Environmental and resource management in Minas Basin, Bay of Fundy – the role of appropriate indicators and indices to assess marine ecosystem health

By

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The undersigned hereby certify that they have read and recommend to Marine Affairs Program for acceptance a graduate research project titled "Environmental and resource management in Minas Basin, Bay of Fundy – the role of appropriate indicators and indices to assess marine ecosystem health" by Jaime Vickers in partial fulfillment of the requirements for the degree of Master of Marine Management.

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Dedication

To my Mom, Dad, and Sis.

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Abstract

There is a general consensus in the Gulf of Maine, Bay of Fundy, and Minas Basin that state of the environment reports are required to assess the status and trends of marine ecosystems. These reports can evaluate the effectiveness of management actions in minimizing the impacts of human activities. A discussion of ecosystem health concepts, indicators and indices, and monitoring is presented. The importance of linking indicators to management objectives and actions is recognized. Current long-term monitoring programs that use indexes of indicators are examined, and some lessons learned from these programs are outlined. Main environmental and resource management issues in the Gulf of Maine, Bay of Fundy, and Minas Basin are identified. Though some overarching issues are a concern throughout the entire Gulf of Maine watershed, issues vary with geographic location and local "hot-spots" exist, and the indicators selected need to reflect this. Monitoring and research programs are evaluated, management questions are developed, and a suite of indicators is selected for Minas Basin. An overall "Minas Basin Health Index" is recommended and is comprised of four indexes ("Water Quality and Contaminants Index", "Fishery Resources Index", "Benthic Index", and "Development Index"). Next steps are identified to facilitate the implementation of monitoring programs and indicators that assess the health of the Minas Basin. General management recommendations are suggested and conclusions made about monitoring programs and the use of indicators to assess marine ecosystem health and limitations are recognized.

Abbreviations and Acronyms

ACAP	Atlantic Coastal Action Program
BIO	Bedford Institute of Oceanography
BoFEP	Bay of Fundy Ecosystem Partnership
CBP	Chesapeake Bay Program
CCG	Canadian Coast Guard
CEPA	Canadian Environmental Protection Act
CFIA	Canadian Food Inspection Agency
CHS	Canadian Hydrographic Service
COGS	Centre of Geographic Sciences
CSA	Canadian Space Agency
CSSP	Canadian Shellfish Sanitation Program
CWS	Canadian Wildlife Service
DFO	Department of Fisheries and Oceans
EC	Environment Canada
EEM	Environmental Effects Monitoring
EFP	Environmental Farm Plan
EH	Ecosystem Health
EMAN	Ecological Monitoring and Assessment Network
EPA	Environmental Protection Agency
GIS	Geographic Information System
GLWQA	Great Lakes Water Quality Agreement
GOMCME	Gulf of Maine Council on the Marine Environment
GPAC	Global Program of Action Coalition for the Gulf of Maine
GPS	Global Positioning System
HAB	Harmful algal bloom
IW	Indicators Workgroup
MASC	Monitoring and Analysis Subcommittee
MBWG	Minas Basin Working Group
MCTS	Marine Communications and Traffic Services
MEH	marine ecosystem health
MEQ	marine environmental quality
NB	New Brunswick
NBEPC	New Brunswick Electrical Power Commission
NS	Nova Scotia
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
SOLEC	State of the Lakes Ecosystem Conference
US	United States

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1. Introduction

Ecosystem health (EH) assessment has been playing an ever increasing role in environmental management over the past couple of decades as there has been greater demand for data concerning local, regional, national, and global ecosystem health. When EH is assessed, many questions are asked, such as what is wrong, what caused the problem, and what can be done to make the ecosystem healthier? It is thought that ecological indicators can be applied to answer these questions. Over time, it has become accepted that general indicators need to be supplemented with other indicators that will reflect aspects of case-specific ecosystems; deciding which indicators to apply continues to be a challenge (Jorgensen et al. 2005). More is understood about ecosystem structure and state than function, and many ecological indicators that are used reflect this. Indicators such as temperature, dissolved oxygen, the diversity and abundance of birds, fish, and benthic macrofauna are assessed more commonly than growth, exergy, primary production, and nutrient flux as monitoring programs often do not consider more complex indicators (see Jorgensen et al. 2005). Indicators that reflect function are often heavily based in ecology and difficult for managers and the public to understand; the cooperation of ecological scientists is required. In order to best assess EH, ecological indicators need to reflect the complexities of ecosystem structure, function, and composition, yet remain simple enough to be easily and routinely monitored (Dale and Beyeler 2001).

The task is one of devising criteria for selecting indicators and choosing the optimal combination of indicators to assess marine ecosystem health for effective management actions (Jorgensen et al. 2005). Numerous examples exist of programs that are attempting to assess marine ecosystem health (e.g. State of the Great Lakes reports and National Coastal Condition reports); the lessons from which we can adapt to other programs, such as in the Gulf of Maine, Bay of Fundy, and Minas Basin.

In the Gulf of Maine, Bay of Fundy, and Minas Basin, there is a general consensus that state of the environment reports are required. Work is well underway in these areas to determine management issues and to develop indicators to assess marine ecosystem health. Many frameworks exist outlining ecosystem health assessment; using these, a conceptual framework will be devised to show how indicators and monitoring programs are linked to management objectives and actions. Management issues in the Gulf of Maine, Bay of Fundy, and Minas Basin will be investigated and more specifically, Minas Basin management questions will be devised and current monitoring programs will be examined. Focusing on Minas Basin, a set of indicators will be suggested in attempts to provide an overview of the entire ecosystem so that changes and trends in ecosystem status will be apparent over time. Key environmental and resource management questions must be organized appropriately with indicators, monitoring programs, and marine environmental quality guidelines and it will be examined as to whether this is the case in Minas Basin. The matter of nesting environmental and resource management issues and associated sets of indicators of smaller areas, such as Minas Basin, into larger areas, such as the Bay of Fundy and ultimately the Gulf of Maine will be investigated. Finally, recommendations on how to improve current monitoring regimes will be offered in hopes of improving capacity to monitor key indicators for better environmental and resource management for healthier marine ecosystems.

1.1. Marine Ecosystem Health and Marine Environmental Quality

Ocean health is a commonly used term that is publicly accepted to mean the condition or state of the ocean (Wells 2003; Knap et al., 2002; Wells and Rolston 1991) and the concept of health is readily understandable, has social capital, is transferable to ecosystems and is measurable (Wells 2003). Wells (2003) combines various definitions of health and ultimately states that a "healthy marine environment requires individuals (ecologically, individual organisms) with signs of wellness and productivity, based on vital signs, and the absence of obvious disease or lack of function." Measures of marine ecosystem health (MEH) and marine environmental quality (MEQ) are still in early stages of development. These concepts are constantly evolving and terms are often used interchangeably, so it is important that clear definitions exist. Definitions of MEH vary (see Karr et al. 1986; Ulanowicz 1992; Costanza 1992; Costanza and Mageau 1999; Sherman 2000). Most of them are similar in concept, though some inconsistencies do exist making it difficult to implement for practical use. Some authors believe that it is difficult to devise a precise definition for MEH, while others question the whole concept (Suter 1993). Epstein (1999) defines MEH as "to be healthy and sustainable, an ecosystem must maintain its metabolic activity level, its internal structure and organization, and it must be resistant to stress over a wide range of temporal and spatial scales." MEQ is defined as "the condition of a particular marine environment measured in relation to each of its intended uses and functions" (Wells 1991). This differs from MEH as quality denotes recorded change in condition over time and space, and health is the present condition of an ecosystem and direction of change (Wells 2003). A relationship exists between health concepts (MEQ and MEH), time and space, and biological organization (Table 1). The distinctions reflect the need to develop different indicators to assess condition across structural and functional ecosystem components in order to get a comprehensive view of the ecosystem.

Table 1. How the terms and concepts on health and ecosystem health relate across time, space, and levels of biological organization (from Wells 2003).

Time/space scale	Components and levels of the ecosystem		
	Individuals	Population	Communities and ecosystems
Short-term, local, current state	Health	Health	Ecosystem health, ecological or ecosystem integrity
Long-term, regional, changes/trends	---	Quality, change	Change, environmental quality, ecological or ecosystem integrity

A number of frameworks exist to assess MEH and MEQ, but the common thread is that indicators of health and quality are developed by research and used in monitoring programs to ultimately feed back into management actions (Wells 2003). Many approaches also exist to determine and evaluate ecosystem stress, health status, and disturbances (Karr 1992; Rapport et al. 1998; Epstein and Rapport 1996; HEED 1998) which can be applied to ecosystems of interest. MEH and MEQ assessments require that indicator data be compared to baseline conditions, or ecosystem guidelines, objectives, or standards to help guide management decisions (Wells 2003).

Indicators represent a link between management objectives and management actions and plans (Degnbol 2005). Figure 1 shows how indicators should be embedded in the decision-making process. Initially, environmental and resource management goals need to be established to determine what society wants from the marine ecosystem. Following this, MEH should be assessed using indicators and monitoring programs to allow the assessment of the status of the marine ecosystem. This forms a basis for the development of reference values or baselines so possible trends and changes in MEH can be evaluated. Decision-making criteria (e.g. thresholds, reference points, targets, guidelines) can then be established from which we can evaluate the steps that need to be taken to achieve management objectives. Actions can then be taken to develop and implement management plans. Monitoring plays a critical role in the feedback loop that allows management plans to be changed and practices modified, and to remove or reduce stressors or their impacts that are harming the environment (Strain and Macdonald 2002).

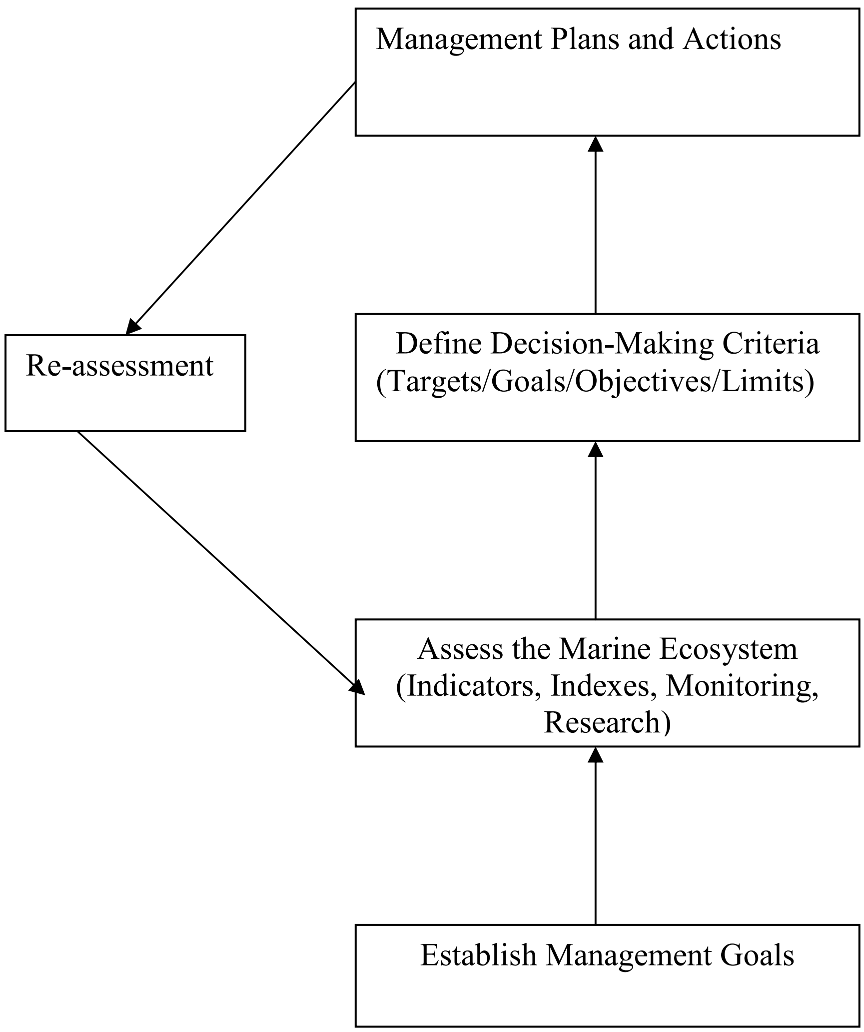

Figure 1. Framework outlining how indicators feed into management plans to ultimately meet management objectives (adapted from Link 2005).

It is important that MEQ standards are nationally uniform to be able to better interpret the information gathered from indicators. This is going to be difficult to achieve in the Gulf of Maine as two countries share it and coordinating standards and guidelines continue to require substantial cooperation and integration. Examples exist where monitoring programs have failed due to a lack of agreed upon numerical MEQ targets and management goals (Bortone 2005), or succeeded where targets and goals have been selected (e.g. shellfish programs, coliform bacteria levels; ocean disposal programs under CEPA, specific toxic chemical levels).

1.2. Links to Human Health

One aspect of assessing ecosystem health is the connection between impacts on the ecosystem and threats to human health. To make people concerned about MEH and MEQ, it would be more effective to put it into terms of the impacts of an impaired ecosystem on human health. There are many examples. Beaches are closed to swimming because of bacterial contamination and shellfish beds are closed to harvesting because of pathogens, contaminants or harmful algal blooms. Synthetic organic chemicals, polycyclic aromatic hydrocarbons (PAHs), metals, marine algal toxins (harmful algal blooms), and microbes (from human and animal wastes) can enter marine ecosystems and primarily impair human health through ingestion of contaminated water or food or exposure to contaminated waters (Knap et al. 2002). In the Gulf of Maine and Bay of Fundy, sewage (treated and untreated) is the primary pollutant that shows the connection between MEH and human health (Hinch et al. 2002). An action plan is currently in place for the Gulf of Maine to address mercury, nitrogen, and sewage to assure protection of human health and MEH by ensuring low levels of these contaminants (GOMCME 2002). Monitoring is important for early detection of environmental threats that can cause human illness, but there is more to MEH than solely human health implications.

1.3. Monitoring, Indicators and Indices

The use of indicators in monitoring programs to assess EH has the potential to inform the general public and decision-makers about the state of the ecosystem. This approach can also help determine if management efforts are effective, and if not, will indicate what actions should be changed. Regular monitoring of indicators is essential for providing short and long-term data that are essential to assess EH. Ecosystem or resource management monitoring usually requires specific site(s) data while information across broader geographical regions is typically required for public policy decisions (Olsen et al. 1999). Hence, it is important to understand both small- and large-scale trends in EH through the monitoring of indicators. It is important that management decisions and policies are based on good science. In addition, lack of coordination between research and monitoring programs can lead to data gaps and a lack of understanding of environmental issues (Coastal Research and Monitoring Strategy Workgroup 2000). Monitoring is necessary to document the status of issues, assess trends, evaluate the cause-effect relationships between stressors and impacts, and assess effectiveness of management actions (Coastal Research and Monitoring Strategy Workgroup 2000).

Environmental indicators should reflect elements that link human activities to their environmental impacts (Smeets and Weterings 1999). Ecological indicators can then be thought of as a subset of environmental indicators that applies to ecological processes (NRC 2000). Many definitions of “ecological indicator” exist. For this study, the definition used by Niemi and McDonald (2004) is chosen, defining ecological indicators as: "measurable characteristics of the structure (e.g. genetic, population, habitat, and landscape pattern), composition (e.g. genes, species, populations, communities, and landscape types), or function (e.g. genetic, demographic/life history, ecosystem, and landscape disturbance processes) of ecological systems." Ecological indicators are primarily biological and respond to chemical, physical, and other biological occurrences (Niemi and McDonald 2004). Ecological indicators can be used to measure natural disturbances, but their primary role is to measure the response of the ecosystem to anthropogenic stress (US EPA 2002). The term "environmental index" is used to show a single number that is derived from two or more indicators and is used as a measure of overall ecological condition or environmental quality (Bortone 2005), in much the same way as indexes for stock markets (e.g. Dow Jones Indexes, NASDAQ).

Ultimately, indicators should be determined in order to answer whether or not the entire ecosystem (or parts of it) is improving or worsening. This usually requires extensive temporal and spatial databases to be able to reveal both short and long-term change (Wells 2003). This may not always be the case though, as some ecosystem shifts are sudden. It is critical to have reference points from which to measure if the ecosystem status is changing, which is difficult to achieve because perfect knowledge of ecosystem function does not exist (Bortone 2005). Monitoring programs and state of the environment reports (e.g. US EPA National Coastal Condition reports, State of the Lakes reports, Gulfwatch, Chesapeake Bay Program) can improve the quality, quantity, and availability of data from indicators that can be used to assess EH. It is important that indicators are current, practical, easily measurable and understandable; Wells (2003) suggests that even though some indicators are important, they are impractical and it is unclear whether they can be measured in the real world. Karr (1992) believes that the development of indicators is the most important step required in gaining social support in hopes of reversing biotic impoverishment trends. This is yet to be seen because of the time, data, and monetary requirements and the refinements and alterations to indicators that occur as more research is performed and advanced technologies become rapidly available.

Before choosing indicators, many questions should be asked: What are the management objectives and issues for the area? What are the valued ecosystem components? What are societal expectations? How should the stressors, issues, and indicators be grouped? (Wells et al. 2005). Much literature exists concerning the approaches and techniques to studying, measuring, and analysing ecosystem change as well as providing criteria for selecting indicators (Cairns et al. 1992; Shear et al. 2003; Rice 2003). Vandermeulen (1998) outlines a comprehensive list of general criteria used for indicator selection: scientific validity, data availability over time, responsive to natural change, representative of the issue, understandable, relevant to needs of users, ability to compare data to a target or threshold value, national/regional perspective, geographic coverage, data adequacy, cost effective list, and predictive (if possible). Wells et al. (2005) suggest that indicators should integrate over areas and over natural communities (especially upper trophic levels within ecosystems) and there must be a good signal to noise ratio (e.g. be able to detect change in an ecosystem that has much natural variability). Optimally, indicators should be capable of detecting and diagnosing environmental conditions over space and time at cellular, organism, habitat, ecosystem, and regional levels (Niemi et al. 2004) and be linked to management issues and integrated into monitoring programs.

Indicators should be related to quantitative or qualitative targets or thresholds that are scientifically based and provide meaningful and understandable data for measuring MEH (Smiley et al. 1998). The trend has been to use integrated indicators of structure and function and it is thought that indicators could be grouped into indices or indexes to fit regional needs to assess condition and develop appropriate management responses (Niemi et al. 2004). The possibility of using combinations of indicators and indices/indexes to give the best possible measure of ecosystem state (e.g. State of the Lakes Reports and National Coastal Condition Reports) has been investigated. It is still unclear whether this method is effective at assessing MEH or to what scale this method can be used (e.g. entire Gulf of Maine vs. Minas Basin). Indexes can help characterize ecological conditions and play an important management role, but this concept is not without criticism either as they can be viewed as oversimplifications of generalizations of ecosystems in which important data can be lost (May 1985; Rakicinski et al. 1997).

1.4. Indicator Reports

1.4.1. Great Lakes Indicator Methodology (State of the Lakes Reports)

The State of the Lakes Ecosystem Conferences (SOLECs) were developed in response to reporting requirements of the Great Lakes Water Quality Agreement (GLWQA) which would ultimately assess the state of the Great Lakes ecosystem based on indicator suites, strengthen management decisions, and increase communication among stakeholders (Shear et al. 2003). More than 850 indicators were identified for this process and were screened to meet certain criteria. This list was eventually shortened to a suite of 80 indicators. At SOLEC 2000, reports were presented on 33 of the 80 indicators because data was readily available for these. Indicators were scored based on 5 categories: “poor”; “mixed/deteriorating”; “mixed”; “mixed/improving”; or “good/restored”. The overall status of the Great Lakes basin based on these 33 indicators was “mixed” (Shear et al. 2003). Figure 2 shows images from the State of the Great Lakes 2003 report based on indicators for which current, comprehensive basin-wide data exists; the overall assessment is incomplete as many indicators were not assessed.

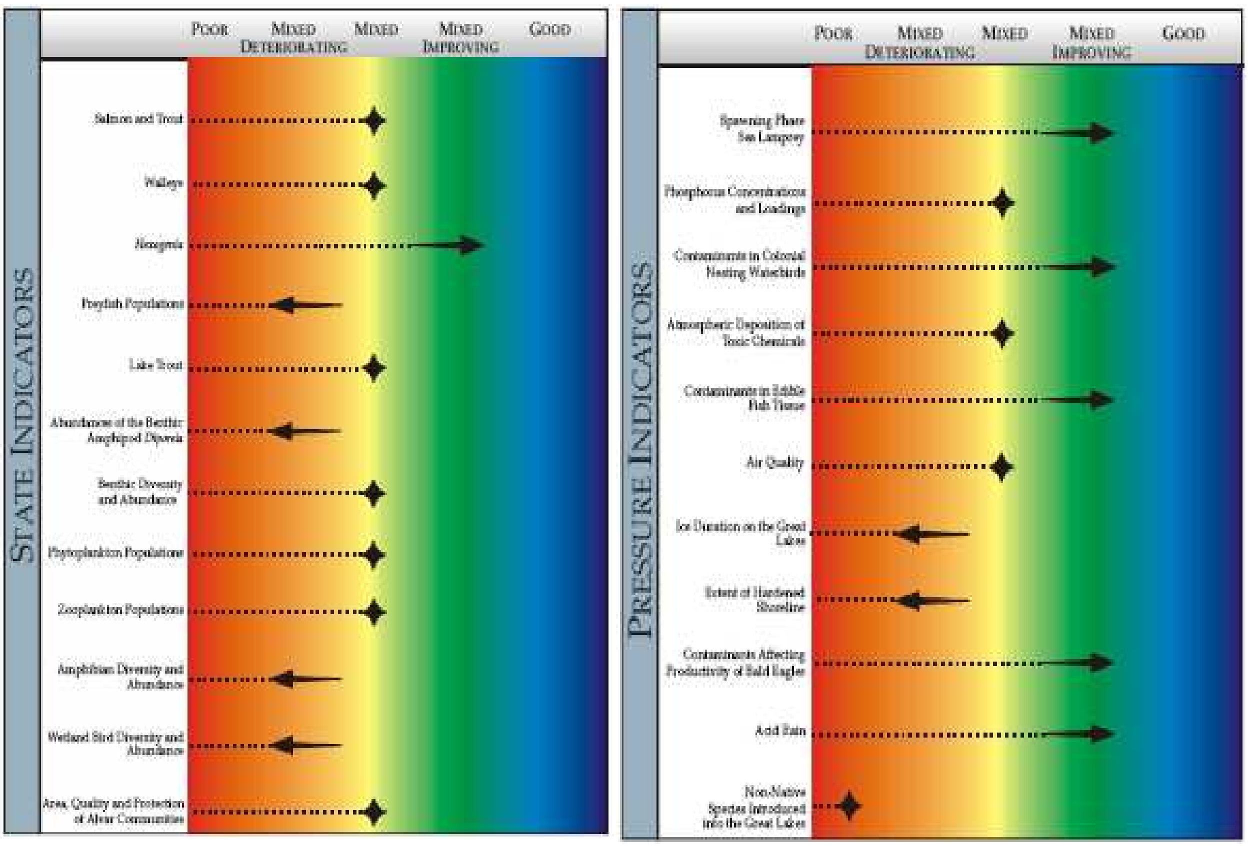

Figure 2. Assessment of state and pressure indicators in the Great Lakes basin for which there is sufficient comprehensive, current basin-wide data (from Environment Canada and US EPA 2003).

In 2004, indicators were further defined or modified and grouped by “bundles”, and five general management challenges were identified. SOLEC 2004 organizers grouped the indicators into these 9 main categories, of which each category contained sub-categories – contamination, biotic communities, invasive species, coastal zones, aquatic habitats, human health, land use/land cover, resource utilization, and climate change (Forst et al. 2004). To characterize the assessments, indicators were scored by colour as “good”, “fair”, “poor”, or “mixed”, which was determined to be less ambiguous than the previous qualitative assessment based on five categories. An ecosystem trajectory (trends over time) was also recognized by shape for each indicator which could be “improving”, “unchanging”, “deteriorating”, or “undetermined”.

Challenges that are being faced include periodically reviewing and refining indicators, nesting local and lake-wide indicators within basin-wide indicators, reporting on indicators in a format to meet the needs of multiple users, and building appropriate monitoring and reporting activities into programs at all levels (Shear at al. 2003). Efforts are made to select indicators based on available data and existing monitoring programs, though many indicators will require new or improved monitoring programs (Shear et al. 2003). For some indicators, lake-by-lake differences may exist in endpoints or reference values, but the indicators themselves should be relevant across lakes (Bertram and Stadler-Salt, 1999). It is important to note that indicators for local conditions should exist for local areas of concern so the appropriate management actions can be taken. It is hoped that in the Great Lakes basin, an easily understood suite of indicators will be developed which can be used to report the status and trends of the ecosystem every two years to give a more complete picture of the ecosystem (Bertram and Stadler-Salt, 1999).

1.4.2. Environmental Protection Agency Methodology (National Coastal Condition Reports)

The US National Coastal Condition Report attempts to compile and summarize data sets from different agencies around the US to present a broad picture of coastal water conditions (both regional and nationally). By using data for some variables that have been measured consistently across six regions from a combination of monitoring programs, the ecological and environmental condition of coastal waters can begin to be described. The first study period lasted from 1990-1997 and the condition of the US estuaries, which was determined to be “fair”, was based on seven basic ecological indicators – water clarity, dissolved oxygen, loss of coastal wetlands, eutrophic condition, sediment contamination, benthic condition, and accumulation of contaminants in fish tissue (US EPA 2001). The seven indicators were assigned a score of “poor”, “fair” or “good” (based on existing criteria, guidelines, or interpretation of scientific literature) for each coastal area. The indicator scores were then averaged for each coastal area to create an indicator score for the overall condition of each coastal area, and eventually a national overall score was calculated for each indicator (US EPA 2001) (Figure 3). The purpose of the first report was to provide a broad baseline picture of the condition of estuaries across the US and highlights data gaps and was not intended to be exhaustive.

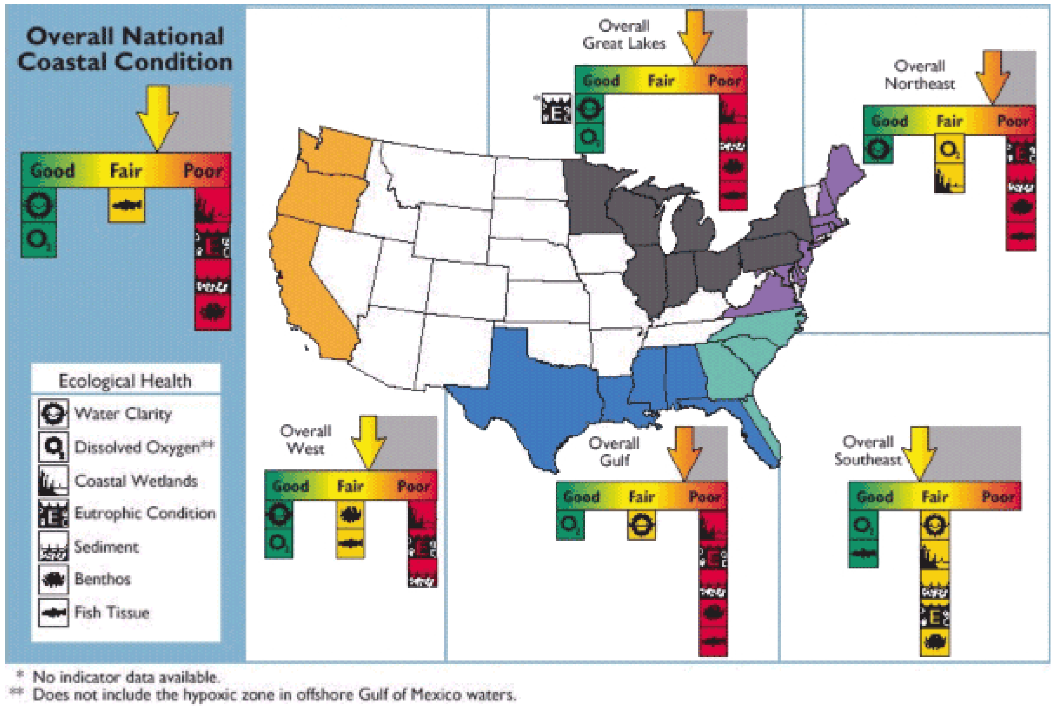

Figure 3. 2001 National Coastal Condition Report showing overall condition of US coastal and overall conditions for each region (from US EPA 2001).

The second National Coastal Condition Report contains data from 1997-2000 and show that US estuaries are still in fair condition (Figure 4) (US EPA 2005). The number of indicators in the second report was reduced from 7 to 5 (the eutrophication index was replaced by a water quality index that includes the distinct indicators in the first report of dissolved oxygen and water clarity) (US EPA 2005). Some other indicators were slightly modified to include additional data sets and comparisons to regional and sub-regional reference conditions (US EPA 2005).

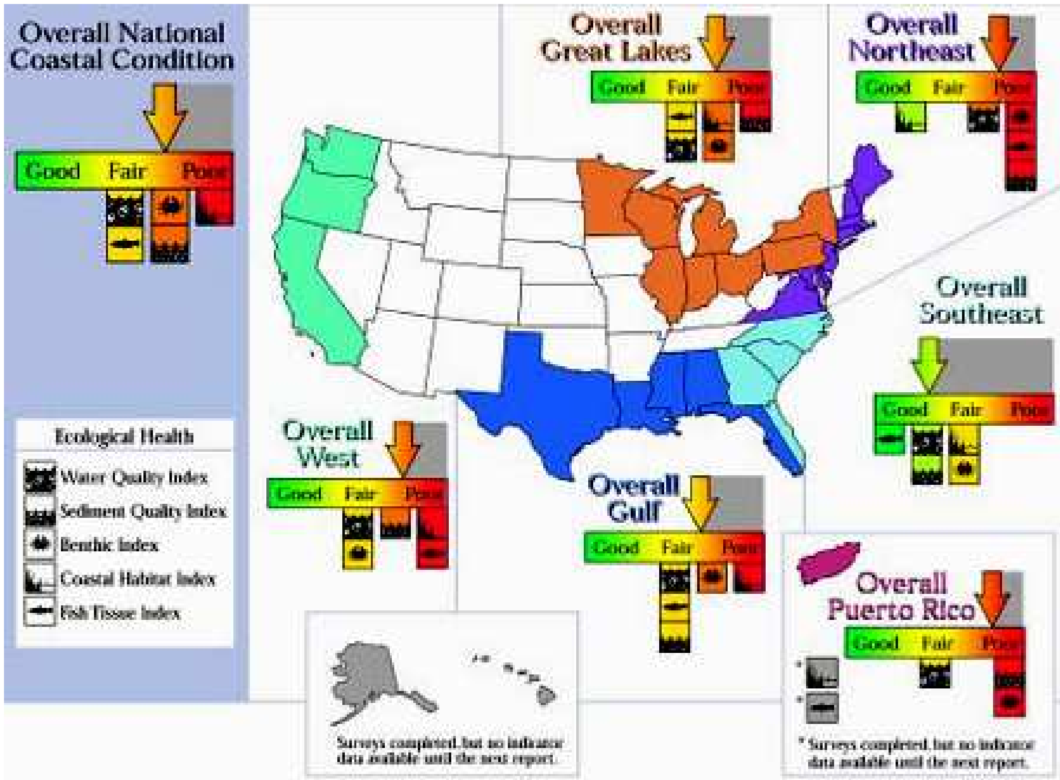

Figure 4. 2005 National Coastal Condition Report showing overall condition of US coastal and overall conditions for each region (from US EPA 2005).

Conditions in each report need to be comparable to be able to analyze trends over time and it was concluded that there was insufficient information to examine potential trends or the status of coastal condition (US EPA 2005). The next report is planned to come out in 2006 and it will include information from 1990 to 2002 and will hopefully be able to be evaluated for potential trends (US EPA 2005).

1.4.3. Gulfwatch Program

Gulfwatch is a bi-national monitoring program that involves Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia and uses the blue mussel (*Mytilus edulis*) as an indicator species in order to give a regional baseline perspective of contaminants through the analysis of tissue contaminants. Since 1991, each fall, blue mussels are sampled from around the Gulf of Maine and Bay of Fundy (multi-year and three-year rotational sites are also sampled). Polychlorinated biphenyls (PCBs), PAHs, chlorinated pesticides, and metals are monitored at up to 58 sites (GOMCME 2003) (Figure 5). The results are entered annually in a database available to those looking for information about the Gulf's water and sediment quality.

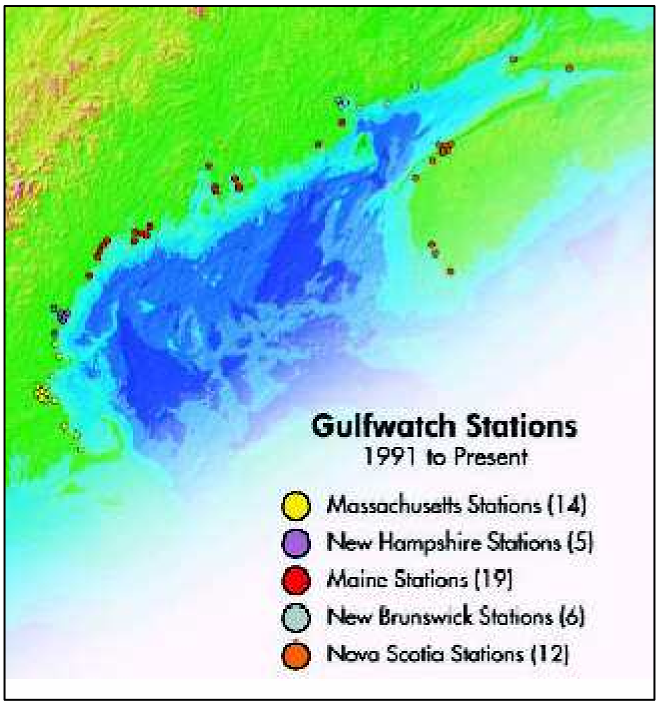

Figure 5. Gulfwatch sites around the Gulf of Maine and Bay of Fundy since 1991 (from GOMCME 2003).

Given the fact that funding has been limited and that bi-national cooperation is required, this program has been successful in determining the status, trends, and risks to the Gulf of Maine ecosystem and human health (Tripp et al. 1997). This program also acts as a source of long-term monitoring information that resource and environmental managers can use to make effective decisions (Tripp et al. 1997). Samples need to be taken with an understanding of ecosystem complexities and the processes governing variability in each compartment of the ecosystem if meaningful data are to be generated. For example, the program should eventually extend its scope beyond tissue sampling and look more closely at changing water masses, variations in contaminant distribution and concentrations in tissue samples, and sampling strategies involving sediments (Tripp et al. 1997). This program needs to evolve with time to integrate objectives and technological advances. The Gulfwatch program could be integrated with other monitoring programs to develop an index that includes other indicators that can assess overall ecosystem health of the entire Gulf of Maine, similar to programs mentioned above.

1.4.4. Chesapeake Bay Program

The Chesapeake Bay Program (CBP) includes a regional partnership (Virginia, Maryland, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, and the US EPA) that has directed the restoration of Chesapeake Bay since 1983. This program is quite extensive, well-developed, has an impressive, informative, up-to-date website (http://www.chesapeakebay.net), and has continued public support. Three "State of the Chesapeake Bay" reports have been produced (2004, 2002, 1999) and the CBP includes numerous technical workgroups and subcommittees (described in CPB 2005a). A Monitoring and Analysis Subcommittee (MASC) coordinates and supports the monitoring activities of the CBP to provide the information needed to guide the restoration of the Chesapeake Bay. The MASC provides a forum for internal communication regarding all CBP monitoring activities which include the collection, management, integration and analysis of data from multiple scientific disciplines. The MASC also seeks external funding and provides support to maintain adequate funding for individual monitoring programs. Monitoring and scientific research efforts are integrated by the MASC to ensure Bay-wide data is consistent and adequate in supporting management decisions. The CBP also includes an Indicators Workgroup (IW) that promotes the development of indicators that best communicate progress in the restoration of water quality and living resources in the Chesapeake Bay and its watershed. The IW is working to develop a framework that relates indicators to each other, devise guidelines for indicator selection, and develop indices that combine numerous indicators.

Currently, the CPB monitors approximately 100 indicators of MEH in the Bay (CBP 2004). Eighty-nine indicators are based on environmental monitoring data and eleven use computer model forecasts to project future water quality conditions resulting from current restoration initiatives (CPB 2004). Some progress has been made resulting from the efforts of the CBP (e.g. decreasing sediments and nutrient inputs, increasing migratory fish habitats through dam removal), but there still is a long way to go to reach many goals (e.g. forest acreage is declining, low oyster and blue crab populations, declines in water clarity, and chemical contamination problems) (CBP 2005b). It is clear that a difference has been made as a result of the CBP's restoration efforts as some aspects of MEH are improving, and the Bay would have been worse off without these monitoring and restoration initiatives.

2. Management Issues in the Gulf of Maine

Major environmental and resource management issues exist in the Gulf of Maine region, from the watershed to the coastal waters to the offshore banks, such as Georges. Nested in this region are other smaller areas/ecosystems, including the Bay of Fundy and the Minas Basin, each of which have their own specific management issues. It is questionable whether management issues in the Gulf of Maine are always the same as those in the Bay of Fundy and Minas Basin. As well, choosing resource and management issues, from which to develop indicators from, is an extensive process that requires participation and input from all stakeholders. It is difficult to determine the optimum method of issue categorization, but it is crucial that management questions relate to these issues to ultimately develop the best indicators, so emerging and intensifying issues can be integrated. Currently, efforts need to focus on integrating existing monitoring programs, developing better indicators, and promoting the region-wide sharing of data. The Minas Basin flows into the Bay of Fundy and ultimately into the Gulf of Maine, so to best assess in relevant detail the MEH and MEQ of the greater Gulf of Maine, state of environment reports are necessary for smaller regions around the Gulf. The following sections outline the main management issues in the Gulf of Maine, the Bay of Fundy, and Minas Basin.

2.1. Gulf of Maine

The Gulf of Maine is surrounded by Nova Scotia, New Brunswick, Maine, New Hampshire, and Massachusetts, is a large semi-enclosed coastal sea in the Northwest Atlantic, and has an extensive watershed (Figure 6). It is a single hydrographic system with a circulation pattern that is similar to that of a large estuary. This region is extremely biologically diverse and productive with interesting oceanographic features so much research has been carried out here over the past century. Many reports have been compiled that document ecological change and issues in the Gulf of Maine region and much time and effort has been spent on exploring main environmental issues. These issues will not be explored in great detail here. Pesch and Wells (2004) and RARGOM (1995) provide detailed descriptions of specific stresses and marine management issues in the Gulf of Maine.

Figure 6. Map of the Gulf of Maine Watershed (from GOMCME 2002).

Six main issues were chosen by the Gulf of Maine Council on the Marine Environment (GOMCME) following discussions with individuals, organizations, and affected communities at two workshops in December 2002 (Atlantic Northeast Coastal Monitoring Summit) and January 2004 (Northeast Coastal Indicators Workshop); land use/coastal development, contaminants and pathogens, fisheries and aquaculture, nutrients, aquatic habitat change/loss, and climate change. Issue concerns were quantified using a similar traffic light approach that the EPA used for the National Coastal Condition Assessments. From these, three priority issues were identified (land use and coastal development, contaminants and pathogens, and fisheries and aquaculture) as having the greatest potential for negative human impact. Issues that fall under the land use category include population growth, sprawl, changes in land use, habitat loss/degradation/fragmentation, loss of species, loss of wetlands, and coastal development pollution (point and non-point sources). The contaminants and pathogens category addresses variables such as bacteria, sewage, mercury, sediment quality, point and non-point sources, shellfish bed closures, and beach closures. The fisheries category includes changes in species, changes in resource use, area of critical habitat and natural areas, and aquaculture and its associate impacts. Regional ecosystem management indicators were chosen at the January 2004 workshop for the region’s three main management issues – fisheries, contaminants, and coastal development. Draft indicators were devised for aquatic habitats, nutrients, and climate change and these will be further described in the near future. Management questions were devised (Table 2) and indicators were selected for each of these issues in hopes of tracking progress, giving a historical context, and revealing the current status of each issue (Table 3). Indicators and issues were chosen based on many workshops and forums that focused on using indicators and monitoring programs to produce better environmental reporting in the Gulf of Maine. Other issues that are of concern are offshore oil pollution/dumping from shipping, harmful algal blooms, and invasive species. Invasive species are addressed in several other issues (see Table 2), but as it becomes an increasing problem, it may warrant its own category to be able to properly manage this problem.

Table 2. Table of management questions for the entire Gulf of Maine region's issues (adapted from NCIW 2004, Pesch and Wells 2004, King and MacKenzie 2005).

Issue	Fisheries	Contaminants and Pathogens	Land Use (Coastal Development)	Eutrophication	Aquatic Habitat Change/Loss	Climate Change
Management Questions	What are the trends in and the status of exploited fisheries stocks? What are the effects of fishing on non-targeted species and their associated communities? What are the effects of fishing and non-fishing activities on marine habitat and fisheries productivity? What are the trends in socioeconomic characteristics of fishing?	How are contaminants in the region changing? How is the input of contaminants changing over time and space? Are management actions changing the extent and severity of human health effects? How well are contaminant management actions protecting ecosystem integrity?	What are the type, pattern and rate of land use change? How are these changes impacting the integrity of coastal ecosystems? How is the region responding to changes in coastal ecosystems?	What are the extent, severity, and trends of eutrophication impacts? What are the sources of nutrients, can they be controlled, how are they changing? What is the state of management measures and how can they be optimized?	How is the extent, distribution, or use of aquatic habitats changing over time? How is the ecological condition of aquatic habitats changing over time? What are the causes of aquatic habitat over time?	How are atmospheric conditions in the Northwest Atlantic Region changing in response to global climate change? What are the impacts of climate changes to: weather, atmospheric and ocean circulation, ecosystems, and society? What are the impacts of climate change on biotic ecosystems?

Table 3. Table of indicators chosen for the entire Gulf of Maine region's issues to be able to answer management questions (adapted from NCIW 2004, Pesch and Wells 2004, King and MacKenzie 2005).

Issue	Fisheries	Contaminants and Pathogens	Land Use/ Coastal Development	Eutrophication	Aquatic Habitat Change/Loss	Climate Change
Indicators	➢ Size/age structure of species from surveys or landings ➢ Spatial distribution of exploited resources (patterns of distribution and abundance through species indices) ➢ Status of a targeted fishery resource (stock assessments – spawning stock biomass and fishing mortality) ➢ Characteristics of bycatch and discards ➢ Species diversity and population levels ➢ Incidental mortality of species of concern ➢ Changes in community structure (track changes in species, size, trophic composition, species/benthic diversity) ➢ Fish habitat protection through marine protected areas (km^2 and percentage of total area closed to fishing) ➢ Spatial distribution of bottom fishing ➢ Availability to habitat to anadromous fishes in rivers of the Gulf of Maine Watershed (number of unobstructed river miles; percentage of available historical habitat; status of stocking programs) ➢ Fishing days at sea ➢ Fleet/industry composition ➢ Recreational fishing value and impacts	➢ Area of contaminated sediments that have contaminated levels above sediment quality guidelines ➢ Days of beach closure due to bacterial contamination ➢ Area of shellfish bed closure ➢ Contaminant levels in sentinel organisms (at various trophic levels) ➢ Bacterial source investigations and eliminations ➢ Annual chemical load by source ➢ Inventory of contaminant problems ➢ Human disease from fish/shellfish consumption and swimming ➢ Annual number of beach and shellfish bed closures ➢ Sediment quality measure by triad approach (contaminant levels, sediment toxicity, infaunal community structure) ➢ Incidence of disease and health problems in marine organisms at different trophic levels ➢ Habitat quality impairment by contaminants	➢ Types and rates of land use/land cover change ➢ Demographic changes (percent change in population in municipalities that border the coast) ➢ Percent change in land cover to more intensive uses ➢ Threatened and endangered coastal species ➢ Occurrence and abundance of invasive species ➢ Migratory species population status ➢ Type, location and pace of restored habitat ➢ Type, location and pace of land conservation in the watershed ➢ Land management (planning, regulatory)	➢ Dissolved oxygen ➢ Chlorophyll concentrations ➢ Water clarity ➢ Submerged aquatic vegetation (distribution/loss) ➢ Measured and modeled nutrient loads	➢ Extent and distribution of habitat type over time ➢ Area, percent designated for permanent habitat protection ➢ Adjacent land use index ➢ Community structure (percent cover, vegetation height, species biomass) ➢ Trophic structure ➢ Species of concern ➢ Invasive species ➢ Extent and percent habitat area altered by tidal restrictions and coastal habitat alterations ➢ Plant growth and nutrient assimilation (Nutrient Pollution Indexes)	➢ Carbon dioxide trends at coastal and offshore stations ➢ Ozone trends at coastal and offshore stations ➢ Cloud cover/solar reflection trends ➢ Methane at coastal and offshore stations ➢ Precipitation trends ➢ Storm frequency and intensity ➢ Surface and bottom water temperatures ➢ Relative sea level rise ➢ Warm vs. cold water finfish species diversity ➢ Planktonic and algal diversity and biomass ➢ Wetlands extent, distribution and composition ➢ Marine disease indices (MSX, dermo, shell disease) ➢ Invasive species

2.2. Bay of Fundy

The Bay of Fundy is the northeast extension of the Gulf of Maine and links Nova Scotia and New Brunswick, where tides can exceed 16m in height (Percy et al. 2005). Subareas have been designated for the Bay – Upper Bay, Inner Bay, Outer Bay, and Lower Bay (general term for outer and inner Bays together) (Figure 7). The environment of the Bay is dynamic with extreme tidal ranges and is continually changing as a result of human activity and natural occurrences.

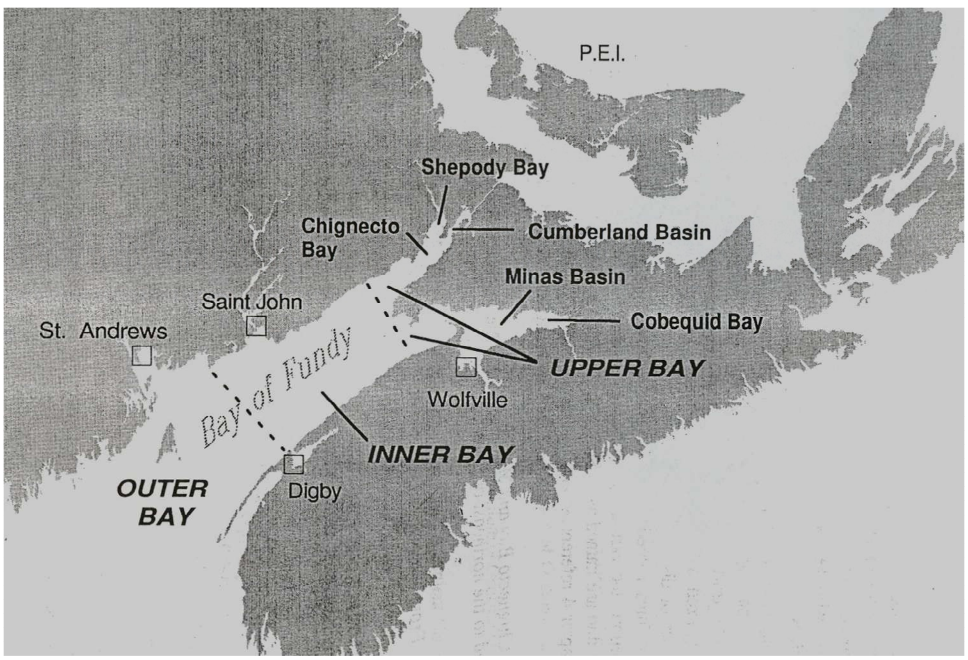

Figure 7. The Bay of Fundy and its principal subareas (from Percy et al. 1997).

The Bay of Fundy Ecosystem Partnership (BoFEP) is a "virtual institute" that involves the cooperation of scientists, resource managers, business operators, resource users, planners, industry and coastal communities in hopes of conserving and effectively managing the Bay's resources and habitats by sharing information and monitoring ecosystem status in the Bay. BoFEP has held six scientific workshops and a coastal forum concerning the Bay of

Fundy since 1996 and another is planned for 2006 (Percy et al. 1997; Burt and Wells 1999; Ollerhead et al. 1999; Chopin and Wells 2001; Wells et al. 2004; Percy et al. 2005; Wells et al. 2005). BoFEP has also made available online 25 fact sheets that are suited for the general public that describe the science behind important environment issues in the Bay (http://www.bofep.org/fundy_issues.htm). New facts sheets are added as they are completed, as new issues emerge, and a deeper understanding of existing issues occurs. Percy et al. (1997) also outlined over 30 of the most pressing environmental issues threatening the Bay of Fundy, so it is clear that an awareness of these environmental and resource management issues exist.

As part of the 5th BoFEP workshop, a Bay of Fundy Coastal Forum was organized (Wells et al. 2005). This forum also used the US EPA traffic light matrix approach to assess the state of chosen indicators. At the forum in 2002, it was determined that people were concerned about the MEH and MEQ of the Bay and goals needed to be established. It was also determined that environmental reporting needs to be manageable, so individual reports on different areas/ecosystems, such as the one currently being prepared for the Minas Basin, are necessary before assessments on the whole Bay can be carried out. It is generally thought that the MEH and MEQ of the Bay is degraded, with some areas, such as Passamaquoddy Bay, are more contaminated than others. Long term data sets exist for the Passamaquoddy Bay (Lotze and Mileski 2002) so deterioration is apparent, but it is difficult to assess MEQ and MEH in other areas where long-term data is lacking. People generally want to know how the Bay has been changing over time and to acquire more knowledge of ecosystem processes to improve management. Issues facing the Bay according to the Coastal Forum participants include: fate of coastlines, salt marsh condition and area, metal contaminants (especially in lobsters), aggregate mining, tidal barriers, lack of knowledge of ecosystem processes in the Bay for management purposes, effects of fishing on benthic habitats, effects of harvesting on inter-tidal habitats, implications of coliform bacterial contamination on human health, knowledge on how the Bay has been changing over time, and wetland protection (Wells et al. 2005).

The Petitcodiac and Avon River causeways and other tidal barriers are issues and need to be studied to determine the movement of sediments as a result of barrier construction, alteration or removal and to determine how this affects sediments, mudflats, and species migration. Specific environmental impacts of habitat restoration efforts (e.g. causeway removal, dyke breaking) need to be looked at. Particular sources of chemical contaminants are issues in the Bay of Fundy, such as seafood processing plants, pulp and paper mills, power plants, mining, and quarries, and fecal contamination and coliform bacteria in bottom sediments and salt marshes (Percy et al. 2005). Finfish aquaculture is increasing without knowing the full extent of its impacts, wild salmon stocks have declined dramatically in the inner bay, and North Atlantic Right whales are getting caught in fishing gear and colliding with ships. Other specific issues in the Bay of Fundy include changes in biodiversity and trophic structure of fish stocks, negative impacts of fishing gear on benthic habitats, and damaged/altered fish migratory routes. Fishing for new species, such as sharks, seaweeds, baitworms, and urchins, has also become an issue, as the ecosystem impacts of removing such species are still largely unknown. In the Bay of Fundy, migratory seabirds play an important role in the area's ecology as they colonize islands and forage on mudflats for amphipods (e.g. *Corophium volutator*). *Corophium* are considered a keystone species in the intertidal mudflats (Daborn et al. 1993). Eutrophication, invasive species such as *Codium* and green crabs, dyking and erosion are all having increasingly negative impacts on salt marshes and eel grass beds in the Bay and other aspects of the Bay's ecosystem function.

In general, the overarching issues in the Bay of Fundy parallel those in the Gulf of Maine – fisheries, aquaculture, chemical contaminants, sewage, land use/coastal development, and loss of aquatic habitat. There is little evidence of eutrophication or climate change impacts in the Bay of Fundy. Extent of concern and seriousness of each issue varies with geographic location. For example, population growth and coastal development are occurring at a faster rate in the US part of the Gulf than in the Bay; managing this is more of a priority issue in the US as the impacts are more harmful. The majority of indicators selected for the Gulf of Maine (see Table 3) are relevant to issues in the Bay of Fundy, though some need to be altered slightly to deal with specific concerns (e.g. right whales, migratory bird populations, aquaculture impacts, Atlantic salmon populations and habitat, area of salt marsh). Similar to the Gulf of Maine, to best assess the Bay of Fundy, smaller environmental reports should be compiled (e.g. Minas Basin, Chignecto Bay, Passamaquoddy Bay, Saint John Harbour, St. Mary's Bay) and feed into an overall report on the Bay to get an idea of the general MEH and MEQ.

2.3. Minas Basin

The Minas Basin watershed is comprised of almost 17% of Nova Scotia's land area, supports almost 18% of the province's population, and is primarily rural land with a small number of slightly more densely populated urban centres (Willcocks-Musselman 2003). There has been little population growth in this area in the past decade, except for some specific areas (e.g. Kings County) (Willcocks-Musselman 2003). The coastal environment is particularly dynamic because of extreme tides and high siltation rates in the majority of the intertidal area (Willcocks-Musselman 2003).

The economy in the area relies mostly on primary resource activities such as agriculture (livestock, fruits, vegetables), forestry (mostly softwood species), mining (aggregates, gypsum, peat), and fishing (Willcocks-Musselman 2003). Local fishing activity and vessel numbers in the Minas Basin have been declining because of higher-powered fishing vessels and the continual input of pollution from the surrounding landscape, and the focus has been shifting towards mollusc (e.g. clams), crustacean (e.g. lobsters), and baitworm harvesting (Willcocks-Musselman 2003). Recreational fishing has also been suffering because of polluted and dammed rivers in the watershed; specifically, salmon in the inner Bay of Fundy have substantially declined (Willcocks-Musselman 2003). The manufacturing of traditional primary resources (e.g. food processing companies and sawmills) and textiles has been a growing industry in the area (Willcocks-Musselman 2003). The tourism industry is also increasing in the Minas Basin, especially for nature and ecotourism destinations, so conserving and protecting natural resources and areas is crucial (Willcocks-Musselman 2003). Wastewater facilities (e.g. Great Village) and landfill closures as a result of provincial waste diversion initiatives are being put into practice. There is also potential for titanium mining in the Shubenacadie River estuary and there is much uncertainty as to how it could affect fish, wildlife, and aquatic habitats.

In 2002, five public forum meetings were held around the Minas Basin watershed (Truro, Parrsboro, Summerville, and two in Wolfville) and three summary reports were produced and integrated into one report (Willcocks-Musselman et al. 2003). In the summary report for the Wolfville, Truro, and Parrsboro meetings, it was determined that the environmental and resource management issues of most concern are agricultural practices, development, fisheries management, forestry practices, sewage treatment/water quality, tourism, and recreation (Willcocks-Musselman et al. 2003). Sewage treatment/water quality and fisheries management are concerns throughout the watershed, but for the other issues geographic variations existed. In the summary report for the Summerville meeting, the main issues are forestry practices, fisheries management, agricultural practices, tourism, the Avon River Causeway, and development (Willcocks-Musselman et al. 2003). Table 4 outlines environmental and resource management issues in Minas Basin that were expressed during community and state of the Minas Basin forums.

Table 4. Issues and concerns raised in the Minas Basin resulting from community meetings (derived from TeKamp 2003 and Wilcocks-Musselman et al. 2003).

Environmental/Resource Issues	Specific Concerns
Agricultural Practices	Agricultural runoff, river pollution, river sedimentation, loss of farmland due to urban sprawl, pesticide and herbicide use, no buffers near rivers, quantity and quality of available water, fertilization
Fisheries management	Integrated fisheries management plan, declining stocks, fish habitat conservation/protection, inventory of fisheries resources and habitats, over-fishing, commercial fleets, review historical data, aquaculture impacts, gear impacts, salmon declines, impacts of commercial bloodworm harvesting, lack of clam flat recovery
Forestry practices	Inventory of activities, management plans, effects of practices, buffers in riparian zones, clear-cutting impacts, reforestation, land ownership, forest value, chemical spraying to eliminate hardwood, erosion, river siltation, effects on air quality
Water quality/Sewage	Sources of contamination, effects on aquatic resources, storm water runoff, water availability, groundwater quality, water quality parameters, sewage treatment plants
Development	Impacts, more planning, coastal access, erosion in residential areas, value of ecosystem services, wetland infilling, urban sprawl, river siltation
Tourism/Recreation	Trail systems, protecting natural areas, lack of tourism infrastructure, concern for/awareness of historical and cultural resources, lack of protected areas, ATV use
Others	Climate change (flooding, habitat loss, species change, affect on coastlines); invasive species impacts (from ship hulls, ballast water, and aquaculture)

There was a general consensus that a state of the environment report is needed for the Minas Basin watershed to be able to address these issues and assess current conditions (MEH and MEQ). People want information on how and why things are changing in the Minas Basin (e.g. increasing number of sandbars, decreasing shorebird numbers). People also want the identification of “hot-spots”, where critical interactions or use conflicts occur. For example, tourism and development can cause high densities of people where migratory seabirds are gathered. It is recognized that fisheries in the Minas Basin should be managed separately from fisheries in the Bay of Fundy because of the uniqueness of the area (e.g. tides, species, ecosystems) (Willcocks-Musselman et al. 2003). There is a need for more information concerning the future and past effects of the Avon River Causeway (e.g. sediment changes, siltation, impacts on fish) on the Avon River environment before any restoration efforts or further highway construction begin. This is the case because a new ecosystem downstream has developed since the causeway was constructed and it supports salt marsh and wildlife. Similar concerns also exist for other smaller tidal barriers in the area.

A GPAC-BoFEP forum was held concerning the state of the Minas Basin in October 2003 to discuss the health and quality of the Minas Basin watershed. Issues and concerns raised in numerous community meetings and results are summarized in TeKamp (2003). The results of this forum ultimately fed into the Gulf of Maine Summit Conference in 2004 that considered the overall state of the Gulf of Maine. In this forum, the Minas Basin was divided into sub-regions and a coloured matrix. This coloured matrix is similar to that of the traffic light methodology used for the EPA National Coastal Condition Reports. This forum resulted in a preliminary list of environmental and resource issues in the Minas Basin watershed on which to prepare future assessments.

Results from this forum showed that several "severe problem" indicators exist:

- Presence of critical habitats or natural areas: benthic habitat, beach and intertidal areas, tidal barriers, dams and dykes
- Water quality: bacteria and inshore nutrients
- Changes in species: populations
- Changes in resource use: Shift in targeted species (pelagic, groundfish, clams)
- Changes in use and integrity of water and riparian zones: clearing and development of natural areas, erosion (select regions)

There are also many indicators where not enough data or knowledge exists to determine if a problem exists with the issue:

- Presence of critical habitats or natural areas: spawning and nursery areas
- Water quality: inshore sediments, organic contaminants, acidification
- Changes in resource use: shift in targeted species (agricultural and forestry species), species introductions (freshwater species and land species)
- Changes in use and integrity of water and riparian zones: clearing and development of natural areas, erosion

This forum, along with other recent workshops, acts as a starting point from which to work from to begin to develop monitoring programs to develop indicators and to begin to fill in knowledge gaps. It is important to take a bottom-up approach such as this, where the community first sets objectives and then identifies and reaches consensus on environmental and resource issues for which indicators are selected to ultimately affect management actions.

3. Case Study – Minas Basin

3.1. Research in Minas Basin

Extensive research is currently being carried out around the Bay of Fundy (see the proceedings of the Bay of Fundy workshops) and significant research has been performed in Minas Basin. Research facilities that exist in or near the Minas Basin and its watershed include the College of Geographical Science (COGS), Acadia University, the Fundy Geological Museum, the Nova Scotia Agricultural College, and many other departments, organizations, and scientists are involved in research here (Chapter 2 in Pesch and Wells 2004). This research is important not only because it increases knowledge, but can also contribute to baseline data from which to develop monitoring programs to address resource and environmental management issues. It is important to note that short-term single studies that last a single season rarely produce meaningful results (Weins 1977) but studies that last years to be able to reflect dynamic nature of ecosystems and show abundance variations (Woodin 1974).

Scientific research in Minas Basin focuses on many topics, such as contaminants (e.g. copper in lobsters (Chou et al. 2002)), the endangered Atlantic salmon (Amiro 2003; Isaacman and Beazley 2005), foraging site selection of migrating birds (Hamilton et al. 2003), salt marsh productivity (Brylinsky and Daborn 1987), salt marsh sedimentation (Davidson-Arnott et al. 2002), mudflat species relationships (Wilson 1989; Hamilton et al., in press) and tidal barrier impacts. More recently, the environmental impacts of tidal barriers (large and small) are being examined (Wells 1999) and specifically, the Avon River causeway is a platform from which much research can be and has been performed over the past few years, primarily by Dr. Danika van Proosdij since 2001 (van Proosdij et al. 2005).

The health of the mudflats in Minas Basin must be protected to ensure adequate abundance of organisms that act as food sources for maintain migratory bird populations (especially *Corophium volutator*) and fish species. Though much research has been conducted on *Corophium volutator* (Wilson et al. 1997), more needs to be done to determine factors influencing changes in its abundance and distribution (see posters in Chopin and Wells 2001; Session 6 in Wells et al. 2004). Sediment dynamics in Minas Basin are complicated and a high variability of mudflat organisms exists making it difficult to determine patterns, so continuous monitoring of key species is required (Westhead 2005). Salt marshes also play an important role in the ecosystem of Minas Basin as they contribute nutrients and provide habitats for many bird and fish species. It is clear that many links exist between ecosystem components, such that if one part is damaged, it could directly or indirectly affect others. Numerous studies in Minas Basin focus on human impacts and investigate baitworm harvesting on shorebirds (Shepherd and Boates 1999) and flounder trawling impacts on habitat (Brylinsky et al. 1994). With new technologies such as GPS and GIS, research and monitoring programs can be integrated to take more comprehensively study the ecosystem.

3.2. Minas Basin Monitoring Programs

The following outlines current long-term monitoring programs that are occurring in the Minas Basin. It should be noted that more volunteer, university, non-governmental organization, and government monitoring and research programs exist, but information on some programs is disorganised, not updated, or difficult to access. Table 5 shows current monitoring programs in the Bay of Fundy and those that occur in Minas Basin are highlighted and by no means is this list exhaustive.

Table 5. List of some current, long-term Bay of Fundy monitoring programs and if known, how long the program has been in existence for (programs located in Minas Basin are highlighted).

Organization	What is being monitored?	Source
St. Andrews Biological Station (St. Andrews, NB)	- Geochemical measures to determine the degree of organic impact from aquaculture - Rate of aquaculture waste build up - the measurement of aquaculture chemicals in water, sediment, and biota - Tagging young salmon (since 2001) - Dynamics and occurrence of phytoplankton in water, shellfish, and ballast water (HAB research) (since 1987), shellfish toxicity (since 1943); temporal and spatial database of phytoplankton - Aquaculture effects on phytoplankton - tuna and swordfish tagging, lobster tagging, at-sea lobster and crab sampling, commercial catch data (pelagics, groundfish, invertebrates), field surveys of fish and invertebrates - water temperature, salinity, currents, dissolved oxygen, weather conditions, nutrients	http://www.mar.dfo-mpo.gc.ca/sabs/index-e.htm
Classification of Estuaries, Inlets and Coastal Embayments Project	- geographic, oceanographic, and hydrological parameters to provide baseline data (since 1993)	Gregory et al. 1993
Point Lepreau Environmental Monitoring Program, DFO (BIO) and NBEPC (Point Lepreau Nuclear Generating Station)	- radioactivity levels in the lower Bay of Fundy in seawater, air, sediments, marine biota, terrestrial and freshwater environments, birds (since 1978)	http://www.mar.dfo-mpo.gc.ca/science/mesd/projects/Contam-e.html#plemp
CWS Seabird Contaminants Monitoring Program (Kent, Manawogonish, Machias Seal Islands)	- organochlorines, PCBs, and metals in herring gulls, cormorants, Leach's storm petrels, and puffins (since 1968)	Chandler 2001

Table 5. cont'd.		
Organization	What is being monitored?	Source
CWS – Seabird Monitoring Surveys	- aerial shorebird surveys in Upper Bay of Fundy (1977-1994); public counts and identifies birds and assesses habitat (present)	Chandler 2001
Monitoring Working Group and Petitcodiac Watershed Monitoring Group (Petiticodiac Causeway)	- water quality (ions, nutrients, metals, fecal coliform bacteria, dissolved oxygen, salinity); sediment toxicity and sedimentation; migratory bird monitoring of numbers, species, and activity; benthic and macrophyte distribution and abundance; fish and invertebrate abundance and sampling; physical conditions (since 1997)	http://www.pwmg-gsbp.org/petitcodiac/north.html
ACAP Sites (4)	- Clean Annapolis River Project (since 1990) – water quality, air quality, fish habitat restoration, wetland monitoring, amphibians; includes Annapolis River Guardians - St. Croix Estuary Project (since 1992) – effects of scallop and estuary dragging, salmon aquaculture impacts, sampling finfish and shellfish for toxins, monitor faecal coliform bacteria, PAHs, nutrients, monitor rockweed harvesting, monitor aquaculture escapees - ACAP Saint John (since 1991) – monitor faecal coliform, salinity, pH, turbidity, dissolved oxygen, ammonia nitrogen, nutrients, electro fishing salmon surveys - Eastern Charlotte Waterways Inc. (1997) – bacterial monitoring program, water quality monitoring	http://atlantic-web1.ns.ec.gc.ca/community/acap/default.asp?lang=En&n=085FF7FC-1
New Brunswick Finfish Aquaculture Monitoring Program	- benthic sediment conditions below aquaculture facilities (since 2002)	Finlayson 2003
Atlantic Beach Guardian Program (2000)	- monitoring beaches and nesting sites of the piping plover (since 2000)	http:/www.atl.ec.gc.ca/press/01-08-13_nsb.html
Canadian Food Inspection Agency Biotoxin Monitoring Program	- marine biotoxin monitoring programs	http://www.shellfishquality.ca/safety2.htm; http://www.atl.ec.gc.ca/epb/sfish/cssp.html

Table 5. cont'd.		
Organization	What is being monitored?	Source
University of New Brunswick (Saint John)	- records from late 1800s – late 1970s - in 2000, sites selected to start up monitoring again (Grand Manan, Letit, Lepreau) - red, green, brown seaweed diversity and abundance	Bates et al 2001
DFO	- salmon populations in 32-42 rivers that drain into the Inner Bay of Fundy (since at least the late 1960s)	Wells et al. 2004
Index of the Quality of the Air (NB)	- air quality (ozone, sulphur dioxide, hydrogen sulphide, etc.) - sites around southern NB (including St. Johns and Fundy National Park, Point Lepreau)	http://www1.gnb.ca/0355/0003/0000.asp
Cumberland Basin research	- research on northwest shore of Cumberland Basin, Allen Creek marsh - monitoring of sediment transport and deposition, marsh dynamics, rate of cliff recession, adjacent mudflats (since 1996)	http://www.uoguelph.ca/geography/faculty/Robin/research/saltmarsh.html
CWS, CSA, CCG (mid 1990's)	- satellite monitoring of oil spills and oily releases from shipping in the offshore (since the mid-1990s)	http://www.gulfofmaine.org/nciw/ANCMSProceedings2.pdf
DFO, CCG (MCTS NB)	- continuously monitors vessel traffic in the Bay of Fundy and collisions with Right Whales are reported here (since late 1990s)	Percy et al. 2005
Kings County Volunteer Water Quality Monitoring Program	- water sampling, temperature, secchi disk measurements - 10 lakes in Kings County (since 1997)	www.county.kings.ns.ca/comdev/lakemon/
Friends of Cornwallis River Society	- water quality, dissolved oxygen, temperature, pH, faecal coliform (since 1994)	http://www.gulfofmaine.org/times/spring2005/visionary2.html
Canadian Shellfish Sanitation Program (NB and NS)	- monitors shellfish growing waters (water quality, pollution, bacteria (since 1948)	CFIA 2005
Ecology Action Centre	- Cheverie Creek salt marsh monitoring (habitat mapping, vegetation, hydrology, fish, soil, sediments, insects, birds) (since 2001)	EAC 2005
Avon River Causeway	- changes in spatial patterns and area of salt marsh (since 1970s)	Percy et al. 2005

Table 5. cont'd.		
Organization	What is being monitored?	Source
Gulfwatch (12 stations in NS, 6 stations in NB)	- monitors mussels for heavy metals and organic compounds (since 1991)	GOMCME 2003
Minas Basin Pulp and Power and CKF, Inc. Environmental Monitoring Programs	- monitor toxicity of effluent, water quality, fish, benthic invertebrates, sediments (since 1994)	http://www.ec.gc.ca/EEM/English/PulpPaper/general.cfm; http://www.atl.ec.gc.ca/epb/eem/em_v1n1e.html
COGS and CHS	- uses satellite images to monitor changes in sea level in the Minas Basin to study extreme tides and tidal surges (since 2002) - SAR imaging system in Minas Basin and Annapolis Basin (soil and erosion mapping, coastal geomorphology, watershed analysis) (since 1990)	http://www.mar.dfo-mpo.gc.ca/science/ocean/coastal_hydrodynamics/MinasBasin/MinasBasin.html; Chopin and Wells 2001
CWS (Maritimes Shorebirds Surveys)	- monitors shorebird populations at approximately 50 sites around the Maritimes (most sites located in NB and NS around Bay of Fundy) (since 1974)	http://www.cwf-fcf.org/pages/wildresources/surveys/survey30.htm; http://www.pnr-rpn.ec.gc.ca/nature/whp/whsrn/index.en.html
Nova Scotia Salmon Association (1963)	- fish habitat, water quantity and quality, thermal monitoring (many streams and rivers in NS) (since 1963)	http://www.novascotiasalmon.ns.ca/

A long-term monitoring program that has existed in Minas Basin since the late 1950s is the Canadian Shellfish Sanitation Program (CSSP), which is jointly administered by DFO, EC, and CFIA and conducts routine bacteriological water quality and planktonic surveys of areas where shellfish are harvested (CFIA 2004). In the Minas Basin, three areas with high populations or heavy agriculture use are closed (Parrsboro harbour, the entire Southern Bight, and upper Cobequid Bay) (Young et al. 2002). Two other smaller areas at Five Islands are closed and this is thought to be due to non-point pollution from livestock and agriculture (Young et al. 2002). Over time (between 1995 and 2003) the percentage of closed areas in Minas Basin has not changed significantly (Young et al. 2002). Because of limited funding and the fact that mussels are not very common in Minas Basin, most recent Gulfwatch data for Minas Basin is from 1994 (one Five Islands site), and low levels of organic contaminants and some metals were found, though nickel and cadmium levels were slightly elevated.

Two pulp and paper mills (Minas Basin Pulp and Power and CFK, Inc.) in Hantsport are monitored for regulatory purposes and they must meet the federal Pulp and Paper Effluent Regulations (*Fisheries Act*). These companies will also be participating in the Pulp and Paper Aquatic Environmental Effects Monitoring Program to determine how their industrial activity is affecting ecosystems. Mills were required to file a pre-design study report outlining the mill history, effluent characterization, descriptions of fish habitat, fishery resources and receiving water quality in the area of the plant's discharges, which these mills have submitted. Based on this data, an EEM study was designed to assess adult fish populations, benthic invertebrate community structure, water and sediment quality, and the sub-lethal toxicity of the effluent. This program has the potential to be successful and to contribute to minimizing the deterioration of MEH in Minas Basin as these companies are active, have completed the third cycle of monitoring and analysis, and are currently in the preliminary stages of the fourth cycle.

The Kings County Water Quality Monitoring Program was initiated in 1997 and reports are regularly produced (See Brylinsky 1999, 2000, 2003, 2005). Volunteers collect water samples, record air and water temperatures, and measure water clarity in ten lakes in the watershed. From these samples, a phosphorus model is being developed in hopes of predicting change in water quality as a result of residential development on the coast. Also from this data, the municipality can validate and refine planning models to predict the capacity of the lakes to support development. Official water quality objectives are used to guide land-use decisions in the county, which is an important step to managing ecosystems.

In 2001-2002, baseline data was collected for Cheverie Creek (West Hants County) to investigate the potential for culvert replacement to ultimately restore the salt marsh here. Since 2002, monitoring of vegetation, fish, birds, insects, salinity, temperature, sediment movement, and groundwater levels have been monitored and habitats have been mapped using GPS (EAC 2005). Monitoring of restoration and post-restoration activities will continue to occur at Cheverie Creek as hopefully this site will act as a model site to show that salt marsh restoration is feasible. Tidal rivers and salt marshes in the area are also being assessed and used as reference sites. The culvert is scheduled to be replaced in September 2005.

The Friends of the Cornwallis River Society has been in existence since 1994. This group monitors water quality and promotes awareness of fish and fish habitats in schools. They are hoping to repopulate the river with salmon. They are also creating riparian edges and restricting livestock access to the water's edge that will both help conserve wildlife habitat and decrease contamination from agricultural runoff. They also educate community members about restoring and protecting the Cornwallis River watershed and are developing a fisheries management plan for the river.

Another important biological component of the coastal ecosystem in Minas Basin are the migratory shorebirds. The Canadian Wildlife Service implemented the Maritimes

Shorebird Surveys program in 1974, which is a volunteer-based shorebird monitoring program. The purpose of this program is to monitor shorebird population trends in hopes of providing direction for government and conservation agencies. A newsletter (Calidris) is distributed presenting the survey results. Sites in Minas Basin include Grand Pré East, Guzzle (Grand Pré), Penny Beach (Bluff Road), Ridge Road Farm Pond, Thomas Cove, Windsor mudflats/causeway, Windsor sewage ponds, Windsor Tourist Bureau, Evangeline Beach, Evangeline Beach East, Wolfville Harbour, and Economy. Sites are monitored between 1-10 times a year.

3.3. Minas Basin Management Questions

If the indicator approach is going to work and conserve MEH, the choice of indicators should depend on the management questions being asked and science should support these indicators (Niemi and McDonald 2004). To answer management questions, we need inventories and baseline data to determine the current status and be able to tell if trends are emerging (Wells et al. 2005). It is vital that management issues and questions are devised that are relevant to the Minas Basin region. As stated in the previous chapter, the main environmental and resource issues facing Minas Basin are: agricultural practices, fisheries management, water quality/sewage, forestry practices, development, and tourism/recreation. Even though climate change is an emerging issue, it is not a priority issue in Minas Basin as direct impacts are not yet being felt by communities to a great extent and more public education on this issue is required. Until climate change affects an important aspect of people's livelihood (e.g. water temperatures rise in Minas Basin causing important commercial fish species to change their distribution resulting in decreased catches, or increased flooding of land and highways) it will not be at the top of resource and environmental management's decision list. Invasive species, though some occur here (e.g. green crab, chain pickerel), do not seem to be having a significant negative impact in the Minas Basin coastal ecosystem (TeKamp 2003). Management approaches, such as ballast water control and aquaculture regulations and monitoring, should be taken to prevent the spread of invasive species in the Basin. Nutrients are not a huge problem in Minas Basin (Pesch and Wells 2004), though there are a few local hotspots as a result of sewage discharge so it is important that this is monitored for as well to ensure that severe eutrophication does not occur.

The following outlines the main, current management issues in Minas Basin and its watershed for which indicators and indices should eventually be selected:

Agricultural Practices

- How are agricultural practices impacting coastal ecosystems? (pollution, runoff, erosion, groundwater quality, manure effects)
- What is the trend of fertilizer, herbicide and pesticide use? (increasing? decreasing?)
- How are agricultural practices and crops changing over time?
- How will climate change affect agriculture?
- How is the development of farmland (e.g. urban sprawl, increasing tourism) affecting coastal ecosystems?
- Is education about proper farm management and consumer perspective increasing and being used?

Fisheries management

- Is the balance between local and distant fleets changing?
- What is the status of fish and fishery resources?
- What are the impacts of fisheries on habitats? (digging in mudflats, trawling)
- What are the effects of fishing on other species and the surrounding ecosystem?
- Is fisheries management improving? (better communication and integration?)
- Are fisheries contributing to greater socioeconomic development in the region?
- How are tidal barriers impacting fish populations?
- How is recreational fishing impacting fish stocks?
- How are fishing methods changing? (drift net to dragging, pelagic to groundfish)
- Are new fisheries emerging and what are their impacts?

Water quality/Sewage

- How are contaminant levels in Minas Basin changing?
- Are management actions of point and non-point source pollution impacting contaminant levels and decreasing effects on human health and improving EH?
- What is the groundwater quantity and quality?
- Is contaminated groundwater entering the Basin?
- Is public access to water quality monitoring data improving?
- Is the percentage of closed shellfish harvesting areas increasing?
- Are wastewater facilities and landfill closure initiatives being put into practice?
- What are the main sources of contaminants and what are the effects on aquatic resources?
- Are nutrient levels in shallow coastal waters changing?

Forestry practices (most issues are a direct or indirect result of clear-cutting)

- Are current forestry practices becoming more sustainable (ecologically, socially, and economically)? (maintaining riparian zones, reducing clear-cutting, using less chemicals, using selective harvesting)
- What are the impacts of forestry on coastal ecosystems? Human health? Air quality?
- Are sustainable forestry management plans for the watershed being developed and implemented?

Development

- What percentage of land is protected for conservation purposes?
- What are the impacts of development on coastal resources?
- Is development affecting coastal habitats and salt marshes?
- What is the direction and rate of land use change?
- Are land management plans being developed and implemented?
- Is there adequate coastal access and wharves for the public and fishers? (percentage of privately owned coastline)

Tourism/Recreation

- What impacts are tourism and recreation activities having on coastal ecosystems?
- Are tourism and recreation activities increasing?
- Are tourism activities taking proper conservation precautions to minimize environmental harm?
- What are the impacts of new and existing tourism infrastructure?
- Are natural, cultural, and historical features being preserved and protected?

Emerging Issues

Climate Change

- How will climate change impact coastal ecosystems, agriculture, marine resources, aquatic life, coastlines, and atmospheric and ocean circulation (or each of the above issues)?
- Are management practices in Minas Basin being implemented to reduce carbon dioxide and other greenhouse gas emissions?

Invasive species

- Are invasive species affecting Minas Basin coastal ecosystems and altering its trophic structure?
- Are the diversity, abundance, and distribution of invasive species changing?

3.4. Suggested Indicators for Minas Basin

Central to the development of a successful monitoring program or a network of monitoring programs is the selection of appropriate indicators to monitor high priority threats to the marine environment (Strain and Macdonald 2002). Each indicator must be selected within the context of available resources (Strain and Macdonald 2002). Thus, indicators in Minas Basin should be chosen with the capacity of the region in mind (e.g. community support and participation, monetary resources, scientific resources, government commitment). The spatial boundary given to the Minas Basin ecosystem for which indicators should be developed will be its watershed (Figure 8); the watershed is also the boundary that was used for the Great Lakes assessments (Shear et al. 2003). The watershed is an appropriate spatial, physical boundary, provides a management focus for water-related activities, and shows linkages between upstream and downstream effects (Yanez-Arancibia and Day 2004; Morimoto et al. 2003).

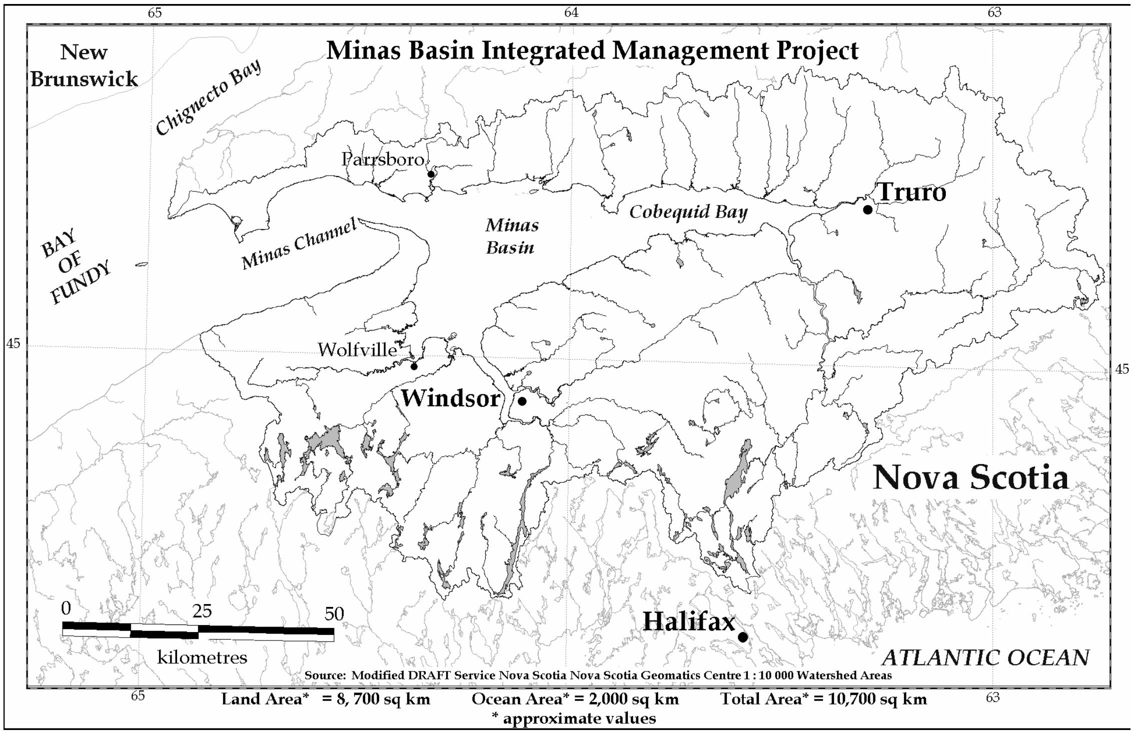

Figure 8. Map of Minas Basin watershed (Minas Basin Working Group in Wells et al. 2004).

While the EPA traffic light approach takes a quantitative approach to assess indicators, the Great Lakes approach takes a qualitative approach. For the purposes of Minas Basin, indicators should be developed with quantitative numerical targets and defined goals so MEH assessment is not subjective. The definition of poor, fair, and good should be based on existing criteria, guidelines, objectives, or interpretation of scientific literature, similar to that of EPA National Coastal Condition Reports (US EPA 2001, 2005). These criteria should be agreed upon by communities in Minas Basin. Each indicator should be scored out of 5 (1-“poor”, 3-“fair”, 5-“good”). A scale out of 5 instead of 10 should be used to keep this approach as simple and as least subjective as possible. Following the assessment of each indicator, the scores of each indicator can be added and then averaged for each health index to give an idea of the condition of the overall Minas Basin. In the case of Minas Basin, four indexes are suggested to comprise the overall Minas Basin Health Index: Water Quality and Contaminants Index, Fishery Resources Index, Benthic Index, and Development Index. This overall health index value should be recalculated at regular intervals to best monitor improvement or deterioration of MEH. Supplemental information concerning areas of local concern should also be put into a report on Minas Basin, in addition to information provided by the indicators.

Table 6 shows a list of proposed indexes and indicators that could possibly be used to determine MEH in Minas Basin and take into account current monitoring programs and scientific research. It is important to note that these indicators show that an environmental threat exists and there still must be efforts made to determine the cause, and determine if long-term measures should be taken to alleviate the cause.

Table 6. Suggested "Minas Basin Health Index" comprised of Indexes and Indicators of Marine Ecosystem Health for Minas Basin, Bay of Fundy.

Index	Indicator or Measure	Comments	Addresses which issues?
Water Quality and Contaminants Index	Water samples: - dissolved oxygen, - temperature - salinity/conductivity - clarity - chlorophyll a - nutrients (N and P) - bacteria (faecal coliform) - percentage of shellfish area closed to harvesting - mussel tissue for contaminants, bacteria, phytotoxins	- many of these measurements can be taken by volunteers - programs need to be integrated (volunteer programs, Gulfwatch, CSSP) - take water quality measurements in rivers throughout watershed - perhaps sample lobsters or a fish species as well as mussels eventually, but need more research on this to get an idea from other trophic levels	- nutrients, sewage, bacteria, metals, contaminants, impacts of land use (forestry, industrial effluents, non-point source, agriculture) - should be able to tell if contaminant, pollution, and sewage management actions are reducing negative effects on human health and improving MEH
Fishery Resources Index	- fisheries landings and independent surveys measurements of size, age, and mean catch size - spatial distribution of bottom fishing	- will tell changes in community structure, status of exploited fish stocks (lobster, eel, dogfish catch increases, decreases in herring, flounder, sturgeon, striped bass) - should also keep an inventory of the industry composition (local/commercial and pelagic/groundfish/crustaceans/new species), and fisheries management plans	- changes in community structure; fishing effects on other ecosystem components - impacts of fisheries on bottom habitat (digging in mudflats, trawling); changes in distribution and intensity of trawling - should be able to tell if fisheries management plans are effective
Benthic Index	- sediment toxicity - diversity, presence and abundance of benthic species	- potentially get volunteers to take samples - polychaetes, amphipods, gastropods; look at presence of pollution tolerant or pollution sensitive species	- point source and non-point source pollution; storm water - industrial (forestry and agricultural; pesticides, chemicals, fertilizers) organic and inorganic contaminants, metals - biological productivity of mudflats

Table 6. cont'd.			
Index	Indicator or Measure	Comments	Addresses which issues?
Development Index	- % of preserved undeveloped land/developed land in watershed - types and rates of land use - population growth and density - sediment/habitat erosion and accretion rates - habitat area altered by tidal barriers and coastal development - area (km2) of restored or unobstructed river habitat (from removal or construction of tidal barriers) - population status of Atlantic salmon - shorebird population surveys (species composition and relative abundance)	- use remote sensing and GIS if possible; aerial photography to determine erosion, accretion, and the impacts of tidal barriers - land use types: natural, residential, disturbed, agricultural, urban, industrial, forestry, etc. - many salmon programs exist already and these should be integrated - shorebirds can be a sign of healthy, productive marine ecosystems and long-term shorebird survey (MSS) in Minas Basin in existence and needs to be integrated with all other areas where there shorebirds visit during their migration (linked with the Western Hemisphere Shorebird Reserve Network which works to conserve migratory birds and their habitats across North and South America)	- effectiveness of land-use plans (currently not much municipal land-use planning exists in Minas Basin, but MBWG working on this) - impacts of development and population growth on coastal ecosystem - area of salt marsh habitat - effects of tidal barrier construction or restoration

Selecting and developing indicators should be based on management issues that are of greatest concern to local communities and stakeholders and should have scientific support to help identify issues that communities may not be able to recognize (e.g. new trace chemicals). Community forums around Minas Basin have been effective in evoking this participation, but it must be an on-going, continually active process. The final indicator selection should ultimately be based on a combination of science and stakeholder input. An inventory of the current management plans in Minas Basin is required (e.g. sewage, agricultural, forestry, fisheries, pollution, contaminants, land-use plans) and this database should be kept active to see if progress is being made over time and if these plans are improving or sustaining MEH. From this, we should be able to compare MEH in Minas Basin before and after these plans are activated and completed. For example, in Nova Scotia, farmers have the option of voluntary using an Environmental Farm Plan (EFP). This EFP allows farmers to get assistance with identifying and assessing environmental risk and taking environmental impacts into consideration on issues such as water use and management, pesticide use, and nutrient management (fertilizer and manure use and storage). It is important that indicators are developed that can assess the effectiveness of programs so these people can see the benefits of environmental management plans, be it for agriculture, forestry, land-use, or sewage treatment. As the monitoring of indicators occurs over time, a clearer and more complete picture of MEH of Minas Basin should emerge. Information gaps will also become apparent, so monitoring programs and indicators may have to be added, refined, or removed.

4. Coastal Management Challenges for Minas Basin

4.1. Organization of Monitoring Programs

In any geographic region, it is important that management questions are organized appropriately with monitoring programs. Presently, much of the monitoring and research data for the Bay of Fundy are scattered and difficult to locate and access (Percy et al. 1997). The fact that this information is as yet disorganized makes it difficult to answer the question of whether monitoring programs are organized appropriately with key management questions, especially in Minas Basin. Inventories of monitoring programs are more organized and complete for the US part of the Gulf of Maine and these programs are often further developed than those in the Bay of Fundy (see Finlayson 2003). Fortunately, the amount of GIS-based information being made available in the Bay of Fundy is rapidly increasing and hopefully this will be used effectively to help organize monitoring programs and assess trends in MEH.

Limited programs, personnel and funding in Minas Basin has led to basic monitoring of local concerns and of some regulated indicators because of potential human health effects (e.g. industrial effluents and shellfish harvesting areas). It is encouraging that volunteer groups (Kings County Water Quality Monitoring and Friends of the Cornwallis River Society) are having success with their monitoring programs and have lasted over time. Local communities are interested and concerned.

Table 7 outlines steps that the more developed and successful monitoring programs in North America suggested to develop a successful monitoring program. It is encouraging that some long-term monitoring programs are successful (e.g. Chesapeake Bay Program and the Gulfwatch Program) and that we can learn from them. Through MBWG efforts and forums involving the public, scientists, managers, and resource users, some steps have been taken in hopes of developing long-term integrated monitoring programs in Minas Basin (e.g. identifying goals for Minas Basin, implementing small individual monitoring programs, holding meetings of smaller breakout groups, and keeping in contact and encouraging communication with involved parties). These small initial steps are positive, but there is still a long way to go. Implementing a coordinated monitoring program to measure indicators in Minas Basin is feasible. Besides choosing the best indicators, another daunting task will be coordinating potential monitoring programs around with Minas Basin watershed with all of the other monitoring programs around the Bay of Fundy and Gulf of Maine, which is an ongoing goal of the GOMCME.

Table 7. Key steps identified for developing an effective monitoring program (adapted from ANCMS 2002) and whether these steps are currently relevant to Minas Basin.

Requirement	Description	Relevant to Minas Basin?
Planning and products	▪ Identify and agree on program goals, objectives, and products	Yes
	▪ Adaptive management plan	No
What, when, where, and how	▪ Identify a core set of indicators that have a clear use related to the purpose of the program	No
	▪ New indicators should be able to be incorporated	No
	▪ Minimum spatial and temporal requirements defined for indicators	No
	▪ Use appropriate monitoring techniques to ensure data comparability among programs	No
Data Management and Reporting Results	▪ Report results in a timely manner	No
	▪ Ensure easy access to data and results	No
	▪ Ensure results are meaningfully communicated to decision-makers, the public, and scientists	No
Program Review	▪ Flexibility in program design to drop ineffective indicators and adding new indicators	No
	▪ A five-year review cycle was suggested for maximum efficiency	No
Funding	▪ Lack of sufficient funding is a problem	Yes
	▪ Start programs as smaller pilot projects and then, if successful, build to include more parameters	Yes (partially through the Gulfwatch program)
	▪ Hire a program manager to focus on the goals of the project	No
Communication and Coordination	▪ Requires persistence and patience	Yes
	▪ Coordination is easier when implementation is written into existing agency mandates	No
	▪ Hold large and smaller break-out group meetings	Yes
	▪ Specify what each group will supply from the beginning	No
	▪ Ensure open channels of communications across all levels	Yes

4.2. Applicability, Use and Scale of Indicators and Reports

The entire Gulf of Maine is comprised of many estuarine habitats, such as salt marsh, seagrass beds, tidal mud flats, underwater rocky outcrops, and kelp beds and each has its own associated biota. Consequently, environmental and resource management issues may vary throughout, so as habitats and biota vary, so should the indicators used to assess MEH. State of the environment reports of smaller ecosystems should feed into environmental reports of larger ecosystems to get a comprehensive view of total ecosystem health. For example, state of the environment reports for Minas Basin, Chignecto Bay, St. Mary's Bay, Saint John Harbour, and Passamaquoddy Bay should be integrated to get an overall idea concerning the state of MEH in the Bay of Fundy (e.g. Regional ← Subregional ← Local Watershed and Embayment). This state of the Bay of Fundy report could then feed into a state of the Gulf of Maine report. In Pesch and Wells (2004), issues were identified in community forums and the results are displayed on a regional basis in the Gulf of Maine; these could possibly be the smaller regions for which state of the environment reports could be prepared. A challenge is going to be determining the spatial boundaries of these smaller ecosystems, especially those areas that are shared with the US; boundaries ideally should not be based on jurisdiction, but on ecosystem characteristics.

Overarching management issues are similar for the entire Gulf of Maine, Bay of Fundy, and Minas Basin, though there are some geographic variations and local issue "hot-spots." Other monitoring programs have suggested that indicators that reflect the "big picture" condition of a larger ecosystem, such as the Gulf of Maine, are not particularly useful at a local level, such as examining the Avon River (Pidot 2003). Thus, Gulf-wide indicators have yet to be proven highly relevant in addressing local concerns. In the case of the Great Lakes, indicators were chosen focusing on the whole Great Lakes basin or on individual lakes; it was necessary to develop indicators that are relevant to local areas and assess these areas on a smaller scale (GLRC 2005). Ultimately it was decided when choosing suites of indicators that they must be able to assess trends and conditions from both a large-scale (basin-wide/Gulf-wide) and on an individual watershed level, and that the choice should depend on specific concerns (GLRC 2005).

4.3. Limitations of Indicator Use

Choosing appropriate indicators is an essential part in developing successful monitoring programs (Strain et al. 2002). It is recognized using indicators to assess MEH is an integral part in environmental and resource management (Rogers and Greenaway 2005); some limitations to using indicators do exist and should be recognized. Emerging and changing coastal activities and issues pose a challenge for scientists and managers who are developing indicators to assess current MEH. The cost, equipment, and expertise required to measure some indicators may be too high resulting in the omission of certain important indicators from monitoring programs (Strain et al. 2002). There is a need for integration of indicators across ecosystem structure and function, as this is currently lacking (Boesch and Paul 2001). Indicators should provide a comprehensive description of the status of marine ecosystems, and it will be a challenge to choose indicators that can do this until a better understanding of how the ecosystem interacts exists (Rogers and Greenaway 2005). For now, ecologists need to simplify and explain the more complicated indicators (e.g. indicators of ecosystem function) and work together with managers and local communities to achieve understanding, best meet the needs of monitoring programs, and assess MEH.

Setting reference points for indicators from which to measure changes in the ecosystem is also a challenge. To support decision-making, values, or reference points, associated with specific ecosystem states need to be known (Rice 2003). Jennings and Dulvy (2005) state that reference points that relate to an impaired ecosystem might be affected by the "shifting baseline syndrome", where baselines set with a short-term perspective represent an increasingly impacted state over time (Pauly 1995). The shift of the baseline represents a gradual accommodation of the degradations of ecosystems from activities such as overfishing or pollution inputs, which makes it difficult to identify targets for restoration and rehabilitation measure (Pauly 1995). Indicators should be assessed regularly, in relation to reference points to identify changes in the ecosystem. It is important that appropriate indicators and reference points are chosen so effective management decisions can be made to ultimately improve MEH.

5. Management Recommendations

Along with international indicator initiatives (e.g. IOC 2003), many federal initiatives exist in Canada that are working to develop and promote the use of indicators, such as the Federal-Provincial-Territorial Coastal and Ocean Indicators in Support of the Integrated Management of the Oceans (2004), Ecological Monitoring and Assessment Network (1990s), and a national workshop on the objectives and indicators for ecosystem based management (Jamieson et al. 2001). All of these initiatives worked to develop general indicators that are applicable to various ecosystems. Even though commonalities exist amongst different ecosystems, indicators may have to be altered slightly to fit the characteristics of a specific ecosystem. In the Gulf of Maine and Bay of Fundy, many suggestions exist from forums and surveys on indicator selection, the number of indicators to use, monitoring improvements, and data reporting. We need to take the results into consideration when developing a similar approach in Minas Basin.

Currently, the GOMCME is reaching a consensus on suitable indicators for the Gulf of Maine and Bay of Fundy and it will be years before these indicators and associated monitoring programs are implemented. It is questionable if this process is going to be effective because the issues that emerge in the near future may not be the same issues that exist today. We must keep these action plans adaptable and flexible and learn from the experiences of other long-term monitoring programs that have incorporated new indicators into their management plans. These flexible plans need to be able to accommodate various temporal and spatial scales, environmental issues, and ecosystem components to be able to meet the needs of multiple stakeholders and decision-makers (GLRC 2005). Valuable lessons can be learned from the State of the Lakes reports, the National Coastal Condition

Reports, and the CPB, as these long-term monitoring programs are currently dealing with these challenges. Such reports are a culmination of years of hard work, experience, scientific research, and efforts from many people. Perhaps representatives from the CPB, EPA and Environment Canada who participated in the process of preparing these state of the environment reports could be consulted with for the selection of indicators in the Gulf of Maine.

A long-term commitment and plan is required for monitoring programs to be able to measure ecosystem trends and changes. This is a challenge because governments usually do not plan for more than a few years in advance. Volunteer groups should get involved in monitoring, such as the Kings County Water Quality Monitoring Program, but scientists are also required to confirm methodologies and statistically analyse the collected data. Keeping volunteers engaged and interested over the long-term is also a challenge as local interests change over time and volunteer-burnout occurs. Atlantic Coastal Action Program (ACAP) sites could be placed around the Minas Basin watershed in a few select locations. The ACAP program has been successful in initiating the community-based management of coastal areas and watersheds and each site is partnered with Environment Canada. BoFEP and GOMCME involvement with the ACAP program should be encouraged.

Considerable scientific research and synthesis is occurring in the Bay of Fundy as is evident in the biennial Fundy Science workshops where the sharing of scientific information is encouraged. It is important that this scientific information is relevant to the resource and environmental management issues in the area and that this information is transferred to marine managers. This is recognised in the Bay of Fundy. Much research is also focused in Minas Basin, as outlined in Chapter 3, and this research could provide baseline data and scientific understanding for potential conversion to long-term monitoring programs, as few currently exist. Scientists need to apply monitoring data to scientific questions and to apply this data to the understanding of the impacts of ecosystem stressors (Strain and Macdonald 2002). Implementing monitoring programs can also help identify gaps in the understanding of stressors that can lead to research topics (Strain and Macdonald 2002).

Copious amounts of information concerning the use of indicators and monitoring to improve MEH exist. The amount of information is becoming overwhelming and repetitive, so it is crucial that it is inventoried and organised. We know what the marine environmental problems are and what should be done to alleviate environmental stress, but funding and the enforcement of existing regulations are limited. We need to develop a current inventory of all of the monitoring and scientific research going on in Minas Basin as well as the entire Bay of Fundy. This could be accomplished, in part, through surveys given to participants in the Bay of Fundy Workshops and the community forum meetings around Minas Basin. This database would have to be continually maintained; someone should be hired to be responsible for this and investigating the programs and identifying where the data gaps are so management objectives can be met. One group (perhaps the MBWG as they have already performed substantial research and consultation in Minas Basin) should take a lead role in organizing and coordinating monitoring and research programs in Minas Basin. Someone should be hired to carry out this task and keep the database up to date so that changes and trends in MEH can be documented. More widespread monitoring is required to be able to detect emerging threats and other impacts such as changes in fish community structure and climate change impacts. If research and monitoring programs were to become more coordinated through a region-wide strategy, funding would not be such a limiting factor in achieving environmental and resource management benefits (GLRC 2005). Some resource and environmental issues and their associated impacts cross boundaries, such as fishing, aquaculture, air pollution, and sewage, so indicators and monitoring should be consistent for each of these issues.

When outlining management questions for an area and identifying which indicators should be measured, a long list of potential indicators is going to be the outcome. From this list, the most feasible indicators that reflect the capacity of the area should be measured, and priority issues, such as the monitoring of harmful algal blooms, should be monitored for first, before looking at the non-harmful stresses. It has been suggested that the best way forward is to select a limited indicator suite over the short-term that is well understood, and eventually to develop a more comprehensive set as time progresses (EEA 2002). In practice, this has occurred in the process of developing the US EPA National Coastal Condition reports. Successful monitoring programs suggest starting a small pilot project, with a few select indicators, and after success, the program should grow to include more indicators.

Indicators and environmental reports that are produced need to be kept short and simple; at the same time indicators need to be able to answer both simple and complex questions about the marine ecosystem. Indicator descriptions, assessments, and monitoring data and information need to be available to the public. This is being done in a few programs in Minas Basin (e.g. Maritimes Shorebird Surveys, Kings County Volunteer Water Quality Monitoring Program, Gulfwatch). Monitoring efforts need to be integrated among all agencies (e.g. government, non-governmental organisations, local community groups, and internationally). Indicators are important for supporting the objectives of the ecosystem approach and for this indicator approach to be useful, it should be coordinated and not sectorally driven (Rogers and Greenaway 2005).

People care more about issues that are of economic and health value to them. For example, people throughout the Minas Basin watershed are especially concerned about sewage impacts because it has the potential to negatively affect water quality (e.g. the water that they drink, swim in, and harvest fish from). It is difficult to get people to change their activities in order to conserve MEH, as harmful impacts of their current activities may not occur for years. Information sessions should be held around the Minas Basin watershed to engage community members to be concerned about issues that are currently of concern (e.g. water quality), but also about issues that could have the potential for detrimental impacts in the future (e.g. climate change). When it comes to an environmental crisis, currently we are a reactive society instead of preventative one, so it is important that management systems respond to indicator warnings before a crisis status is reached, as is done with the shellfish and biotoxin programs previously mentioned (Wells 2005). Monitoring is important, but eventually the problem must be fixed, which is why determining the cause is important. Indicators can bring to light environmental threats through observations of biological impacts, but the cause must be determined and understood in order to mitigate or fix the problem and devise indicators that are preventative (Strain and Macdonald 2002). Fixing the cause of the problem is a long-term task, which may or may not be a management objective as it is usually more practical to mitigate the stressor than remove it completely (Strain and Macdonald 2002). For example, in the Minas Basin, should groundfish catches decrease, fishing for these species will not be prohibited, but fisheries management plans will be altered to decrease quotas.

Information needs to be collected on influencing factors that are exerting pressure on the ecosystem, from a local to a regional (large marine ecosystem) scale, to ultimately be able to properly assess trends. It will be a continuous challenge to develop management approaches and spatial boundaries for ecosystems in the entire Gulf of Maine, shared by Canada and the US. Management will have to be cooperative, coordinated and effective at addressing multiple issues, building on the current GOMCME model.

Finally, it should be noted how indicators and monitoring need to play a key role in implementing Canada's Ocean Action Plan which will operationalize the *Oceans Act*. The Oceans Action Plan is based on four pillars: international leadership, sovereignty and security; integrated oceans management for sustainable development; health of the oceans; and ocean science and technology. Monitoring and indicators support three interlinked elements of Part II of Canada's *Oceans Act* (integrated oceans management, marine protected areas, marine environmental quality). Canada has committed to working collaboratively with the US to build upon the work of the GOMCME in the Gulf of Maine in hopes of advancing sustainable resource use and watershed preservation actions (DFO 2005). Governments and other agencies will need to work together to come up with integrated monitoring programs that cover entire watersheds and coordinate the choice of indicators if large marine ecosystems, like the entire Gulf of Maine, are to be protected. Canada has committed to implementing a network of marine protected areas that includes Marine Wildlife Areas, Migratory Bird Sanctuaries, and National Marine Conservation Areas. For these types of protected areas to be identified, the long-term monitoring of certain indicators is required. For example, in Minas Basin, Boot Island is a National Wildlife Area because it supports various species of migratory shorebirds, and this would not have been discovered in the absence of continuous long-term monitoring. Another aim of the Ocean Actions Plan is to maintain biodiversity, productivity and physical-chemical properties of marine ecosystems; if these are to be maintained, we must continually monitor indicators to assess these and other indicators of MEH in order to evaluate trends. DFO will use ecosystem overview and assessment reports (one of which is currently in the process of being prepared for the Minas Basin) as an ocean management tool to assess ecosystem components and properties, causality and pressures, land-water interface, and water quality (DFO 2005). One purpose of these overviews and assessments is to provide decision-makers with information on long-term environmental trends upon which they may make the most appropriate management decisions. Indicators need to be monitored on a long-term basis in order to be able to see these long-term environmental trends, which is why continued commitment, support, and funding are critical.

6. Summary, Overall Recommendations, and Conclusions

There is a general consensus that state of the environment reports are needed to address resource and environmental management issues and assess current conditions (MEH) and long-term trends (MEQ) of marine ecosystems. It is generally recognized that through the use of indicators and monitoring programs, this can be accomplished; some general conclusions have been reached. We have the benefit of being able to learn from the experiences of and consult with successful, long-term monitoring programs that are using indicators to assess the state of marine ecosystems. The monitoring of indicators represents a vital link between management objectives and management actions and plans. Indicators should be based on numerical targets, existing criteria, guidelines, objectives, or the interpretation of scientific literature. For an integrated approach to work for the Gulf of Maine, MEH and MEQ standards need to be consistent around the entire Gulf. Indicators should ultimately be able to diagnose and detect ecosystem structure, function and state, though this continues to be a challenge. Indicators need to be linked to management issues and be able to be integrated into monitoring programs. When used correctly, indexes of indicators can act in much the same way as stock market indexes, where people can become aware, on a regular basis, of what the condition and trends of marine ecosystems are.

Overarching management issues are similar for the entire Gulf of Maine and Bay of Fundy, though some geographic variations and local “hot-spots” exist. In the Gulf of Maine, as you move to a smaller scale, such as the Minas Basin, issues may vary even more as you take into consideration local specifics. To best assess the MEH and MEQ of the entire Gulf of Maine, ecosystem assessments are required for smaller regions around the Gulf. Similar to the Gulf of Maine, to best assess the Bay of Fundy, smaller marine ecosystem assessments should be compiled (e.g. Minas Basin, Chignecto Bay, Passamaquoddy Bay, Saint John Harbour, St. Mary's Bay). A list of large-scale, Gulf-wide indicators can be devised for the entire Gulf of Maine, as some commonalities exist amongst ecosystems, but indicators are also required that address local issues on a smaller scale.

Pertaining to Minas Basin, the following outlines specific recommendations to help work towards achieving coordinated monitoring programs that use indicators to assess MEH:

- Hire someone to take a lead role in organizing, coordinating, and keeping an active inventory of monitoring programs around the Minas Basin watershed.
- Examine scientific research in the Minas Basin watershed that could contribute to the collection of baseline data, resulting in the potential conversion to long-term monitoring programs.
- Implement a select few monitoring programs to assess indicators based on community support, monetary and scientific resources, and government commitment; build upon this until eventually, an overall health index for the Minas Basin can be assessed.
- Encourage BoFEP and GOMCME involvement with the ACAP program in hopes of establishing a community-based stewardship program site in the Minas Basin watershed.
- The MBWG should hold information sessions on current as well as emerging issues in the Minas Basin watershed to educate people, engage interest, and share information.

In the Minas Basin watershed, through the use of forums, workshops, and the encouragement of communication, a bottom-up approach has been taken so far in identifying environmental and resource issues for which effective management is required. As the issues have been identified, indicator selection for monitoring programs can now occur to evaluate whether MEH is improving, deteriorating, or being sustained as a result of management actions. An integrated and coordinated monitoring strategy is a feasible task in Minas Basin; the size of the watershed is not overly extensive, resource and environmental issues have been identified, and though these small, initial steps are positive, there still is a long way to go. We will never know everything about ecosystem structure and function. As long as limitations and challenges are recognized, we should work with our current knowledge of ecosystems and indicators in the Bay of Fundy and Minas Basin, and implement monitoring programs for what we do know now and ensure that we are able to adapt and expand from there.

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