President Policy at that time, Inka Milewski, took the paper to the U.N. session as delegates of the CEN.

Working from this analytical framework, CCNB then began to put meat on the bones of an in-depth critique of current fisheries management and an alternative proposal that would address the needs of coastal communities and the marine environment. A report entitled "Beyond Crisis in the Fisheries: A Proposal for Community-based Ecological Fisheries Management" (Harvey and Coon 1997) was published in March 1997. It analyses the major contributors to the dramatic decline in the groundfish resources and proposes a management regime which respects ecological parameters and places management control at the community level. CCNB's report argues that coastal communities should have propriety rights to marine resources and that these resources be managed by new community-based institutions in an ecological manner. The report is now being advanced through meetings, presentations, conferences and hearings on both the east and west coasts of Canada, as well as New England. CCNB hopes to develop, cooperatively with a fishermen's association, a case study of the proposed alternative management approach to test and expand the concepts.

As the first step, CCNB is interviewing fishermen throughout the outer Bay of Fundy to assemble what is known about the location and extent of spawning and nursary habitats for ground fish, herring and lobster. CCNB also participates in the Bay of Fundy research and advisory committee of the Fundy fixed gear council, a fishermen's board interested in advancing community-based ecological fisheries.

Estuary Habitat

The extent to which fisheries decline is exacerbated by the degradation and loss of habitat and ecological functions. While there is no scientific work to quantify this, CCNB is convinced that it is a major factor. To that end, a priority has been placed on intervening where threats to these vital areas occur and working to restore habitat and functions where possible. CCNB has been active on marine pollution issues for 10 years, specifically focusing on pulp mills and their impact on fish health. CCNB organized a delegation of fishermen, pulp mill workers and environmentalists to address this issue with the provincial Minister of Environment. This work will continue on an ongoing basis as part of CCNB's "Healthy Environment Program".

More recently, CCNB initiated a public education program around the direct links between habitat and fisheries health. CCNB marine educator/biologist Inka Milewski developed a slide show and free-standing display and conducted public meetings in several coastal communities. These meetings provided essential dialogue and feedback on CCNB's ongoing development of an ecological and community-based framework for fisheries management.

Part of this work was to highlight the importance of rockweed beds as habitat for as many as 22 commercial species of fish, their food sources and as a major source of nutrients to coastal waters. The start-up of a commercial rockweed harvest was lobbied against. Many meetings were held with coastal community residents, politicians, government officials and fishermen's organizations for this purpose. CCNB was successful in galvanizing strong opposition to the commercial harvest of rockweed on the New Brunswick side of the Bay of Fundy among fishers and coastal communities. In the face of such opposition, the government approved a three-year pilot harvest at the end of which time (fall/winter 1997) a decision will be made regarding a full- scale commercial industry. CCNB will dedicate resources to continuing the education process, monitoring the pilot program, and intervening in the decision-making process to ensure this critical habitat and nutrient source is not undermined.

In Spring 1996, CCNB, in partnership with the Conservation Law Foundation (Boston, Rockland) and the Island Institute (Rockland), began an in-depth look at Gulf of Maine estuaries with the ultimate goal of actual estuarine habitat restoration. The short term (two-year) objectives include baseline assessments of individual estuaries, a legal and policy review of tools for estuarine protection in the bi-national context of the Gulf, and the development of an action plan for restoring acres of habitat. This work will feed into the 15-year Restore America's Estuaries program funded in part by The Pew Charitable Trusts.

CCNB MCP staff are also participating as a stakeholder in the Gulf of Maine pilot project for implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, sponsored by the Commission for Environmental Cooperation (CEC) established under the auspices of the North America Free Trade Agreement (NAFTA).

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Petitcodiac Watershed Monitoring Group

As industries expand, and as our population increases, the need for water monitoring grows.

It used to be that the government handled all monitoring of water quality, however with increased environmental interest, private individuals and organized groups with the help of volunteers, have been collecting water quality data. An association called the Petitcodiac Watershed Monitoring Group was formed in the Moncton area for this purpose.

The Petitcodiac Watershed Monitoring Group runs a water quality monitoring program, which includes 36 freshwater sites in the Petitcodiac River watershed. Also there are 4 tidal sites, at the Hopewell Rocks and at Mary's Point in Shepody Bay.

The group, with the help of manuals and training sessions, prepares volunteers to collect and analyze water samples. The information collected is valuable and much needed, as the data collected by volunteers lead to an assessment of water quality and identification of existing or potential problems of the Petitcodiac River.

The volunteers are given test kits along with a standard water quality data sheet. Each volunteer has responsibility for their own specific test spot and takes a bi-weekly sample as well as noting the following water quality parameters;

1. Air temperature
2. Water temperature
3. pH
4. Dissolved oxygen
5. Turbidity
6. Conductivity/Salinity

The data collected by the volunteer must be of top quality in order to provide the basis for making informed decisions to protect the environment. The criteria and conclusions must be based on sound science and good data.

What Happens to the Data Collected By the Volunteers?

Data from each water sampling is provided by the volunteers and placed into the group's LaMotle database. A second database is maintained containing lab results for each sample as received from the New Brunswick Department of the Environment (NBDOE) and Environment Canada.

This information is made available to the public, universities, local/provincial/federal government agencies, and other stakeholder groups having an interest or responsibility for establishing guidelines and programs related to water quality in the Petitcodiac watershed.

Data collected can be used to:

establish baseline data
increase public awareness
reveal long and short-term trends in water quality
identify pollution sources
assist scientists and regulators in planning and policing development.
determine the over-all health of the Petitcodiac River ecosystem

It is required that the water quality monitoring program establish background conditions for water quality in the Petitcodiac watershed. Once the watershed status is assessed, we can then prioritize, develop, and act to restore areas to their natural beauty. It can also provide us with the information needed to help prevent further problems with water quality, and all that is affected by it, down the road.

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Resource Management Associates

Tom Young spoke about his organization's current projects in the eco-tourism field.

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BoFEP General Meeting

Chair: Graham Daborn, Acadia University

Bay of Fundy Ecosystem Partnership
Minutes of the Annual General Meeting
Chair: Graham **Daborn,** Acadia University

In Attendance:

Graham Daborn, Chair	Bob Rutherford
Gail Chmura	Barry Jones, Secretary
Pamela Chang	Elsie Sunderland
Peter Wells	Anne Monette
Thomas Young	Larry Hildebrand
Jack Terhune	John Kearney
Thierry Chopin	Robin Davidson-Arnott
Jon Percy	Mick Burt
Doug Campbell	Jeff Ollerhead
Peter Fenety	David Mossman
Peter Hicklin	William Gardiner

1. Introduction

The meeting began at 9:00 am with Graham Daborn as Chair. The agenda was approved with the addition of an item on budget under Other Business.

2. Minutes of Previous Meeting

The minutes of the last meeting of BoFEP participants held in Digby, NS. on October 8, 1998 were approved as written. There was no business arising from the minutes.

3. Background Report

Graham Daborn gave a presentation on the development of BoFEP, noting activities and recommendations arising from recent relevant workshops and projects, in particular, ones on tidal barriers, the Minas Basin, storm surges and the 3rd Bay of Fundy Science Workshop just ended.

4. BoFEP Working Groups

During the 3rd Bay of Fundy Science Workshop it was recommended that several Working Groups be established to pursue specific issues of interest to members. The following were identified, along with contact/leaders:

- Eutrophication & Nutrition (Thierry Chopin)
- Saltmarsh Dynamics & Restoration (Jeff Ollerhead)
- Fish Migration Studies (Rod Bradford)
- Marine Protected Areas (Maria-Ines Buzeta)

- Ecotourism (Tom Young)
- Defining Stress & Cumulative Effects (Mick Burt)
- Barriers & Tidal Restrictions (Peter Wells)
- Sedimentation (Dave Mossman)
- Resource Development (Peter Fenety)
- Communication and Web Site Development (Jon Percy)
- Toxics (Peter Wells)
- Corophium (Peter Wells)

It was also suggested that BoFEP should incorporate a social science perspective in its activities, not just natural science.

5. BoFEP Officers and Structure

The existing structure consisted of a Steering Committee of all present at our previous meeting, with a chair and secretariat. Jon Percy will update the contact persons information on the web site and distinguish our site from DFO's Fundy Forum. The Steering Committee will remain in place, but considerable discussion on the pros and cons of greater structure for financial and promotionary reasons resulted in a consensus for the establishment of a BoFEP Management Committee consisting of the following positions and officers:

- Chair (Graham Daborn)
- Secretary (Barry Jones)
- Treasurer (vacant)
- Webmaster (Jon Percy)
- "At-Large" (Larry Hildebrand)

There was also considerable discussion on what constituted "the membership" and recognition of the need to develop a list of organizations that are represented on BoFEP, the latter to be called affiliates rather than members or partners. Action: Mick Burt agreed to develop a definition of the "consortium" concept for our next meeting.

It was agreed that the permanent home of BoFEP would reside with Acadia University (ACER) for the forseeable future. However, for representation on either side of the Bay, it was suggested that Huntsman might provide the same role on the New Brunswick side. It was also suggested that BoFEP should seek a permanent seat on the Gulf of Maine Council on the Marine Environment Working Group, and that our Chair should make a presentation on BoFEP to the next GOMC Working Group meeting in June, 1999, in Yarmouth, NS. Action: Barry Jones agreed to look into such arrangements.

6. Funding Options

Two models were considered for possible funding for BoFEP projects: (a) BoFEP receives and administers research funding or (b) partners receive and administer funding, with BoFEP simply facilitating and coordinating partnerships. In the latter option we would need to develop a mechanism for BoFEP to receive some funding to carry out its routine activities. Two possible sources were identified, namely, NSERC Research Network funding and a grant from the Canadian University Research Alliance. These should be looked into. Action: Peter Wells agreed to look into possible funding for the web site, proceedings, fact sheets, etc.

7. Next Meetings

The next meeting of the BoFEP membership will be held in the fall near the end of October, 1999, to be called by the Management Committee. The principal agenda items will include a review/ confirmation of the structure question, a clarification of the mission statement and consideration of a budget. It was also noted that the 4th Bay of Fundy Science Workshop will be held at and during the CZC2000 Conference in September, 2000, in Saint John, NB., along with our Annual General Meeting for that year.

8. Adjournment

No other business was discussed. The meeting adjourned at 11:45 am.

Meeting Highlights

MEETING HIGHLIGHTS

Jeff **Ollerhead**, Mount Allison University

The three day meeting involved scientific paper and poster sessions, a heartfelt public lecture by author Harry Thurston, a panel discussion and several group discussions including a series of informal presentations by members of several non-governmental organizations (NGOs). The workshop was attended by 80 people including 10 students and was a success by most measures. The only real disappointment was the low number of people from community groups and other NGOs unable to attend.

The most difficult issue tackled at the workshop was that of trying to identify all of the relevant changes which should be considered in any assessment of the 'health' of the Bay of Fundy ecosystem. There are numerous realms within which change may be occurring (biological, sedimentary, economic, social, cultural, etc.) and each must be considered in concert with the others. It became clear as discussions evolved that no single group or organization can measure the 'pulse' of the Bay in isolation and then draw meaningful conclusions. A consensus was reached that a holistic approach to assessing change is essential and that the only way to achieve this is to involve as many interested stakeholders as possible (this might even involve working to convince some people and/or groups that they are in fact stakeholders).

The frequent absence of good baseline data and/or long-term measurements was identified as a significant hurdle to identifying change in many cases. Methods of addressing these challenges were discussed including the use of key informants who may have witnessed change over the years or decades and the role that community groups might play in longer-term monitoring projects that other agencies either cannot or will not undertake. The activities of many groups (*e.g.*, the Conservation Council of New Brunswick) are generating much valuable data that may be accessible to researchers should they seek it. Coming to appreciate the valuable role that such groups can play in research and monitoring was a definite highlight of the meeting.

A principal outcome of the meeting was an enhanced appreciation by many attendees that identifying, monitoring, and responding to change in all of its various facets is a monumental task. At times the magnitude of such an undertaking led some speakers to despair. It was concluded that the key to making headway is to act strategically and undertake projects that are manageable, meaningful, and which might attract broad support and input from all interested parties.

Appendices

APPENDIX ONE
Program

Thursday April 22, 1999

08:00-09:00 **Registration**
Avard Dixon Building (Mount Allison University)
Room G9

09:00-09:30 **Welcome/Introduction (G12)**
Jeff Ollerhead, Mount Allison University

SESSION ONE: Variation in the Bay's Ecosystem **Chair:** Jeff Ollerhead, Mount Allison

09:30-09:50 "Climate Change and the Bay of Fundy"
Dave Wartman, Environment Canada

09:50-10:10 "Spatial and Temporal Variation in Sediment Accumulation Rates Along the New Brunswick Coast, Bay of Fundy"
G.L. Chmura, McGill University

10:10-10:30 "Suspended Sediment Circulation and Deposition over Single Tidal Cycles at Allen Creek Saltmarsh"
Jeff Ollerhead, Mount Allison University

10:30-11:00 *Health Break and Posters (G9 and G10)*

SESSION TWO: From Invertebrates to Fish **Chair:** Peter Wells, Environment Canada

11:00-11:20 "Horse Mussel Reef Project in the Inner Bay of Fundy"
Hugh Akagi, Dept. Of Fisheries and Oceans

11:20-11:40 "Habitat Requirements of Striped Bass (*Morone saxatilis*) in Eastern Canada With an emphasis on the Shubenacadie-Stewiacke, Inner Bay of Fundy"
Rodney G. Bradford, Dept. Of Fisheries and Oceans

11:40-12:00 "Reproductive Cycling in Mummichogs (*Fundulus heteroclitus*) in the Bay of Fundy Estuaries Close to Saint John, NB"
D.L. MacLatchy, University of New Brunswick

12:00-13:10 *Lunch (G9)*

SESSION THREE: Avian Ecology **Chair:** Richard Elliot, CWS

13:10-13:30 "The Loons of the Bay of Fundy"
Joe Kerekes, Canadian Wildlife Service

13:30-13:50 "Survival of Common Eider Ducklings in The Southern Bay of Fundy and the Northen Gulf of Maine"
Kim Mawhinney, University of New Brunswick

13:50-14:10 "Aspects of Change for Wintering Razorbills *(Alca torda)* in the Lower Bay of Fundy"
Falk Huettmann and Tony Diamond, University of New Brunswick

14:10-14:30 "Time-Budget Flexibility and Behaviour of Breeding Arctic Terns (*Sterna Paradisaea)"*
Julie Paquet, University of New Brunswick

14:30-14:50 "Trends in Organochlorine Contaminants in Seabird Eggs from the Bay of Fundy, 1972-1996"
Neil Burgess, Canadian Wildlife Service

14:50-15:20 ***Health Break and Posters (G9 and G10)***

SESSION FOUR: Environmental Quality and Aquaculture **Chair:** Jon Percy, CARP

15:20-15:40 "Nutrification in the Bay of Fundy: Sustainable Integrated Aquaculture as one of the Bioremediation Tools"
Thierry Chopin, University of New Brunswick

15:40-16:00 "Salmonid Aquaculture Mortalities and a Bloom Of *Mesodinium rubrum* in Passamaquoddy Bay"
Jennifer Martin, Dept. Of Fisheries and Oceans

16:00-16:20 "Effects of Different Effluent Streams from a Bleached Kraft Pulp Mill on *Fundulus heteroclitus"*
Monique Dubé, University of New Brunswick

16:30-17:15 **Discussion**

18:00-18:30 **Cash Bar (Tweedie Hall)**
18:30-19:45 **Banquet (Tweedie Hall)**

20:00-21:30 **Public Lecture/KeyNote Speaker (Wu Centre)**
Harry Thurston (author)
"Understanding Change in the Bay of Fundy: A Personal Perspective"

21:30- **Reception (University Club)**

Friday April 23, 1999

08:45-09:15 **Registration**
Avard Dixon Building 144 Main Street
Room G9

09:15-09:30 **Welcome/Introduction**
Jeff Ollerhead, Mount Allison

SESSION FIVE: Monitoring and Management **Chair:** Barry Jones, NB Fish & Aquaculture

09:30-09:50 "A 20 Year Environmental Monitoring Record of the Point Lepreau Nuclear Power Generating Station in The Bay of Fundy"
Katherine Ellis, Bedford Institute of Oceanography

09:50-10:10 "Implementation of the Global Programme of Action For the Protection of the Marine Environment from Land-Based Activities Gulf of Maine Pilot Project"
Joseph H. Arbour, Environment Canada

10:10-10:30 "An Ecological Classification of the Marine Environment: Framework for Management"
Inka Milewski, World Wildlife Fund

10:30-11:00 ***Health Break and Posters (G9 and G10)***

11:00-11:20 "Marine Protected Areas in the Bay of Fundy - An Update"
Maria-Ines Buzeta and Derek Fenton, Bedford Institute of Oceanography

11:20-11:40 "Semipermeable Membrane Devices for Environmental Monitoring of Polycyclic Aromatic Hydrocarbons"
Sean Brillant, ACAP

11:40-12:00 "Summary of findings at Tidal Barriers Workshop"
David Coon, Conservation Council of New Brunswick

12:00-13:30 ***Lunch (G9)***

13:10-13:30 "A Review and Update of Aquaculture Impact Studies Carried Out on the Magaguadavic River, Southern Bay of Fundy, New Brunswick"
Fred Whoriskey, Atlantic Salmon Federation

13:30-14:30 **Panel Discussion**
"Understanding Change in the Bay of Fundy"

14:30-15:00 ***Health Break and Posters (G9 and G10)***

15:00-17:00 **Group Discussion**
"Research Needs in the next Millennium"

17:00-19:00 ***Dinner (on your own in Sackville)***

19:00-21:00 **Liaison with NGO's Chair:** Jeff Ollerhead, Mount Allison University

Saturday April 24, 1999

09:00-10:30 **BoFEP General Meeting: (G12)**
Future Directions
Chair: Graham Daborn, Acadia University

10:30-11:00 ***Health Break (G9)***

11:00-12:00 **Conclusion of Meeting**

APPENDIX TWO

Participant List

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