A Strategy for Gulf of Maine Ecosystem Indicators and State of the Environment Reporting

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Executive Summary

Ecosystem indicators document changes in important environmental, cultural, and economic aspects of an ecosystem. Trends can be tracked over time to provide insights into conditions, stressors, and societal responses. Coupled with state of the environment (SOE) reports, indicators draw attention to the challenges or benefits created by ecosystem conditions and to progress towards addressing these challenges or sustaining these benefits. In addition, presenting indicators through SOE reports offers a powerful way to communicate ecosystem information and provide guidance to decision-makers that will encourage appropriate management actions.

While many indicator and reporting efforts exist within and encompass the Gulf of Maine, a gulf-wide indicators and reporting program is currently lacking. The Gulf of Maine Council on the Marine Environment (GOMC) and its partners focused regional attention on ecosystem indicators and reporting through a series of efforts that culminated in the Gulf of Maine Summit in October 2004. Through the Governors' and Premiers' *Committing to Change* proclamation that was released at the Summit, the GOMC was called upon to "provide timely and responsive information to decision-makers (including a comprehensive state of the environment reporting and indicators series)."

This strategy lays out a plan for how the Ecosystem Indicators Partnership (ESIP) should proceed in developing a regional ecosystem indicators and reporting program. This document outlines the guiding principles, fundamental approach, and organizational structure for a gulf-wide indicators and reporting program. At its core, the program recognizes the importance of partnering with existing monitoring, indicator, and reporting programs to build on and enhance current capacities in the region. It also recognizes the need to constantly reassess the target audience's information needs, preferred formats for receiving information, and uses of the products so that the program will prove relevant to decision-makers in the Gulf of Maine region.

Recognizing that a complete and sustainable program to track ecological integrity in the Gulf of Maine will require years to build, this strategy lays out a plan for gradual development so that the initial steps serve as building blocks for later phases. Indicators will focus on the six issues managers deemed most important in a 2004 survey—coastal development, contaminants and pathogens, fisheries and aquaculture, eutrophication, aquatic habitat, and climate change. Integrated questions that cross over multiple individual issues may be addressed as the indicators and reporting program develops.

Developing a regional indicators and reporting program entails 1) harmonizing and building on existing efforts, 2) creating regional indicators, 3) developing a data and information management infrastructure, 4) producing state of the environment reports, 5) building and sustaining partnerships, 6) conducting effective communication and outreach and 7) securing multi-partner sustained funding. Steps towards achieving each of these components of a regional program are outlined in this strategy document. A regional indicators and reporting program requires sustained long-term commitments of partners and resources. It is anticipated that substantial in-kind support will be provided by major partner agencies and the GOMC, and additional funds will be sought opportunistically from a variety of sources.

1. Introduction

The Gulf of Maine lies between Cape Cod and the southern edge of Nova Scotia. It extends into the Bay of Fundy and is partially isolated from the Atlantic Ocean by Georges and Browns Banks. The seaward portions of the Gulf of Maine, including its deep basins and shallow banks, constitute one of the most productive ecosystems in the world. Landward to the northeast and west, the ecosystem encompasses major rivers, such as the Penobscot, St. Croix and St. John with human communities distributed across rural farmlands and concentrated in urban centers. On land and in coastal waters, diverse habitats provide homes for a wide array of organisms, including plants and animals.

The Gulf of Maine ecosystem[1]—including its physical, biological, and human components—is dynamic. Over the course of history, the Gulf of Maine has changed as a result of both natural processes and human interventions. Some changes are widely recognized, such as the decline in groundfish stocks. Other changes are less readily apparent, such as increased rural land development as more people emigrate from cities. Some ecosystem conditions directly affect human health and well-being; others impact human ethical values and aesthetic preferences. Although human activities drive many ecosystem changes, humans also maintain the unique capacity to manage certain conditions—whether by reducing water pollution, restoring coastal habitats, permanently protecting land, or taking a variety of other actions.

Information regarding changes in the ecosystem and its resulting condition enables humans to recognize these changes and take appropriate and timely actions. Ecosystem indicators and state of the environment reports are commonly used to communicate information about ecosystem conditions, support decision-making within management processes, track effectiveness of management actions, and target resources to areas of greatest need. Indicators are developed from monitoring data and focus on key factors within the ecosystem to summarize complex information into a simplified form. Trends in indicators can be tracked over time to provide insights into environmental conditions, stressors, and societal responses. Indicators can draw attention to challenges or benefits created by ecosystem conditions, to progress towards addressing these challenges or sustaining these benefits, and to additional management efforts that may be necessary (Figure 1).

> Indicators are quantitative or qualitative measures that provide information about the status of or changes in natural, cultural, and economic aspects of an ecosystem.

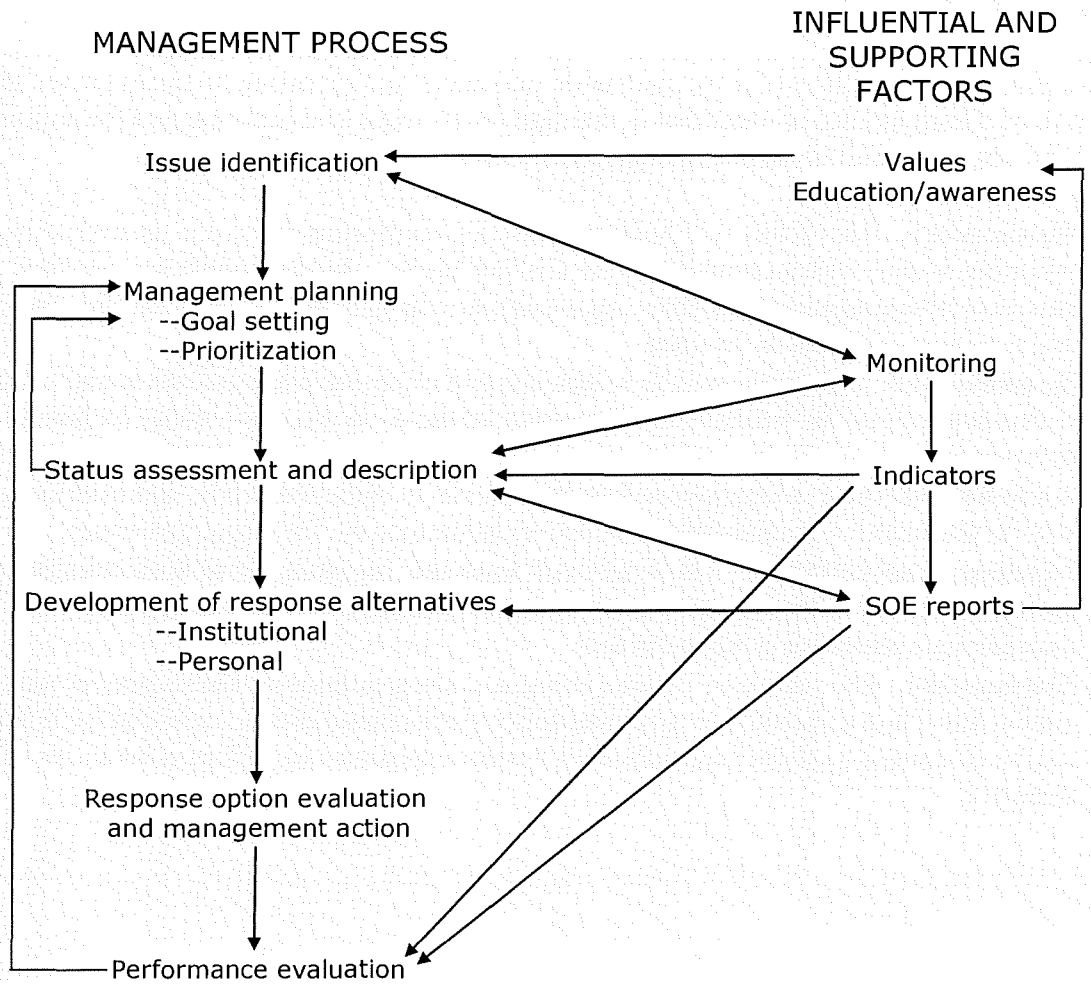
While many indicator and reporting efforts exist within and encompass the Gulf of Maine, a regional-scale indicators and reporting program is lacking, as is an integrated set of indicators that reflect the overall "health" of the Gulf. The Gulf of Maine Council on the Marine Environment (GOMC) and its partners focused regional attention on ecosystem indicators and reporting through a series of efforts that culminated in the Gulf of Maine Summit in October

[1] Throughout this document, "ecosystem" refers to a geographically specified system of organisms, the environment, and the processes that control its dynamics. "Environment" is more narrowly defined as the biological, chemical, physical, and social conditions that surround organisms (NOAA 2005). While the environment is part of the broader ecosystem, focusing on the environment alone neglects the integral role that humans play in ecosystems. This strategy intends to develop a framework for tracking and reporting on multiple components of the ecosystem and the dynamic interactions between these components, including human activities and outcomes. Use of the word "environment" is retained when referring to "state of the environment" reports generally, as this phrase has become standard terminology.

2004 (Appendix A). The *Committing to Change* proclamation—released at the Summit by the Premiers of Nova Scotia and New Brunswick and the Governors of Maine, New Hampshire, and Massachusetts—called upon the GOMC to "provide timely and responsive information to decision-makers (including a comprehensive state of the environment reporting and indicators series)." The Ecosystem Indicators Partnership (ESIP) was tasked by the GOMC with fulfilling this mandate; towards this end, this document formulates a strategy to guide the regional indicators and reporting effort.

This strategy describes the guiding principles, fundamental approach, and organizational structure for a Gulf of Maine regional indicators and reporting program. It outlines actions necessary to initiate a gulf-wide ecosystem indicators and reporting effort that builds upon existing programs. Recognizing that a complete program to track the status of the Gulf of Maine will require years to build, this strategy lays out a plan for gradually developing the regional program so that the initial steps serve as building blocks for later phases. In addition, it describes the resources and partnerships that will be necessary to successfully implement this program.

Figure 1. Relationship between indicators, state of the environment reporting, monitoring programs, and broader elements of the management process (adapted from Hodge 1997 and Jones and Wells 2001).



2. Program guidance, fundamental approach, and structure

2.1 *Vision statement*

Decision-makers in the Gulf of Maine and Bay of Fundy region will possess the necessary information to preserve ecological integrity and to sustain economically and socially healthy human communities.

Regional ecosystem indicators, developed in a manner that is guided by science and supported by routine monitoring, demonstrate patterns of change in the ecosystem. By presenting and interpreting these indicators in biennial state of the environment reports, information will be communicated in a manner that decision-makers at all societal levels can use to shape their priorities and guide their choices. The gulf-wide insights provided through indicators and state of the environment reports will integrate across multiple jurisdictional boundaries that exist within the Gulf ecosystem and will complement other information used by decision-makers. By creating links between science, management, ecosystem, and community goals at both regional and local levels, this information will help decision-makers understand the larger implications of their choices.

2.2 *Core principles*

The core principles established for the gulf-wide indicators and reporting program ensure the production of a high quality product that is relevant for its users and is developed through a transparent, science-based process that engages a wide group of partners.

- **Partnerships.** This effort will build on existing monitoring, indicator, and reporting programs within and encompassing the Gulf of Maine. Strong, robust partnerships between these programs and other organizations will be vital for a region-wide indicators and reporting program to succeed.
- **Science-based.** Indicators will be selected based on the best natural and social scientific understandings of the structure and functions of the ecosystem, including its human components.
- **Audience-relevant.** Indicators will be responsive to audience needs, and information will be presented in formats that are clearly understood by the target audiences.
- **Necessary and sufficient**. This effort will track the minimum set of indicators necessary to determine whether ecosystem goals and objectives associated with specific management issues are being achieved.
- **Transparent.** The selection, development, and interpretation of the indicators will be conducted and documented in a manner that ensures transparency such that each indicator can be evaluated by users and replicated by other programs or in future iterations of this initiative.

2.3 *Fundamental approach*

The Gulf of Maine regional indicators and reporting initiative will be guided by the following objectives:

- Provide baseline data and information, using historical data where available, about ecosystem conditions against which future changes can be compared;
- Develop ecosystem indicators for assessing the state of the Gulf of Maine and Bay of Fundy that have a scientific grounding and that are relevant to management issues of concern in the region;
- Provide consistent, scientifically-sound, credible information that can be used to strengthen environmental policy and guide management decisions with environmental and social implications;
- Utilize a collaborative, interactive process that involves a variety of partners and data sources; and
- Ensure that information reaches decision-makers within the Gulf of Maine and Bay of Fundy region in a manner that is useful to them.

Although decision-makers receive information from multiple sources, the Gulf of Maine indicators and reporting program will uniquely convey linkages between science, management, and ecosystem goals at a regional scale and elucidate connections between ecosystem conditions and human needs. This initiative will begin with modest short-term goals and gradually extend the scope of its effort to expand 1) the depth and breadth of management-relevant issues that are covered, 2) the level of integration across specific management issues, 3) the spatial scale of focus, and 4) the audience that is reached through products of this program. It will rely heavily on partnerships with existing government agencies, environmental organizations, community groups, business and trade groups, academic institutions, and other programs operating within the region and at national and international scales.

2.4 *Program structure*

The core structure of the regional indicators and reporting initiative will consist of an ESIP steering committee, work groups associated with each of the topical indicator issues, a technical advisory panel, and a small staff. In addition, the GOMC will play a high-level role in guiding the direction of the program and supporting its activities (Figure 2). Numerous other partners in the region will be vital to the success of this program as well.

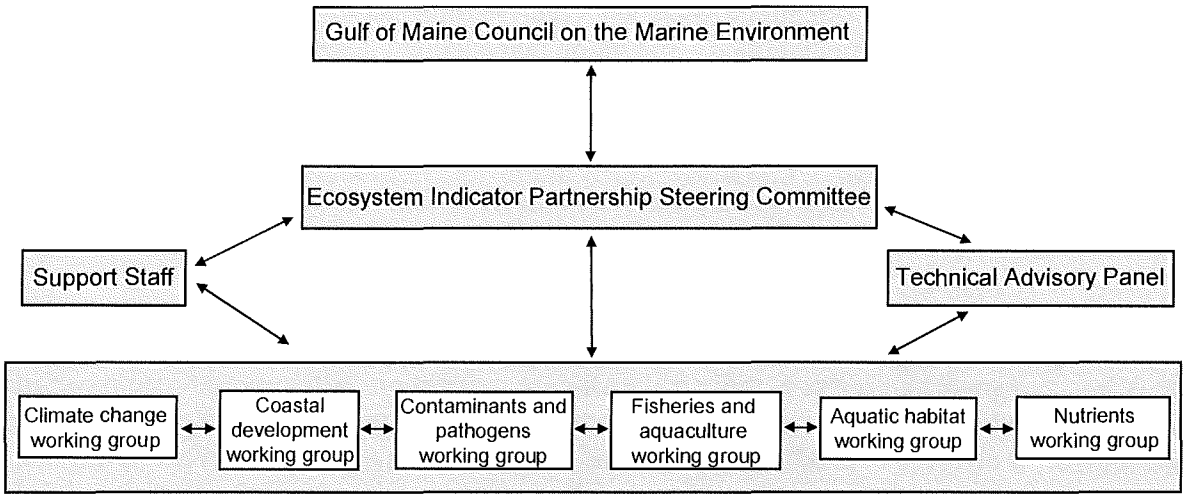
2.4.1 *Roles and responsibilities of the Gulf of Maine Council*

Through the *Committing to Change* proclamation, the GOMC was charged with facilitating the development of a comprehensive set of ecosystem indicators and periodic state of the environment reports. ESIP is an on-going partnership initiative of the GOMC, and the GOMC will play a high-level role in the indicator, monitoring and reporting efforts by advising on the general direction and scope of the initiative. Its responsibilities will primarily entail:

- Being an outspoken advocate for the region's long-term commitment to implement and maintain an ecosystem indicators and state of the environment reporting program;
- Assisting public and private entities to apply the indicators and reporting products in their decision-making processes;

- Joining with other partners to allocate resources on a routine basis that are necessary to implement the ecosystem monitoring, indicators and reporting program; and
- Providing ongoing input to the strategy and activities of the indicators and reporting program to ensure consistency with GOMC priorities.

Figure 2. Organizational chart for the proposed Gulf of Maine indicators and reporting program.



2.4.2 *Structure, roles, and responsibilities of ESIP Steering Committee*

A steering committee will head the ESIP and serve as the coordinating body for the Gulf of Maine regional indicators and reporting effort.

Leadership. ESIP is co-chaired by two leads from the United States (from the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA)) and two leads from Canada (from Fisheries and Oceans Canada (DFO) and Environment Canada (EC)). Recognizing that other agencies have mandates related to the Gulf of Maine ecosystem, co-chair positions may be added or rotated to represent different agencies in leadership roles as desired.

Membership. ESIP steering committee members will have expertise in the development and implementation of indicators and monitoring programs. Co-leads of the current six issue-specific indicator work groups will participate as members of the ESIP steering committee. In addition, a panel of advisors will provide periodic guidance to the ESIP steering committee regarding the direction of the indicators and reporting program. These advisors may participate in steering committee meetings to the extent they are willing, but they will be specifically engaged at certain points to provide input to action plans, review draft documents, and participate in the development of products and workshops.

The primary responsibilities for the ESIP steering committee include:

- Serving as the oversight and coordinating mechanism for the Gulf of Maine indicators and reporting program;
- Establishing work plans, timelines, and budgets for the program that are responsive to end-user needs;
- Working to secure the resources required for the program to be successful;
- Providing direction and supporting the indicator work groups, including assistance in recruiting and retaining members;
- Maintaining communication with work groups and program partners to ensure a consistent understanding about the program, its goals and tasks, and the application of the indicators to pressing management issues;
- Engaging ESIP advisors as needed to shape the direction of the program; and
- Preparing and submitting evaluations and annual progress reports regarding the indicators and reporting initiative to the GOMC and other partners.

2.4.3 *Structure, roles, and responsibilities of the indicator work groups*

A work group will be responsible for each of the key issues for which ecosystem indicators will be developed.

Leadership. Two co-leads, one from the U.S. and one from Canada, will head each of the work groups. These individuals should be employees of key partner agencies or organizations, possess an understanding of the indicator issue, and have experience communicating scientific information to decision-makers. Their primary responsibilities are to:

- Select indicators to be developed in consultation with the end-users, the Steering Committee, the other work groups, and applicable national and sub-regional indicator efforts;
- Oversee the development of indicators, including identifying relevant partners, obtaining and evaluating the necessary data, and assisting in the design of indicator products;
- Guide and contribute to pertinent sections of state of the environment reports; and
- Assist in shaping end-user communication and dissemination strategies.

Membership. Each work group will be composed of members distributed throughout the Gulf of Maine region with diverse expertise regarding the issue-specific topic of the group. At least one social scientist, and ideally a minimum of two, should be represented on each work group. They will play key roles in:

- Selecting indicators to be developed;
- Providing guidance to staff and overseeing the development of indicators, including identifying relevant partners and evaluating data sources associated with each indicator;
- Guiding the content of sections of the state of the environment report associated with each indicator; and
- Providing input regarding distribution opportunities and communication channels to disseminate the state of the environment report.

2.4.4 *Structure, roles, and responsibilities of the technical advisory panel*

A technical advisory panel will be established to serve as a consulting body that will independently review protocols for developing, interpreting, and presenting indicators. This

panel will be comprised of members with expertise that is relevant to all of the work groups but that is unlikely to be available within each work group. Panel members should possess expertise in marine environmental sciences, spatial statistics, geographic information systems, communication, outreach, and policy analysis. Additional areas of expertise that would likely prove beneficial may include risk assessment, risk communication, and visualization tools. Responsibilities of the technical advisory panel are to:

- Provide input regarding the proposed data sources for each indicator and protocols for compiling and analyzing these data at appropriate spatial and temporal scales;
- Offer guidance for remedying temporal and/or spatial gaps in data availability that preclude development of certain indicators;
- Evaluate interpretations and presentations of indicators and offer suggestions to increase clarity and impact;
- Provide advice regarding dissemination plans; and
- Identify opportunities to use the report products as leverage tools to increase the underlying capacity to develop indicators in the region.

2.4.5 *Staff support for indicators and reporting program*

Much of the work associated with developing gulf-wide ecosystem indicators and state of the environment reporting will be conducted by a small core staff of independent contractors. The size of the staff can be gradually increased as available resources and program interest increase. Minimum initial staff needs include:

- A program manager to broadly oversee and manage the indicators and reporting initiative; and
- A data management specialist to create a web-based home for the indicators program, maintain metadata, and implement quality assurance protocols.

Other staffing needs consist of:

- Staff members to work closely with the work groups to develop the indicators, maintain linkages to key monitoring programs, produce the state of the environment report, and organize and facilitate communications among the work groups and with other partners; and
- A communication and outreach specialist to develop detailed plans for conveying and disseminating information.

Occasional needs will include:

- An analyst to conduct a follow-up evaluation of the usefulness of the report to decision-makers and to document future priorities and needs of the target audience;
- Workshop coordinators; and
- Style and production editors for the state of the environment reports.

3. Harmonizing and building on existing programs

3.1 *Gulf of Maine indicators and reporting program in local, regional, and national contexts*

A gulf-wide indicators and reporting program will be implemented within broader local, regional, and national contexts. Integration with existing programs, wherever possible, will be

vital for the Gulf of Maine program's success. The indicators and reporting program will be influenced from the bottom up by communities and monitoring programs within the Gulf of Maine and from the top down by national programs in the United States and Canada that encompass the Gulf (Appendices B and C). Other regional programs, such as the Gulf of Maine Ocean Observing System (GoMOOS), Bay of Fundy Ecosystem Partnership (BoFEP), and the Regional Association for Research on the Gulf of Maine (RARGOM), while not focused on developing indicators, will shape the monitoring data and ecosystem understanding that are available to support a gulf-wide indicators program. By selecting indicators that are complimentary to those used by local, regional, and national programs, the Gulf of Maine effort can tap into existing data sources, reach broader audiences, and leverage programs, funding, and in-kind contributions.

Local context. While the gulf-wide reporting program will focus on regional ecosystem trends, it must also accurately convey local distinctions within these broader trends. These distinctions can only be detected and portrayed if local indicator (Appendix B) and monitoring (Appendix C) programs are well integrated into the effort. In addition, local indicator and reporting programs within the Gulf of Maine have already identified issues that are important to citizens in the area, gathered data, and developed indicators to track these issues.

Regional context. A variety of other regional monitoring (Appendix C) and reporting (Appendix B) efforts exist within the Gulf of Maine, and the regional indicators and reporting program must link to and integrate with these efforts. Of particular importance, it must remain consistent with the priorities, resources, and objectives of other GOMC committees and partner agencies. These groups have developed baseline information, established management priorities, and monitored changes in marine habitats and environmental quality. The regional indicators and reporting program will benefit from the data and guidance available from these groups as well as from other groups within the region, including the Gulf of Maine Ocean Data Partnership, Census of Marine Life, Gulf of Maine Ocean Observing System, Gulfwatch, and the Coastal Ocean Observation and Analysis Program. The indicators and reporting program will, in turn, create a structure for broader dissemination of data and key messages from these groups, while also contributing new information to regional priority-setting and decision-making processes in which multiple committees, agencies, and organizations participate.

National context. Compatibility with national programs in the United States and Canada is important for interpreting Gulf of Maine ecosystem trends and conditions within a broader context. Such compatibility allows an evaluation of how the Gulf of Maine ecosystem is doing relative to other regional ecosystems and to its adjacent nations as a whole. In addition, national programs (e.g., National Coastal Assessment - USA, Environmental Signals - CA) may have already compiled data that can be downscaled to use for the development of regional indicators. It is also important to note that a number of new efforts around indicators are beginning to develop in the region. For example, NOAA Fisheries and DFO are both working towards ecosystem indicators to support ecosystem-based fisheries management in the region, and the New England Fishery Management Council has sought stakeholder input into potential indicators. It will be important for the gulf-wide program to coordinate with and build upon initiatives that are already underway to avoid duplicating efforts and working at cross purposes.

3.2 *Divergence from existing programs*

While compatibility with other programs is vital, the Gulf of Maine regional indicators and reporting effort will need to uniquely diverge from existing programs in certain ways. Currently, most indicator programs track the status of the natural environment only (Appendix B), but the Gulf of Maine effort interprets *ecosystem integrity* broadly and views humans as integral components of the ecosystem. The ability of the ecosystem to sustain human communities, the environmental implications of human activities, and feedbacks between the natural and human ecosystem must all be considered as part of the integrity of the Gulf of Maine. Therefore, the Gulf of Maine indicators and reporting effort will ultimately need to include indicators that focus explicitly on the status of human communities, human health, and the connections between humans and the environment. Achieving this goal necessitates inclusion of the social sciences as an extension beyond the predominant reliance on natural sciences in existing indicator programs.

3.3 *Actions required to harmonize indicator and reporting efforts*

Harmonizing the Gulf of Maine indicator and reporting effort with existing programs will require several actions to ensure that regional indicators are compatible with those used by other efforts, data are valid and accessible for supporting indicators at a regional scale, and existing management objectives are utilized to establish targets for the indicators. These actions include:

- Engaging partners from a variety of monitoring and reporting programs in the region, including social scientists active in related efforts, in collaborative discussions of which indicators might be prioritized for development, which data will be used to implement indicators, and how results will be presented;
- Identifying sources of data and information for each of the regional indicators;
- Developing data-sharing agreements to enable the regional indicators and reporting effort to utilize data that have been gathered or compiled by other programs; and
- Working with leaders of other programs to develop strategies to expand existing or create new monitoring programs to fill data gaps that inhibit the implementation of certain indicators.

4. Creating regional indicators

4.1 *Description of indicator development process*

The process for developing regional ecosystem indicators includes five major components: 1) program planning, 2) conceptual models development, 3) indicators specification, 4) indicators implementation, and 5) program evaluation (adapted from Hall 2005). The Gulf of Maine indicators initiative has made progress towards fulfilling some of these tasks as part of the Atlantic Northeast Coastal Monitoring Summit (Durham, NH; December 2002), Northeast Coastal Indicators Workshop (Durham, NH; January 2004), and Gulf of Maine Summit (Appendix A). However, work to fully complete each component remains.

4.1.1 *Program planning*

Initial planning is necessary to establish a framework for a regional indicators program. This planning process will clarify the purpose and need for indicators, identify key issues to be addressed initially by the program, develop a baseline assessment of each issue, and specify management questions to be answered by each indicator.

Need for indicators. The Northeast Coastal Indicators Workshop identified a need to select and develop indicators that would enable evaluation of regional ecosystem integrity. The usefulness of indicators was also recognized by participants at the Gulf of Maine Summit, and the importance of indicators as part of the information that is available to decision-makers was reinforced by the *Committing to Change* proclamation.

Key issues. Issues related to coastal development, contaminants and pathogens, fisheries and aquaculture, eutrophication, aquatic habitat, and climate change will be addressed initially by the Gulf of Maine indicators program. Together these topical issues provide insights into the integrity of the Gulf ecosystem, but they do not create a comprehensive assessment. These issues will become integrated with one another and may be expanded upon as needed to better track ecosystem integrity after the initial cycles of the indicators and reporting initiative are completed; see "Phased development of indicators" in Section 4.2.

Baseline assessment. The *Tides of Change* report provides a baseline assessment of three issues—land use, contaminants and pathogens, and fisheries and aquaculture. Regional baseline assessments have not been conducted yet for eutrophication, aquatic habitats, and climate change.

Management objectives and questions. Each topical work group at the Northeast Coastal Indicators Workshop identified key management questions and appropriate indicators to address them. This work served as the starting point for the proposed questions and indicators that are listed in the Table 1. Management objectives have not been identified specifically for the indicators program, but other efforts in the region have developed goals for the Gulf ecosystem (Appendix D) that provide general guidance regarding desired ecosystem features and states. Formulating more specific ecosystem objectives and indicator targets to track progress towards those objectives will require a broad stakeholder process as well as scientific guidance.

4.1.2 *Developing conceptual models*

Conceptual models describe how different ecosystem factors and characteristics are believed to relate to one another and how changes in one attribute are believed to affect other components of the ecosystem. Conceptual models capture these relationships without requiring that the dynamics of the ecosystem be expressed in quantitative forms. Conceptual models are needed for three purposes: 1) to organize indicators; 2) to clarify the purposes and assumptions associated with indicators; and to communicate clearly about the objectives and goals of the strategy and suggested programs.

Organizing indicators. The Gulf of Maine indicators effort is using the pressure-state-response (PSR) model to organize indicators. The PSR model is based on causal links between human activities that place pressures on the ecosystem that may change the ecosystem's state; in turn,

societal responses may lead to actions to relieve or manage the human-induced pressures. Working groups for each of the six indicator issues have selected indicators within each category of the PSR framework, and the PSR models have gained consensus within the relevant work groups.

Clarifying indicators. While the PSR framework provides a way to organize the indicators, conceptual mechanistic models are needed to evaluate the purpose for each indicator (i.e., "What is it indicating?") and the assumptions behind its presumed causal links (i.e., "What is assumed to be happening in the ecosystem to cause a certain trend in an indicator?"). Clarifying these presumed mechanistic relationships is crucial for evaluating an indicator's usefulness as well as for guiding its interpretation (e.g., Mendelson 2004). These conceptual models are needed within each focus issue and across issues encompassed in the gulf-wide indicators and reporting program.

4.1.3 *Indicator selection*

The selection of indicators requires evaluating the current availability of monitoring data, establishing an indicator selection process, and compiling a list of potential indicators.

Current monitoring. Monitoring programs are prevalent and active in the Gulf of Maine region, and the types of information that are collected by many of these programs has been compiled in Appendix C. As the work groups prioritize specific indicators for development, they will conduct a needs assessment of data to populate each indicator. This needs assessment will identify gaps in data availability and consistency that remain to be filled, either through new monitoring programs, enhanced spatial or temporal coverage of existing programs, or efforts to achieve consistent information from current programs that may use different techniques to gather data.

Indicator selection process. An indicator selection process will be strongly guided by three considerations, which should serve as the primary criteria for prioritizing indicators for development: 1) relevance of the indicator to management questions of interest and responsibilities in the region; 2) relevance of the indicator to the target audience, the public, and government; and 3) the presence of a scientific rationale behind an indicator and its interpretation. In addition, the timeliness, quality, and comparability of data across jurisdictions will influence indicators that are selected for development. Furthermore, the choice of indicators at the gulf-wide scale will be shaped to some extent by the indicators that are tracked and reported by local programs in the region and by national programs that encompass the Gulf of Maine (refer to "Harmonization" section). A more detailed, objective framework for screening and selecting indicators is presented in Appendix E.

Potential indicators. A list of potential indicators to be tracked by a regional program was developed for six issue areas at the Northeast Coastal Indicators Workshop, and the indicators proposed for three issues were vetted at the Gulf of Maine Summit. Indicators that will be developed first will be selected from this larger pool, but a few indicators will be phased in at a time. Example questions and indicators that may serve as starting points have been proposed in Table 1.

Table 1. Organizing management questions and indicators that may be used to structure the Gulf of Maine indicators and reporting program.

What is the state of the Gulf of Maine ecosystem?

Issues	Management questions	Indicators
What are the patterns and effects of **coastal development** in the Gulf of Maine region?	What are the types, patterns, and rates of land use change?	% change to more intense uses (or land consumption index)
	How are these changes impacting the integrity of coastal ecosystems?	% change in human population
	How is the region responding to changes in coastal ecosystems?	Area of conserved land
What are the levels and implications of **contaminants and pathogens** in the Gulf of Maine?	How are contaminants in the region changing?	Area of sediment or volume of water with contaminants above guidelines Days of beach or shellfish bed closures
	What are the ecological effects of contaminants?	Contaminant levels in shellfish & finfish Contaminants in higher trophic levels (e.g., marine mammals, birds)
What is the state of **fisheries and aquaculture** in the Gulf of Maine?	What are the trends in and status of exploited fish stocks?	Biomass trends for select stocks
	What is the status of non-target species and associated marine communities?	Trends in bycatch levels or rates Change in fish/invertebrate community diversity
	What are the socio-economic implications of fisheries in the ecosystem?	
What is the extent and condition of **aquatic habitats**?	How is the extent and distribution of aquatic habitats changing over time?	Current mapped area of seagrass, salt marsh, and nearshore subtidal soft bottoms Historical extent of same habitats in representative areas
	How is the ecological condition of aquatic habitats changing over time?	Proportion of salt marsh plan community as halophytes and invasive species % seagrass cover within index sites
	What are the causes of coastal habitat change?	Quantity and density of coastal habitat alterations (e.g., tidal restrictions)
Is **eutrophication** occurring in the Gulf of Maine ecosystem?	What are the trends of eutrophication?	Trends in dissolved oxygen % change in chlorophyll concentrations Trends in water clarity
	What are the effects of eutrophication on the ecosystem?	Number and duration of harmful algal blooms
Is **climate change** affecting the Gulf of Maine ecosystem?	What are the impacts of climate change to physical conditions?	Trends in air temperature anomalies Change in seasonal precipitation amounts Trends in surface and bottom water temperature anomalies
	What ecological changes are associated with climate change?	Abundance and spatial distribution of marine species Change in types or extent of marine diseases

4.1.4 *Indicator program evaluation*

A continual evaluation process is needed to re-assess conceptual frameworks and models that underlie indicators, the selected indicators themselves, data availability for indicators, and the relevance of indicators and their presentation to target audiences. Program evaluation has been applied routinely in the Gulf of Maine indicator and reporting effort to date, including:

- Surveying managers to guide the issues addressed and indicators considered at the Northeast Coastal Indicators Workshop;
- Interviewing users to evaluate the usefulness of the *Tides of Change* report to its intended audiences; and
- Conducting listening sessions with potential users of future indicator products to understand the information that is most relevant and presentation formats that are most useful and accessible to them.

Evaluation processes such as these will remain important in future indicator and report development stages.

4.2 *Phased development of indicators*

Indicator development in the Gulf of Maine region will be built up incrementally over time. Indicators will be phased in terms of the number of indicators developed per issue, integration of the indicators, and the spatial scope of coverage. While a plan for this phasing is outlined below, certain issues or types of indicators may advance more quickly than others. In some cases, the pace of indicator development may be influenced by broader scientific understanding. For example, dissolved oxygen is widely accepted as an indicator of water quality, but indicators for issues such as fisheries and coastal development in an ecosystem context have not yet become standard and will require more forethought. In other situations, funding opportunities or the priorities and needs of other programs in the region may influence the pace of indicator development. ESIP and the work groups should actively and strategically seize upon relevant opportunities that advance the development of indicators selected for implementation as part of this program.

Number of indicators. Stakeholders in the Gulf of Maine region chose and ranked six leading management issues prior to the Northeast Coastal Indicators Workshop: coastal development, fisheries and aquaculture, aquatic habitats, contaminants and pathogens, eutrophication, and climate change. While a number of indicators have been put forward for each of these six issues, the regional indicators program will need to develop a few indicators per issue at a time. Indicators will be prioritized based on the criteria presented in the "indicator selection process" section above and further expanded upon in Appendix E.

Initially, each work group will develop a few indicators to clarify the approach and procedures that will be used in developing indicators, establish working relationships and data-sharing agreements with partner agencies and organizations that hold monitoring data to support the indicator, and consider options for effective presentation of the indicator. This initial work will produce products that can be shared with stakeholders and with future partners.

For the first reporting cycle, each work group will focus on articulating management-relevant guiding questions and developing two to three appropriate indicators to address those questions.

Starting points for management questions and indicators have been identified based on input from the managers' survey administered prior to the Northeast Coastal Indicators Workshop and from initial communication with the existing work group leads (Table 1). The suggested indicators are relevant to the target audience and their development is feasible for the first iterations of the indicators and reporting cycle. However, the final selection of indicators to develop will be made by the work groups and ESIP steering committee and should follow from a cross-group dialogue to ensure that linkages across issues are properly accommodated in the indicator choices.

Although only two to three indicators per work group will be reported at the end of the first biennial cycle, the work groups and staff will select and begin work towards developing three to four additional indicators for the next reporting cycle as well. Data to support the indicators for the next reporting cycle may require more time to gather, compile, analyze, and interpret, so progress towards developing those indicators must begin during the initial biennial phase of the program. On-going evaluations of each indicator's ability to provide insights into the state of the ecosystem, its relevance to the target audience, and the need for cross-issue integration will influence the choice of specific indicators to be developed and reported.

Integration of indicators. It is assumed that assessing indicators related to each of the six focus issues will provide meaningful insights into key aspects of the state of the Gulf of Maine ecosystem. However, the issue-focused approach using stand-alone indicators does not address linkages between issues and the implications of those linkages for the ecosystem. Understanding these linkages and addressing questions that cut across multiple issues is challenging but vital. Some of these linkages will be conveyed in the integrated conceptual models developed by the working groups. These conceptual models should be regularly updated and routinely revisited after each cycle of indicator development to identify relevant indicators that will support an integrated expansion of the effort. This process of integrating indicators will allow cross-cutting questions, such as "Does the diversity of life in the Gulf of Maine represent a well-functioning ecosystem?" or "Does water quality in the Gulf of Maine support human health and living marine resources?", to be addressed.

Integration is also needed to bring multiple indicators together into indices. Indices represent a compilation of several individual indicators and can offer powerful summary measures of the status of a particular ecosystem issue or of the state of the ecosystem as a whole. However, the development, use, and interpretation of indices pose a variety of challenges, including choosing an appropriate method to combine and weight separate lines of information as well as the potential risk of losing sight of a few indicators that may show an important pattern different from that of the overall index. In the first cycle of indicator development and reporting for the Gulf of Maine region, one work group will undertake a case study to develop an index from multiple independent indicators. This case study will offer lessons that will guide assessments of whether other work groups should develop indices, how indices might be developed, and whether it is desirable and possible to pursue an overarching index to track the state of the ecosystem as a whole.

Spatial scope. The initial scope of data compilation to support indicators will focus on the portion of the Gulf of Maine that lies between the coastline and the 200-mile extent of the

exclusive economic zone. In later stages, the spatial coverage will be expanded to encompass the entire Gulf of Maine watershed.

4.3 *Key steps in developing gulf-wide indicators*

As suggested in the text above, key steps in the process of developing regional indicators include:

- Facilitating baseline assessments of aquatic habitats, eutrophication, and climate change in the Gulf of Maine region;
- Developing conceptual models to determine the utility of each indicator, articulate assumptions associated with the indicator, and assess duplication or gaps in the group of indicators;
- Conducting a workshop for integrating indicators vertically within issues and horizontally across issues and producing a conceptual model that links the indicators across all issues as a result of this workshop;
- Articulating management objectives and targets and then considering relevant indicators to track progress towards each objective;
- Establishing criteria and an evaluation framework for use in prioritizing indicators that work groups will apply to select indicators for development;
- Developing case studies based on one indicator per issue and an index for one issue; and
- Evaluating available data to support chosen indicators.

5. Creating a gulf-wide data and information management infrastructure for indicators

5.1 *Data management*

A large quantity and variety of data will be accessed and compiled to develop ecosystem indicators across the Gulf of Maine region. These data will be in the form of time-series trends for some indicators and as spatial layers or maps for other indicators. Initially, the data to support indicators will be gathered from an array of existing sources, in partnership with the data providers. ESIP will work collaboratively with the data providers to ensure that these data are in a form that is accessible and useful to current and future users.

Quality assurance. The quality of the data that are used as the basis for developing gulf-wide indicators needs to be known and documented. Quality assurance plans and processes are necessary to evaluate the suitability of data that are gathered from existing programs. They are also important for ensuring that the sampling design, collection methods, and analysis protocols of monitoring programs satisfy necessary criteria to meet the indicator initiative's goals and standards.

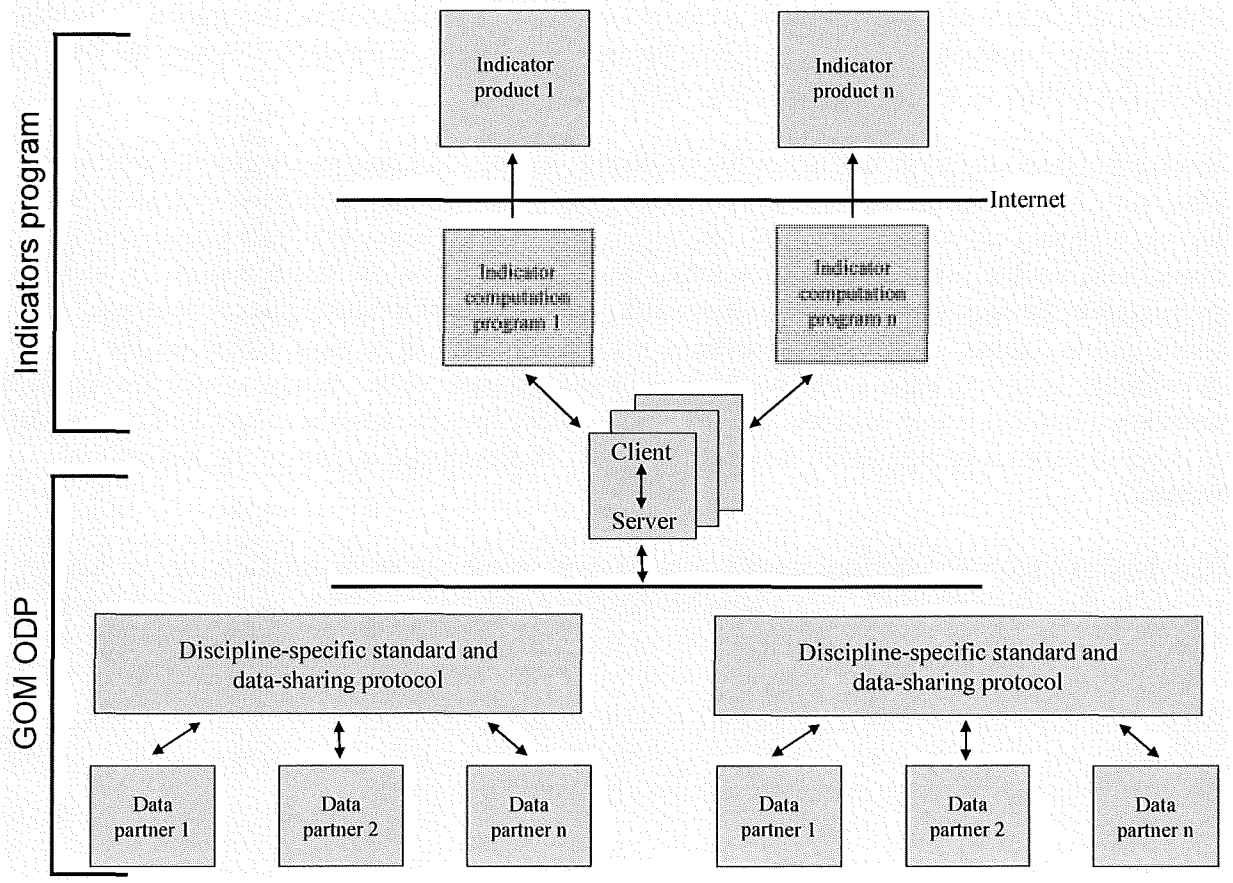
Metadata. Metadata (i.e., information about data) are critical for describing and maintaining a record of the information that is used to populate each indicator and how it is manipulated in the process of creating the indicator. At a minimum, metadata should describe 1) the specific data used to compute the indicator; 2) where, when, and from whom it was obtained; 3) its collection

date, location, and technique; 4) processing steps that were applied to the data to calculate the indicator; and 5) where the raw and processed data are stored. In addition, the geographic and temporal coverage and resolution of the data behind each indicator should be described.

Data management. The Gulf of Maine regional indicators program will rely on a multi-tiered data management system (Figure 3). Raw data needed to support the indicators will remain in databases that are owned and maintained by partner agencies and organizations. The Gulf of Maine Ocean Data Partnership (ODP) offers a structure through which data from multiple partners might be made accessible to the indicators program, provided all relevant partners are willing to serve their data through the ODP. Smaller partners may need additional support to overcome infrastructure limitations or technical challenges that may inhibit their ability to serve data in this manner.

By linking to the ODP, the gulf-wide indicators can be computed and displayed through computational programs that retrieve the necessary data and perform the needed manipulations

Figure 3. Data management system for the gulf-wide indicators program. System builds on the Gulf of Maine Ocean Data Partnership (ODP), as indicated in the lower half of the figure.



and calculations to transform raw input data from the partners into the indicators. The intermediate program for computing each indicator needs to be developed in collaboration with data managers at each partner agency or organization to ensure that all necessary data manipulations are included and applied correctly. In addition, computations need to properly account for temporal and spatial auto-correlation in the data to ensure that a gulf-wide value for the indicator is truly representative of the region as a whole. The retrieval and calculation programs can be linked to a geographical information system (GIS) and to a user interface so that users can interactively request indicator information at a variety of scales, to the extent that data are available at finer spatial scales to support such requests.

5.2 *Web presence and tool development*

To be routinely accessible to users, a website home needs to be created for the indicators and reporting program. The website should be part of the GOMC's website but should be more visible, comprehensive, and interactive than the current indicators page, http://www.gulfofmaine.org/knowledgebase/indicators/. Initially, this website should provide an overview of the regional indicators and reporting effort to date, list current partners and participants, broadcast the program strategy, and link to past activities and documents that have supported this effort. The website should be able to expand as the program develops to include individual pages about each indicator, their trends, and technical documentation. It should interface with the data management system to provide graphical displays of the indicators. Advanced features may allow public access to and use of the data behind the graphical displays. For example, capabilities can be built into the web interface to allow users to query the data for a particular feature or over a specific geographic region.

Interactive graphical tools can be useful for displaying the indicators in a variety of manners chosen by the user as relevant to his/her needs. Users have already expressed an interest in having mapping capabilities available through GIS to display indicators over nested spatial hierarchies, such as watersheds or municipalities, within the Gulf of Maine region. In addition, presentation formats such as amoeba plots offer ways to simultaneously display multiple indicators in a single image. An evaluation of the tools that will be most useful and the desirability of having these tools available as integrated parts of the indicators website should be conducted in focus group sessions with the users. Once specific tools are identified by a sizeable number of users as being useful, they can gradually be developed as part of the indicators website.

The database and web interface should integrate with related existing infrastructure within the region to the extent possible. For example, the data management system and web interface can learn from and link to other programs, such as the Gulf of Maine Biogeographic Information System and the Gulf of Maine Mapping Portal, that have already been developed for similar data. Likewise, the websites maintained by other programs can link to the Gulf of Maine indicators and reporting page. These cross-linkages of web pages will increase visibility of both the gulf-wide indicators program and similar efforts in the region.

5.3 *Support for development of data management system*

ESIP will take the following actions to support development of the data management system:

- A data management specialist with previous experience working with indicator programs and technical environmental and socioeconomic data will be hired to develop the indicators data management system and web interface.
- The ESIP steering committee will designate a subgroup consisting of work group members and data-savvy individuals from partner agencies to work with the data management specialist to design a requirements document for the data management system and develop a cost estimate based on the desired functions.
- The data management system, website, and associated tools will be tested by a few members of each work group and by potential users. This group will attempt to use the system and to explore the functionality of simulated procedures that users may want to perform. This initial test is important to evaluate the functional acceptability of key elements of the data management system.
- Technical and/or financial support will be provided to small, primarily non-governmental and academic, partners who hold useful data and are willing to share it to support the indicators program but lack the infrastructure or technical capacities to make their data available.

6. Creating regional state of the environment reports

Ecosystem information, including its biophysical and socioeconomic components, is only useful if it is understandable, relevant, reliable, and accessible to users. Thus, an effective reporting effort is critical for conveying information that is derived from ecosystem indicators in a manner that is suitable for target audiences. State of the environment (SOE) reports pull the indicators together to describe trends and changes in the ecosystem, causes and consequences of its current status, and underlying management issues or responses that affect the ecosystem's condition. SOE reports commonly address a core set of questions:

1) What is happening to the ecosystem?
2) Why is it happening?
3) Why is it significant?
4) What is being done about it?
5) What outcomes are expected for different management options?
6) Are the management options that are chosen successful?

SOE reports provide a way to deliver important products of research and monitoring programs through presentation and interpretation of ecosystem indicators. These reports can help focus deliberations of marine issues and offer guidance to direct further research and monitoring efforts. Beyond the development and interpretation of indicators, the process of producing SOE reports involves education, communication, and networking among partner groups. Collaborative interactions across multiple agencies, organizations, and other groups encourage broad thinking about the ecosystem, the future of its resources, and needed management actions (Wells 2003). The interactions, collaborations, and new ideas that develop as a result of

producing a SOE report should offer additional value to the gulf-wide indicators and reporting program.

6.1 *Production of SOE reports*

Producing regional SOE information will require nested responsibilities, shared between the ESIP steering committee, work groups, and support staff. In addition, the involvement of users will be important to ensure that products are relevant and useful to their recipients. Further, phased production of a variety of report products and formats will expand the reach of the SOE reporting program.

6.1.1 *Report production*

The ESIP steering committee will coordinate production of the regional SOE report. The steering committee, in collaboration with work group co-leads and ESIP advisors, will 1) secure funding to support production of the report, 2) determine the overall design for the SOE report, 3) identify technical, copy and production editors, 4) work with the editors to develop a common format and set expectations for the sections of the report, and 5) oversee production of the report.

The work groups will provide input on the interpretation and presentation of information within the report. In guiding these aspects of the report, the work groups will consider products of other efforts in the region to ensure consistency and to acknowledge differences that may arise in patterns observed gulf-wide compared to those seen at local scales within the region. In addition to providing overall guidance, the work group co-leads and members will work closely with support staff to review and hone sections of the report.

The support staff will draft and revise all sections of the report. In addition, the staff will coordinate and respond to peer reviews of the report drafts by the work groups, the ESIP steering committee, ESIP advisors, partners who have provided data to develop specific indicators, leaders of reporting programs within the Gulf of Maine region, technical advisory panel members, other relevant persons with specific expertise, and lay readers who can represent the reaction of decision-makers and the public to the report. The support staff will also work with copy and production editors to design, finalize, and publish the report.

6.1.2 *User input*

Focus groups and interviews conducted in 2005 with potential users of the report have provided insights into the types of products that users find relevant, the most effective formats for presenting information, and the means of access that they prefer. This information will shape the design of the SOE report. Interviews with users of *Tides of Change Across the Gulf* (Pesch and Wells 2004) revealed general satisfaction with the format and presentation style of the report. Some interviewees suggested that future reports move beyond a general characterization of issues within the Gulf of Maine towards a quantitative and integrated assessment of the health or state of the ecosystem.

In the listening sessions, potential users of products related to coastal development, contaminants and pathogens, and fisheries and aquaculture indicated a desire for products that could be used to assess and monitor the health of the Gulf, inform the public and build coalitions to protect the

Gulf of Maine, and advise policy- and decision-makers on appropriate actions, investments, and programs. The listening session participants favored web-based access to materials and data, but they also recognized the need for succinct, attention-grabbing items to reach certain audiences, such as resource users. Although web-based materials are useful to many recipients, other members of key audiences may not have web access, and alternative product formats will be necessary as well.

While input from the 2005 listening sessions and interviews will shape the design of upcoming SOE reports, follow-up input from users after its production will be equally valuable, particularly considering the fact that the SOE report will be the first indicators-based report for the gulf-wide region. Evaluating the report's effectiveness at reaching its target audiences and its usefulness to them is a vital step that will provide further insights into the appropriateness of the report's content, format, and dissemination mechanisms. These insights will help identify improvements that should be made in the next iteration of the SOE report.

6.1.3 *Phased development*

SOE reports are produced in different formats to reach different audiences. The most common formats include general reports, technical reports, and in-depth issue reports. As technology has advanced, websites have become increasingly prevalent as a way to disseminate ecosystem information and SOE reports. Production of SOE reports for the Gulf of Maine region will be phased to gradually expand the types of materials that are available and the target audience that they are intended to reach.

The initial target audience for this initiative is decision-makers in the Gulf of Maine, particularly federal, state/provincial, and municipal government staff who make permit decisions, run environmental programs, and set coastal and ocean policy. Web-based formats for the production and dissemination of regional SOE reports will likely prove the most accessible and useful to this audience, as indicated by input from the listening sessions. A web-based format will minimally allow the SOE report to be made available as an electronic file so that users who want a paper copy can print and read the report. In addition, separate web pages presenting graphics, text, and resources associated with each indicator can be created within the indicators section of the website.

A web-based design can support many features that cannot be developed in a typical paper-based report. A web-based interface can be updated more frequently than paper reports can be revised and printed, thereby offering an opportunity to create a dynamic reporting structure. At the extreme, the web-based format could be used to create "living" reports that are linked to the data management system to continually provide updated values for each indicator. Tiered, interactive information structures are likely to be desired by users in the region and can be supported by web-based designs. Using a tiered information structure allows general information to be linked to more detailed information, even to the raw data behind indicators itself, thereby allowing users to drill down for further information. Interactive GIS interfaces can enable users to disaggregate the indicators from the regional level to smaller scales (e.g., watersheds or counties) and view the information at nested spatial scales (to the extent that data are available at local scales). An interactive system would also allow users to compile data for select spatial units or time periods so that they can conduct their own analyses or create their own graphics. Phasing in these web-

based capacities will make the SOE information useful to a broader audience. For example, community groups within the region may want to view data relevant to their local area, and research scientists may be attracted to the availability of raw data.

A web-based SOE reporting structure will not reach all audiences, however, and additional formats for information may be needed. Pamphlet-style summaries of take-home messages from the SOE report can provide key information to the interested public. In addition, short quotations of key messages can be printed onto magnets, post-it notes, bookmarks, coasters, and other items to attract attention from individuals that might not otherwise seek out environmental information about the region in which they live. Visual media, such as cartoons and films, can also reach different audiences and portray the key messages in new ways.

6.2 *Dissemination of SOE reports*

Biennial conferences will serve as a cornerstone of the process of disseminating the SOE reports and results from the indicators and reporting program. These conferences will provide a time for all of the partners in the effort as well as other interested parties from the region to come together for presentations of the indicator trends and discussion of the state of the Gulf of Maine ecosystem. In addition to presenting findings of the SOE report, ample time should be set aside during the conferences to allow for break-out group discussions of potential uses of the findings of the report, implications the findings pose for management actions and decisions within the region, and additional groups that should receive the information.

SOE report products will be disseminated to a broader audience by sending a pamphlet-style summary of key results and a one-page letter describing the project, including a web address and contact information so that the recipient can locate the full report. The following is a minimal list of recipients:

- GOMC members, working group members, advisory panel, and committee participants;
- Project contributors (e.g., work group members, ESIP advisors, science advisory panel, ESIP members, partner organizations);
- Agency directors, regional managers, and other senior staff of state/provincial and federal government agencies;
- Elected public officials at the state/provincial and federal government levels;
- Mayors, municipal councils, town planning authorities, and civic groups (e.g., Chamber of Commerce, Rotary Clubs) in municipalities within the Gulf of Maine watershed;
- Members of Commissions, Councils, and other management boards that guide resource use or protection in the region;
- Communication departments within all environmental management agencies at the federal and state/provincial levels as well as major municipalities along the coast of the Gulf of Maine;
- Leaders of environmental organizations and industry associations in the region;
- Individuals within all partner agencies or organizations that have expressed interest in the project;
- Key media (TV, radio, newspapers) outlets; and
- Educational organizations, museums, and libraries.

Electronic means will also be used to facilitate general broad dissemination of the SOE report. E-mails regarding the report and its availability will be sent to the above recipients for whom e-mails are available as well as individuals on the GOMC's existing listserve, the distribution list for the Gulf of Maine Summit, and partner agencies and organizations in the region. Each partner agency and organization will be asked to provide a link to the SOE webpage from its own website. Project partners will be encouraged to notify their own stakeholder mailing lists of the availability of the SOE report. If ESIP wants to target the SOE report to specific audiences, unique products and dissemination strategies may be needed for these groups.

In conjunction with the release of the SOE report, media outlets must be tapped to further disseminate the messages within the report. Press releases about the report will be sent to media sources that have covered previous GOMC events as well as other major or issue-specific outlets in the region. In addition to providing information about the report, the press releases should identify a central contact person who will arrange interviews with the ESIP steering committee co-chairs, work group contacts for specific issues, or local partners who can relate the regional report to local conditions.

Face-to-face meetings with certain decision-makers will be important for conveying specific messages to governors, premiers, and legislators at the state/provincial and federal levels as well as to networks of municipal officials. In addition to making these decision-makers aware of relevant take-home messages and specific findings in the SOE report, these meetings may be used to connect the report's messages to pending decisions or legislative actions. These meetings may also provide opportunities to explain future plans and identify areas in which support is needed to move the indicators and reporting effort forward.

7. Building and sustaining partnerships

Partnerships with multiple agencies and organizations are vital for the success of a gulf-wide indicators and reporting program. The importance of strong partnerships is reinforced in the program's guiding principles. Partnerships offer a variety of benefits, such as:

- Enabling pooling of resources to expand the breadth and depth of potential indicators, data available for developing indicators, and comprehensiveness and quality of the SOE report;
- Identifying specific target audiences and facilitating access to a broader audience than would be possible with an independent project;
- Accelerating learning and application of innovative ideas;
- Sharing of technical expertise and specialized knowledge;
- Developing agreements between agencies and organizations on analysis and interpretation of data;
- Enabling transmission of consistent messages regarding the state of the Gulf of Maine ecosystem; and
- Building trust, sharing perspectives, and providing a feeling of inclusiveness and shared problem solving.

A multiplicity of partnerships will be required to ensure the success of the Gulf of Maine indicators and reporting program. Information and advice will need to be sought from partners,

advisors, subject experts, representatives of target audiences, and scientists. The agencies, organizations, and groups that become partners in the regional indicators and reporting program will take on different types of roles and different levels of commitment, and they may have different interests and concerns that will influence their roles in the indicators and reporting initiative.

Partners must be engaged collaboratively in the indicators and reporting effort. They must feel that they are contributing meaningfully to this effort and that their involvement is mutually beneficial to them as well as to the program. Attention to the process of collaboration to maintain strong partnerships will be equally or more important than attention to the technical details of this gulf-wide effort. Workshops offer one avenue of supporting collaboration among partners, but routine collaborations with partners are also important, as these guide the immediate decisions that will shape the program.

To ensure that the gulf-wide indicators and reporting program continues moving forward, it is important to recognize that while collaboration requires an inclusive process that allows for fair engagement of opinions and suggestions from all partners, it does not require consensus among all partners. Consensus solutions should be sought to the extent possible, but the lack of consensus must not result in stalemate. Difference of opinions on issues can indeed be recorded in SOE reports in situations when consensus is not achieved. The ESIP steering committee and working group co-chairs will retain ultimate authority for making decisions at their respective levels. However, these leaders must also be accountable for their decisions and should be able to explain the rationale behind their decisions to maintain transparency.

7.1 *Levels of partnership*

To implement an effective gulf-wide indicators and reporting programs, ESIP partners will need to take on leadership roles within work groups, provide data and participate in its analysis and interpretation, raise awareness and transmit the findings of the effort, and contribute resources to implement and sustain the program. Key partners will be derived from federal and state/provincial governments, academic and research institutes, existing regional indicator initiatives, environmental groups, trade organizations, community groups, and the private sector.

Partners will play an important role in strengthening the issue-specific work groups, integrating across work groups, enabling the development of indicators, identifying target audiences, and supporting the dissemination of the SOE report and project results. While some partners that may play key roles in the regional initiative are identified in the monitoring and reporting programs in Appendices B and C, this list should not be viewed as comprehensive; a variety of other partners can offer substantial insights and contributions to the gulf-wide indicators and reporting program.

Partnerships can exist at multiple levels. Some partners will bear the core responsibility for certain aspects of this project by their involvement in work groups, for example. Others will support these tasks but will not be ultimately responsible for their success, such as by providing data to enable the development of indicators. Some partners will be informed of actions that are being undertaken by the indicators and reporting program but will not be directly involved in

those activities. These tiers of partners will be engaged by the ESIP steering committee and work group leads.

Recognition of the different levels of partnership is important, as it reveals that some partners are more closely engaged in the program than others. ESIP should encourage some form of participation by all interested partners, but it must also recognize the demands of partnership arrangements. As the number of partners increases, the effort required to maintain these partnerships and effectively collaborate with all involved parties increases. To maintain the ability to work efficiently, ESIP should carefully evaluate its ability to include more partners in core responsibility roles and gradually expand this group of partners.

7.2 *Supporting involvement of partners*

The involvement of partners, their ability to participate effectively, and the benefits that accrue to them can be enhanced through biennial meetings and by technical and financial assistance.

Biennial meetings. ESIP must initiate and foster collaborations with partners, and a kick-off workshop in 2006 or 2007 will serve as an initial venue for bringing together an expanded group of partners who may participate in the gulf-wide indicators and reporting program. ESIP should particularly strive to engage new partners and to re-energize those who have not participated in recent months. Subsequent meetings will be conducted on a biennial basis, during the years in which a conference is not held to present program findings.

These meetings will provide an opportunity for partners and interested parties to provide high-level input to the program. The needs of the partners should be discussed thoroughly at these meetings, and how well the regional indicators and reporting program is satisfying these needs should be evaluated. Workshops associated with each meeting will provide educational opportunities related to specific topics and training in skills that will benefit a variety of partners.

These venues will also provide an opportunity for collaborative assessment and planning that engages a broad suite of partners. During the meetings, all partners will be able to discuss progress of the gulf-wide indicators and reporting program over the past two years and contribute to plans for progress over the next two years, including identifying partners who will take on specific responsibilities. In addition, the policy implications of findings from the indicators and reporting program will be discussed, and plans of action for how the program may seek to inform and guide policy directions and decisions will be developed.

Financial arrangements. Input gathered during the 2005 listening sessions indicated that financial contributions from a wide range of partners were important for establishing credibility of the gulf-wide indicators and reporting program as a true partnership. Some stakeholders perceive the contribution of resources from partners as an indication of the partners' buy-in to the program and its goals. Towards this end, some partners may be able to offer direct financial support to the regional indicators and reporting program. Others may be able to write grant proposals to garner resources or may contribute in-kind services.

While financial contributions may shape public perceptions of the program and should be encouraged to the extent possible, many partners within the region have valuable experience developing indicators, acquiring or accessing the data to support those indicators, and networking contacts through which to disseminate results, but they may not have financial resources or staff support to expand their efforts to contribute to a gulf-wide indicators and reporting initiative. These partners are vitally important to the success of the regional program. ESIP may need to provide financial support to offset costs associated with participation in this effort for certain partners, including but not limited to local indicator and reporting initiatives, small non-governmental organizations, municipalities, academic scientists, research groups and private entities.

Technical assistance. Technical support will also be needed to enable groups holding data that will be brought into the regional indicators program to develop metadata, meet quality assurance requirements, and participate in activities to develop consistent regional data for each indicator. The technical support may be provided directly to the partners, or financial support may be made available to offset the costs associated with the use of in-house technical support provided by each partner organization.

8. Effective communication and outreach

Several types and levels of communication and outreach will be necessary to develop and sustain an indicators and reporting program in the Gulf of Maine region. Effective communication and outreach will 1) accurately represent the indicators and reporting initiative, 2) engage partners, and 3) disseminate information in useful manners to the target audience. Further, outreach will be needed to gain broad support for the initiative and to ensure that findings from the program are appropriately used to shape management decisions and actions within the region. The following sections outline basic components of program communication and outreach, but a specific communications and outreach strategy should be developed for the program as it is initiated.

8.1 *Communication*

8.1.1 *Representing the indicators and reporting initiative*

Consistent information must be put forward regarding the indicators and reporting initiative. To ensure that all involved parties and partners are conveying the same messages, standard descriptions of the program in different lengths of text must be developed. In addition, standard messages regarding the state of the ecosystem and general ramifications of its state must be used across all partners to ensure that the core, overarching messages coming from the program are consistent. At the same time however, local and issue-specific distinctions can be recognized and related to the core regional messages.

In addition to the development of consistent messages from the initiative, the program logo can be useful for establishing the identity of the program among partners, audience members, and other interested parties in the region. This logo should be used on all program materials and by partners who want to draw attention to their participation in the gulf-wide indicators and

reporting initiative. In this manner, program recognition will increase and program partners will be more easily identified.

8.1.2 *Engaging partners*

Communication with partners is important at all phases of the indicators and reporting effort. Initial communications to potential partners must describe the intent, goals, and purpose of the regional indicators and reporting program and highlight progress that has been made towards developing this program. These communications should also explain various roles that the partners may play in the effort. A broad pool of potential partners is already recognized within the region and will serve as the initial targets for further engagement in the program. However, discussion of the program at meetings and forums beyond those organized by ESIP or the GOMC will also be important for engaging and energizing new partners who may not yet be involved with the program or targeted by its initial communications.

The potential partners' abilities, interests, concerns, and limitations must be considered prior to their engagement in the gulf-wide indicators and reporting program. The role for and extent of involvement of each partner must be clarified, and potential resources that can be provided by or offered to the partner must be defined. Through the process of developing the indicators and SOE report, routine updates should be sent to all partners, including those who are not directly involved in program activities. Following completion of each cycle of indicator development and reporting, the partners' experiences related to participation in the program should be fully evaluated to improve the relationship with and involvement of partners in the future.

8.1.3 *Engaging the target audience*

Consultation with the target audience—decision-makers at federal, state/provincial, and municipal levels in the Gulf of Maine region—is necessary to ensure that materials that are produced are relevant and useful. Focus groups, surveys, and interviews may be used to gain insights into how the target audience prioritizes ecosystem issues and the types of information that would complement existing resources for managing those issues. Members of the target audience should be directly involved in the development of products from the indicators and reporting initiative as part of a collaborative peer review group. They should provide input regarding issues of importance to them, understandability of textual descriptions and graphical displays of data, as well as preferences for website formats, content, and tools as these are designed and tested.

Initial steps towards this task have been taken as part of the listening sessions that were conducted in the fall of 2005, but future repetitions of this process will be necessary for honing and improving the SOE report and other program products. Following each cycle of production of a SOE report, it will be important to evaluate whether the audience received the report, what users found relevant and useful in it, and how they applied the material. These insights can be gathered from surveys, focus groups, interviews, and web-based evaluation forms. The results will be important for planning content, format, dissemination, communication, and outreach strategies for the next cycle of reporting.

8.2 *Outreach*

Outreach efforts will be conducted during and following the SOE report's distribution to expand awareness of its messages and to encourage appropriate actions in the region. The outreach plan should ensure that the report's release draws attention to regional as well as local environmental issues and efforts, and that the momentum created by the report is tapped to build support for future efforts. Media outlets must be made aware of the report's findings through press releases and press conferences throughout the Gulf of Maine region. In addition, ESIP steering committee co-chairs, work group contacts, and involved local partners should be available for interviews.

Outreach will also be extended to decision-makers, including governors, premiers, state/provincial and federal legislators, and municipal officials as well as other targeted audiences. Outreach efforts should make these decision-makers aware of the report's main take-home messages and should connect those messages to pending decisions or actions. Outreach directed towards these officials should also be used to leverage support that is needed to remedy gaps in data availability or other resources that constrained the capacity of the current indicators and reporting effort.

9. Next steps in developing a regional indicators and reporting program

This section reviews and consolidates actions that are necessary as early steps to build a gulf-wide indicators and reporting programs.

Filling of roles in ESIP and issue work groups

- The ESIP steering committee should evaluate the representation among the co-leads and determine whether additional agencies with mandates related to the Gulf of Maine ecosystem should be represented.
- Some work group participants are already in place, but certain leadership roles need to be filled and many work group members remain to be identified. ESIP should identify work group co-chairs and gain annual commitments from them. The work group co-leads should initiate the process of identifying work group members.
- In addition to contacting individuals of known expertise and asking them to participate in the work groups, the ESIP steering committee and work group co-leads should build connections with new partners and integrate these groups into the program. Involving partners that have not become a part of the program yet is a critical step for building the program and developing a broad base of engagement across diverse groups.
- ESIP should identify potential technical advisors, determine the interest and capacity of these individuals to serve as advisors to the program, and secure commitments where appropriate.
- ESIP should hire a manager for the indicators and reporting program at the earliest possible opportunity.

Harmonizing indicator and reporting efforts

- Engage partners from monitoring and reporting programs in the region in collaborative discussions of the gulf-wide indicator and reporting program, indicators that may be developed, data available to support indicators, and how results may be presented.

Creating regional indicators

- Facilitate regional baseline assessments of aquatic habitats, eutrophication, and climate change.
- Develop conceptual models to determine the utility and assumptions of each indicator, to assess duplication or gaps in the group of indicators, and to integrate indicators across issues.
- Articulate regional management objectives and targets as well as relevant indicators to track progress towards each objective.
- Establish criteria for prioritizing indicators and a process for selecting indicators to be developed within each work group.
- Develop a few indicators per issue and an index or indices for one issue.
- Evaluate available data to support indicators.

Data and information management

- Hire a data management specialist to create a website and data management system for the indicators and reporting program.
- Ensure early dialogue and coordination with the Ocean Data Partnership via the data management specialist.
- Designate a small ESIP sub-group to work with data management specialist to determine the necessary design and functionality of the system.

Building and sustaining partnerships

- Contact potential partners to explain the gulf-wide indicators and reporting program and determine their interest in participating in the program as well as the nature of their potential involvement.
- Conduct an inaugural workshop to bring together a wide group of potential partners for the program.

Communication and outreach

- Develop a communications and outreach strategy for the indicators and reporting program.

10. Budget requirements and funding options

10.1 *Budget requirements*

A variety of activities must be financially supported to develop and implement an effective regional indicators and reporting program for the Gulf of Maine. These needs and projected costs for the first two years of the program are listed below by relevant categories.

	Cost in year 1	Cost in year 2
Core staffing needs		
ESIP steering committee co-leads[1]	$25,000.00	$25,000.00 (in-kind*)
Work group co-leads[2]	$60,000.00	$60,000.00 (in-kind*)
Work group members[3]	$90,000.00	$90,000.00 (in-kind*)
Support staff: program manager, data management specialist, and communications specialist	$150,000.00	$175,000.00
Operational activities and associated staff		
Harmonizing efforts		
Review indicators used by other programs, document monitoring protocols and data characteristics, identify management-relevant objectives for indicators	$12,000.00	$5,000.00
Development of data sharing arrangements	$5,000.00	$5,000.00
Workshop to identify priorities and strategies to improve monitoring of ecosystem attributes and conditions for which a lack of data inhibits indicator development		$25,000.00
Developing indicators		
Baseline assessment of aquatic habitats, eutrophication, and climate change	$30,000.00	
Workshop to vertically and horizontally integrate indicators	$15,000.00	
Evaluation of usefulness of indicators and presentation formats to users		$15,000.00
Creating state of the environment reports		
Style and production editors for report and associated products		$15,000.00
Evaluation of usefulness of report content and format to decision-makers; identification of future priorities and needs of members of target audience		$15,000.00
Biennial conference to disseminate results of report		$60,000.00
Other forms of report dissemination (pamphlet production, mailing costs, media outreach, direct outreach to decision-makers)		$25,000.00
Building and sustaining partnerships		
Biennial meetings of partners	$40,000.00	
Financial and/or technical assistance to partners	$30,000.00	$30,000.00
Communication and outreach		
Program communication	$10,000.00	$10,000.00
Program outreach	$15,000.00	$15,000.00
Total budget	**$482,000.00**	**$570,000.00**
In kind contributions	$175,000.00	$175,000.00
Total remaining to fund	$307,000.00	$395,000.00

[1] Computed as a 10% time commitment for five co-leads

[2] Computed as a 10% time commitment for two co-leads for each of the 6 groups

[3] Computed as a 5% time commitment of 6 members for each of the 6 groups

* All in kind contributions calculated at a rate of $25 per hour.

10.2 *Potential funding sources*

The federal, state, and provincial agencies, and coastal municipalities and associations with mandates in the coastal and marine environment will play major roles in this indicators and reporting program. Consequently, the budget proposes that over one-third of the costs associated with implementing and running the program will be provided as in-kind contributions from participating partner agencies and organizations. ESIP will function as a partnership within the GOMC, and a recurring annual amount of $100,000 (US) will be sought from the GOMC to support core staffing needs for the program.

While in-kind and financial support from governmental partner agencies and the GOMC will be necessary for the success and stability of the gulf-wide indicators and reporting program, input garnered from the listening sessions indicated that financial contributions from all partners will enhance the program's credibility. These cost-sharing arrangements support external perceptions of buy-in from the program's partners. Such arrangements will be pursued to the extent possible, but partners will not be excluded from participation if they are not able to contribute financial resources to the program.

Other funds to support activities of the indicators and reporting program will be sought from a variety of sources, including but not limited to:

- Opportunities available through agency funding processes and competitive grants;
- Action plan grant opportunities through the GOMC; and
- Partnerships with academic programs to support student interns or graduate students to work with the ESIP program.

References

Anon. 2004. Regional ecosystem indicators for the Gulf of Maine: pre-Summit draft—fisheries, contaminants, and coastal development. <http://www.gulfofmainesummit.org/docs/Draft%20Ecosystem%20Indicators%20Report%20(1).pdf> Accessed 10 May 2005.

Bertram, P., H. Shear, N. Stadler-Salt, and P. Horvatin. 1999. Environmental and socioeconomic indicators of Great Lakes basin ecosystem health. Pages 703-720 in D. J. Rapport, W. L. Lasley, D. E. Rolston, N. O. Nielsen, C. O. Qualset, and A. B. Damania. Managing for Healthy Ecosystems. Lewis Publishers, New York. On the internet at: http://www.epa.gov/glnpo/solec/peer_reviewed/Managing%20for%20Healthy%20Ecosystems%20A.pdf. Accessed 3 June 2005.

Bertram, P., N. Stadler-Salt, P. Horvatin, and H. Shear. 2003. Bi-national assessment of the Great Lakes-SOLEC partnerships. Environmental Monitoring and Assessment 81(1-3):27-33. On the internet at: http://www.epa.gov/glnpo/solec/peer_reviewed/bi-national-assessment_of_the_great-lakesA.pdf. Accessed 3 June 2005.

Bond, W., D. O'Farrell, G. Ironside, B. Buckland, and R. Smith. 2005a. Current status, trends, and perceptions regarding environmental indicators and state of the environment reporting in Canada. Background paper to an environmental indicators and state of the environment reporting strategy, 2004-2009, Environment Canada. National Indicators and Reporting Office, Environment Canada, Gatineau, Quebec, K1A OH3. On the internet at: http://www.ec.gc.ca/soer-ree/English/documents/bg_paper1_e.cfm. Accessed 16 June 2005.

Bond, W., D. O'Farrell, G. Ironside, B. Buckland, and R. Smith. 2005b. Environmental indicators and state of the environment reporting: an overview for Canada. Background paper to an environmental indicators and state of the environment reporting strategy, 2004-2009, Environment Canada. National Indicators and Reporting Office, Environment Canada, Gatineau, Quebec, K1A OH3. On the internet at: http://www.ec.gc.ca/soer-ree/English/documents/bg_paper2_e.cfm. Accessed 16 June 2005.

California EPA/Office of Environmental Health Hazard Assessment. Environmental Protection Indicators for California (EPIC). <http://www.oehha.ca.gov/multimedia/epic/index.html> Accessed 20 January 2006.

Chandler, H. 2001. Marine monitoring programs in the Gulf of Maine: an inventory. <http://www.gulfofmaine.org/library/monitoring_inventory.html> Accessed 18 May 2005.

Chesapeake Bay Program. 1999. Environmental outcome-based management: using environmental goals and measures in the Chesapeake Bay Program. EPA 903-R-00-016, CBP/TRS 248/00. <http://www.chesapeakebay.net/pubs/indpub/cover.pdf> Accessed 31 May 2005.

Chow, A., D. Hamilton, and J. Kanov. 2003. Making ecological information usable: designing an information system for the general public. University of Washington, Information School. Capstone report.

Dale, V. H. and S. C. Beyeler. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1: 3-10.

Farrey, P. M., M. L. Mooney-Seus, and H. C. Tausig (eds.). 1999. Out of the fog: furthering the establishment of an electronic environmental information exchange for the Gulf of Maine. New England Aquarium Aquatic Forum Series Report 99-1. <http://www.gulfofmaine.org/gominfoex/pdf/ootf.pdf> Accessed 15 August 2005.

Frost, C., L. Silk, N. Stadler-Salt, and P. Bertram. 2004. State of the Lakes Ecosystem Conference peer review report, Part 2: stakeholder review of the Great Lakes indicators. On the internet at: http://www.epa.gov/glnpo/solec/solec_2004/indicator_review.pdf.

Gibson, G., C. Chess, B. Johnson, and S. Carey. 2000. Communicating environmental indicators: phase II research results. Center for Environmental Communication, Rutgers University. <http://aesop.rutgers.edu/~cec/indreport.pdf> 10 May 2005.

Griffith, J. A. 1998. Connecting ecological monitoring and environmental indicators: a review of the literature. Journal of Environmental Systems 26(4): 325-363.

Gulf of Maine Council on the Marine Environment. 2002. Action Plan 2001-2006. On the internet at: http://www.gulfofmaine.org/council/action_plan/action_plan2001-06.pdf. Accessed 20 July 2005.

Gulf of Maine Ocean Data Partnership. 2006. <http://www.gomoos.org/coml/bin/view> Accessed 20 January 2006.

Hall, J. N. II. 2005. Indicators development in the National Estuary Program. Presentation at Coastal Zone '05.

Harwell, M. A., V. Myers, T. Young, A. Bartuska, N. Gassman, J. H. Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card. BioScience 49(7): 543-556.

Hodge, T. 1997. Toward a conceptual framework for assessing progress towards sustainability. Social Indicators Research 40: 5-98.

Jackson, L. E., J. C. Kurtz, and W. S. Fisher, eds. 2000. Evaluation guidelines for ecological indicators. EPA/620/R-99/005. U. S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC. 107 p.

Jacob, K., D. A. Swanson, L. Pinter, F. Bregha, A. Volkery. Sustainable development and national government actions: new study identifies key issues in national sustainable development strategy process. <http://www.iisd.org/publications/pub.aspx?id=645> Accessed 18 July 2005.

Jones, S. and P. G. Wells. 2001. Report on a monitoring workshop, Portsmouth, NH, May 2001. Gulf of Maine Council on the Marine Environment, Augusta Maine

Kellem, D. 2004. New Hampshire Estuaries Project Strategic Communication Plan. <http://www.nhep.unh.edu/resources/pdf/nhepstrategiccommunication-nhep-04.pdf> Accessed 28 October 2005.

King, P. and C. MacKenzie (eds.). 2005. Gulf of Maine Summit: Committing to Change, Summit Report, Gulf of Maine Council on the Marine Environment and the Global Programme of Action Coalition for the Gulf of Maine. <http://www.gulfofmainesummit.org/Summit%20Report/Summit%20Report.pdf> Accessed 8 July 2005.

Mendelson, M. 2004. In pursuit of data: populating the coastal development indicators. A report to the Gulf of Maine Council on the Marine Environment. <http://www.gulfofmainesummit.org/docs/CDI%20Report.> Accessed 8 July 2005.

Mills, E. 2003. State of the Gulf report: Nutrient indicators. <http://www.gulfofmainesummit.org/docs/state_of_gulf_report_nutrients10_03.pdf> Accessed 8 July 2005.

National Oceanic and Atmospheric Administration (NOAA). 2005. New priorities for the 21st century: NOAA's strategic plan, Updated for FY 2006-FY 2011. <http://www.spo.noaa.gov/pdfs/STRATEGIC%20PLANS/Strategic_Plan_2006_FINAL_04282005.pdf> Accessed 28 October 2005.

Niemi, G. J. and M. E. McDonald. 2004. Application of ecological indicators. Annual Review of Ecology, Evolution, and Systematics 35: 89-111.

Niemi, G. J, D. Wardrop, R. Brooks, S. Anderson, V. Brandy, H. Paerl, C. Rakocinski, M. Brouwer, B. Levinson, and M. McDonald. 2004. Rationale for a new generation of indicators for coastal waters. Environmental Health Perspectives 112(9): 979-986.

Organization for Economic Co-operation and Development. 1993. OECD core set of indicators for environmental performance review. Environment Monographs no. 83. OECD/GD(93)179. < http://lead.virtualcentre.org/en/dec/toolbox/Refer/gd93179.pdf> Accessed 27 January 2006.

Pesch, G. G. and P. G. Wells (eds.). 2004. Tides of change across the Gulf: an environmental report on the Gulf of Maine and Bay of Fundy. Prepared for the Gulf of Maine Summit: Committing to Change, Fairmont Algonquin Hotel, St. Andrews, New Brunswick, Canada, October 26-29, 2004. Gulf of Maine Council on the Marine Environment and the Global Program of Action Coalition for the Gulf of Maine. 81 p.

Percy, J. A. and P. G. Wells. 2002. Fundy Issues #22. Taking Fundy's pulse: monitoring the health of the Bay of Fundy. <http://www.bofep.org/meq.htm> Accessed 18 July 2005.

Pidot, L. 2003. Tapping the indicators knowledge-base: "lessons learned" by developers of environmental indicators. <http://www.gulfofmainesummit.org/docs/Lessons_Learned_Report.pdf> Accessed 18 May 2005.

Pidot, L. 2003. Tapping the indicators knowledge-base: "lessons learned" by developers of environmental indicators. Report supplement: the interviews. <http://www.gulfofmainesummit.org/docs/Lessons%20Learned%20Supplement.pdf> Accessed 18 May 2005.

Rice, J. and M-J. Rochet. 2005. A framework for selecting a suite of indicators for fisheries management. ICES Journal of Marine Science 62: 516-527.

Schiller, A., C. T. Hunsaker, M. A. Kane, A. K. Wolfe, V. H. Dale, G. W. Suter, C. S. Russell, G. Pion, M. H. Jensen, and V. C. Konar. 2001. Communicating ecological indicators to decision makers and the public. Conservation Ecology 5(1): 19. [online] URL: http://www.consecol.org/vol5/iss1/art19.

Siegelbaum, H. 2005. Communications strategy: the Puget Sound Georgia Basin ecosystem indicators report, phase II. Available from H. Siegelbaum at wastenot@speakeasy.net.

Stem, C., R. Margoluis, N. Salafsky, and M. Brown. 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology 19(2): 295-309.

Tsontos, V. M. and D. A. Kiefer. 2000. Development of a dynamic biogeographic information system for the Gulf of Maine. Oceanography 13(3): 25-30.

United Nations Educational, Scientific, and Cultural Organization (UNESCO). 2005. An implementation strategy for the coastal module of the Global Ocean Observing System. GOOS Report no. 148. IOC Information Documents Series No. 1217. <http://ioc.unesco.org/goos/docs/GOOS-148-COOP-lowres.pdf> Accessed 22 November 2005.

U. S. Government Accountability Office. Environmental indicators: better coordination is needed to develop environmental indicator sets that inform decisions. GAO-05-52. <http://www.gao.gov/new.items/d0552.pdf> Accessed 18 July 2005.

WebCOAST. Environmental Monitoring Program Locator. <http://www.cooa.unh.edu/webcoast/MP/mp.jsp> Accessed 21 December 2005.

Wells, P. G. 2003. Assessing health of the Bay of Fundy—concepts and framework. Marine Pollution Bulletin 46: 1059-1077.

Wells, P. G. 2003. State of the marine environment reports—a need to evaluate their role in marine environmental protection and conservation. Marine Pollution Bulletin 46: 1219-1223.

Wells, P.G., J. Harvey, J.A. Percy, G.R. Daborn and S.J. Rolston. (Eds). 2005. The Bay of Fundy Coastal Forum. Taking the Pulse of the Bay. A GPAC-BoFEP Coastal Forum held May 15-16th, 2002, as part of the 5th BoFEP Bay of Fundy Science Workshop, Wolfville, NS. Environment Canada - Atlantic Region, Occasional Report No. 25, Environment Canada, Dartmouth, NS and Sackville, NB. 54 p. plus appendices (CD ROM format).

Bibliography of indicator efforts

Alberta Government. 2005. State of the Environment. <http://www3.gov.ab.ca/env/soe/index.html> Accessed 21 June 2005.

Cape Cod National Seashore. Prototype long-term ecosystem monitoring program. <http://www.nature.nps.gov/im/units/caco/CACO_IM_monitor.htm> Accessed 20 June 2005.

Casco Bay Estuary Project. 2000. State of the Bay. <http://www.cascobay.usm.maine.edu/BayReportFinal.pdf> Accessed 17 June 2005.

Chesapeake Bay Foundation. 2004. 2004 State of the Bay Report. <http://www.cbf.org/site/DocServer/w33475.pdf?docID=2563> Accessed 19 June 2005.

Chesapeake Bay Program. 2005. Bay Trends and Indicators. <http://www.chesapeakebay.net/indicators.htm> Accessed 17 June 2005.

Environment Canada. Environmental Signals: Canada's National Environmental Indicator Series 2003. <http://www.ec.gc.ca/soer-ree/English/Indicator_series/default.cfm#pic> Accessed 13 June 2005.

Environment Canada. Monitoring the state of the St. Lawrence River. <http://www.slv2000.qc.ca/plan_action/phase3/biodiversite/suivi_ecosysteme/fiches_a.htm> Accessed 26 June 2005.

Georgia Basin-Puget Sound Ecosystem Indicators Report. 2002. <http://wlapwww.gov.bc.ca/cppl/gbpsei/> Accessed 15 June 2005.

Gulfwatch Contaminants Monitoring Program. 2005. <http://www.gulfofmaine.org/gulfwatch/> Accessed 18 July 2005.

Heinig, Christopher S. for New Meadows River Watershed Project Steering Committee. 2002. State of the New Meadows River: a report on the current environmental and resource status of the New Meadows River and surrounding watershed. <http://www.bowdoin.edu/new_meadows/dissemination/SOTNMR.pdf> Accessed 21 June 2005.

H. John Heinz III Center for Science, Economics and the Environment. 2002. The state of the nation's ecosystems: measuring the lands, waters, and living resources of the United States. <http://www.heinzctr.org/ecosystems/report.html> Accessed 15 June 2005.

Hodge, T. 1997. Toward a conceptual framework for assessing progress towards sustainability. Social Indicators Research 40: 5-98.

Long Island Sound Study. 2003. Sound Health 2003: a report on the status and trends in the health of Long Island Sound. <http://www.longislandsoundstudy.net/pubs/reports/soundhealth2003.htm> Accessed 17 June 2005.

Milstead, B., S. Stevens, M. Albert, and G. Entsminger. 2004. Northeast Coastal and Barrier Network: Vital Signs Monitoring Plan Phase III. December 15, 2004 Draft. <http://www1.nature.nps.gov/im/units/ncbn/products/Phase_III_Plan/NCBN_Phase_3_Vital_Signs_Monitoring_Plan.pdf> Accessed 8 July 2005.

New Hampshire Estuaries Project. 2003. 2003 State of the Estuaries. <http://www.nhep.unh.edu/resources/pdf/2003stateofthe-nhep-03.pdf> Accessed 17 June 2005.

Nova Scotia Department of the Environment. 1998. The State of the Nova Scotia Environment 1998. <http://www.gov.ns.ca/enla/pubs/envdoc.PDF> Accessed 20 June 2005.

Puget Sound Action Team. 2004. State of the Sound 2004. <http://www.psat.wa.gov/Publications/StateSound2004/State_Sound_Report.htm> Accessed 15 June 2005.

State of the Lakes Ecosystem Conference. 2004. State of the Great Lakes 2005—Draft. <http://www.epa.gov/glnpo/solec/solec_2004/sogl_2005(full).pdf> Accessed 13 June 2005.

Statistics Canada. 2000. Human Activity and the Environment. <http://estat.statcan.ca/content/HAE/english/modules/module-0/mod-o.htm> Accessed 22 June 2005.

Surfrider Foundation. 2004. State of the Beach 2004. <http://www.surfrider.org/stateofthebeach/home.asp> Accessed 21 June 2005.

United States Environmental Protection Agency. 2001. National Coastal Condition Report. EPA-620/R-01/005. Office of Research and Development/Office of Water, Washington, D. C.

United States Environmental Protection Agency. 2003. Draft Report on the Environment. <http://www.epa.gov/indicators/roe/html/roeTOC.htm> Accessed 16 June 2005.

United States Environmental Protection Agency. 2004. National Coastal Condition Report II. EPA-620/R-03/002. Office of Research and Development/Office of Water, Washington, D. C.

Appendix A. Timeline of major events and products sponsored by the Gulf of Maine Council and its partners associated with environmental indicators and reporting.

2001 Completion of marine monitoring program inventory

2002 Atlantic Northeast Coastal Monitoring Summit
Outlined a strategy and framework for developing a regional monitoring network to ensure that data are available to quantify ecosystem indicators

2003 Review of environmental indicators programs and compilation of *Tapping the Indicators Knowledge-base: "Lessons Learned" by Developers of Environmental Indicators*

2004 Northeast Coastal Indicators Workshop
Over 100 scientists and managers developed initial lists of key indicators related to six major management issues: coastal development, contaminants, fisheries, eutrophication, aquatic habitat, and climate change

Data evaluation for indicators and production of *In Pursuit of Data: Populating the Coastal Development Indicators*

Release of *Tides of Change Across the Gulf: An Environmental Report on the Gulf of Maine and Bay of Fundy*
Examined three priority issues—land use, contaminants, and fisheries—through an assessment of their history and status, factors that have led to current conditions, and actions taken to improve conditions

Gulf of Maine Summit
Evaluated and refined over 40 proposed ecosystem indicators related coastal development, contaminants, and fisheries

Committing to Change proclamation signed by Premiers of Nova Scotia and New Brunswick and Governors of Maine, New Hampshire, and Massachusetts; called on Gulf of Maine Council to "provide timely and responsive information to decision-makers (including a comprehensive state of the environment reporting and indicators series)"

2005 Listening sessions and in-depth interviews to understand use of the *Tides of Change* report and to gain input into types and formats of information sought by potential users of future indicators and SOE reports

Appendix B. Review of ecosystem indicator and reporting programs that establish context for the Gulf of Maine effort.

A variety of ecosystem indicator programs have been established at local, regional, and national scales. The Gulf of Maine (GOM) indicators effort can draw important lessons from these programs by considering ways in which the proposed GOM effort is consistent with or diverges from them. To evaluate the consistencies and distinctions in indicators that have been proposed for the GOM and those that are used by other programs, seven indicator programs within the GOM, ten regional programs outside of the GOM, and eight national-level programs within the United States and Canada were reviewed. This review identified issues and indicators that are tracked by each program (Table B-1) and serves as the basis for an analysis of how the GOM regional effort compares to existing programs.

Indicator and reporting programs within local ecosystems of the Gulf of Maine

A regional indicators effort must be built up from and consistent with programs that already exist within the GOM. Capitalizing upon the existing local capacity within the GOM will be essential for a number of reasons. First, local programs have already identified issues that are considered important to citizens in the area and have compiled data to track a variety of indicators that are relevant to these issues. Further, a regional reporting effort must strive to complement the findings and interpretations established by local programs, rather than ignore local distinctions from the larger trend.

Indicators and reporting programs within the GOM region include the following: New Hampshire Estuaries Project, Casco Bay Estuary Partnership, New Meadows River Watershed Project, State of the Nova Scotia Environment, Quoddy Report, Cape Cod National Seashore, and Gulfwatch. Although issues and indicators are organized in different manners (Figure B-1), the existing programs cover each of the six issue areas that have been the focus of work at the regional GOM scale—land use, contaminants, fisheries, aquatic habitats, eutrophication, and climate change (Figure B-2). Thus, there is a high degree of consistency between issues that have been proposed as the initial starting points for a regional ecosystem indicators effort and those issues that are the focus of indicators at more local scales within the GOM. However, indicators developed by many of the existing programs focus more heavily on certain topics (e.g., contaminants) than they do on the other issues (e.g., climate change). In addition, certain programs report on issues that extend beyond those proposed by the GOMC regional effort—stewardship (in Casco Bay Estuary Project) and air quality (in State of the Nova Scotia Environment).

Indicator and reporting programs in regions outside the Gulf of Maine

Indicator and reporting programs in regions outside of the GOM may serve as examples to guide the GOM effort, and if similar issues and indicators are tracked by these programs, they will enable GOM patterns of change to be interpreted in a broader context. The issues and indicators reported on by programs in U. S. and Canadian regions outside of the GOM were examined. These efforts range extensively in scope—from six indicators to represent the Georgia Basin-Puget Sound region to over 100 indicators for the Great Lakes region. The content across regional programs and between these programs and the proposed GOM issues is highly consistent. The six major issues identified as important in the GOM are tracked in other regional programs, yet certain regional

programs encompass issues, such as stewardship and air quality, that extend beyond those proposed as starting points for the GOM effort.

National indicator and reporting programs

National indicator programs and state of the environment reports provide high-level context for the GOM region. Although national indicator programs cover a broader scope of topics than are tracked at most regional levels, the issues that have been identified as starting points for the GOM effort are encompassed by national programs. Knowing the relevant features that are tracked and reported at the national scale enables the GOM effort to tailor indicators to more easily gain context for regional trends.

Local indicators program within Gulf of Maine (Illustrative examples)	**Issues**	**Indicators**
New Hampshire Estuaries Project	Water quality Contaminants Land use Shellfish Habitats	Dissolved oxygen Fecal coliform levels Toxins in shellfish tissues Protected areas in watershed Unfragmented land blocks Extent of impervious surfaces Extent of "sprawl" Number harvestable oysters Harvestable clam density Eelgrass coverage Tidal wetland restoration
Casco Bay Estuary Partnership	Population change Water quality Toxics Land use Shellfish Swimming beaches Stormwater discharge Species of interest Stewardship	Water quality in bay Water quality in rivers and streams Toxics in sediments Toxics in mussel tissues Acres of protected land Acres of undeveloped blocks Extent of impervious surfaces Open shellfish beds CSO abatement Eelgrass distributions Waterbird populations
New Meadows River Watershed Project	Population change Water quality Toxics Water quality/zoning Shellfish Marine uses Remediation efforts	Population growth Population rate of change Temperature Salinity Dissolved oxygen Nutrients Toxics in sediments Toxics in mussel tissues Toxics in lobster tissues Maximum land use density

		Minimum lot area Maximum impervious surface coverage Bacterial contamination in shellfish Shellfish growing area classifications Marine fisheries Shellfish licenses and productivity Aquaculture leaseholds Boating Non-point pollution sources Other remediation efforts
Gulfwatch	Contaminants in blue mussels	Polycyclic aromatic hydrocarbons Polychlorinated biphenyls Chlorinated pesticides Metals
State of the Nova Scotia Environment	Water resources Waste resources management Air quality	Municipal water supplies with Protected Water Area designation or comprehensive water supply protection strategy Municipal water supply samples testing negative for total coliform bacteria Municipal water supplies meeting guidelines for Canadian drinking water quality Water table levels Number boil orders Contamination threat to private wells Nitrates in private wells Number of community groups active in river or lake enhancement initiatives or % bays, inlets, and estuaries covered by community led initiatives Toxins in shellfish Annual number of beach closures Number of waterbodies that do not meet Canadian Water Quality guidelines for protection of aquatic life Number hectares of freshwater wetlands Mercury levels in water Quality of industrial discharges to environment Number of contaminated sites by category Number contaminated sites assessed and number remediated Number certified sewage treatment plant operators Number Nova Scotians on municipal sewage systems with treatment Number municipal sewage treatment facilities operating properly Number private central sewage treatment facilities Number solid waste disposal sites Diversion of solid waste from disposal sites Number kilograms of waste produced per capita % organic waste being composted Quality of pulp and paper discharge Particulate levels Ground level ozone Atmospheric mercury

		Air quality index Greenhouse gas emissions Sulphur dioxide Sulphate deposition Mercury bioaccumulation
Quoddy Report		Pollution Habitat change Fishing pressure Phytoplankton Invertebrates Fish Birds Whales
Cape Cod National Seashore	(organized by habitat type) Estuaries/marshes Beaches, spits, barrier islands Ponds and freshwater wetlands Coastal uplands Park-wide/multi-system	Salt marsh sedimentation rate Salt marsh vegetation Estuarine benthic macrofauna Estuarine nekton Migrating waterbirds Geomorphic shoreline change Beach macroinvertebrates Colonial waterbirds Piping plovers Kettle pond water quality Pond vegetation Vernal wetland vegetation Freshwater aquatic invertebrates Freshwater fish Aquatic turtles Pond-breeding amphibians Marsh birds Dune grassland vegetation Coastal heathlands Coastal forests Landbirds-avian point counts Landbirds-avian productivity and survivorship Small mammals Meso-mammals Meterologic and atmospheric monitoring Hydrology Groundwater quality Cover type mapping Visitor use and resource impact Contaminants

Regional indicator programs outside of the Gulf of Maine	Issues	Indicators
Great Lakes	Land use-land cover Contamination Aquatic habitats Biotic communities Invasive species Coastal zones Resource utilization Human health Climate change	Land cover-land conversion Groundwater and land: use and intensity Forest lands—conservation of biodiversity Sustainable agricultural practices Integrated pest management Urban density Brownfield redevelopment Area, quality, and protection of cobble beaches Area, quality, and protection of alvars Phosphorus concentrations and loadings Nutrient management plans Contaminants in young-of-year spottail shiners Contaminants in colonial nesting waterbirds Contaminants in whole fish External anomaly prevalence index for nearshore fish Biological markers of human exposure to persistent chemicals Contaminants in sport fish Contaminants in snapping turtle eggs Contaminants affecting productivity of bald eagles Contaminants affecting American otter Atmospheric deposition of toxic chemicals Toxic chemical concentrations in offshore waters Concentrations of contaminants in sediment cores Drinking water quality Air quality Acid rain Extent of hardened shoreline Natural groundwater quality and human-induced changes Base flow due to groundwater discharge Groundwater dependent animal and plant communities Salmon and trout Walleye Prey fish populations Lake trout Status of lake sturgeon Coastal wetland fish community health Wetland-dependent bird diversity and abundance Coastal wetland amphibian diversity and abundance Native freshwater mussels Benthos: diversity and abundance Zooplankton populations *Hexagenia* Abundances of *Diporeia* Coastal wetland invertebrate community health Phytoplankton populations Coastal wetland plant community health Sea lamprey

		Non-native species Coastal wetland area by type Effects of water level fluctuations Beach advisories, postings, and closures Commercial/industrial eco-efficiency Economic prosperity Water withdrawal Energy consumption Solid waste generation Ice duration on the Great Lakes
Georgia Basin-Puget Sound	Population Contaminants in harbour seals Species at risk Air quality Solid waste Terrestrial protected areas	Population in region % of population in districts and counties Average annual population growth rates by district and county Levels of PCBs in harbour seals Levels of dioxins and furans in harbour seals Number of threatened or endangered taxa Species at risk as % of native breeding species % of communities exposed to PM10 concentrations > 25 micrograms/m^3 > 5% of the time PM10 levels in Puget Sound Per capita solid waste disposed and recycled in Georgia Basin Per capita solid waste disposed and recycled in Puget Sound % land protected in Georgia Basin-Puget Sound ecosystem
State of the [Puget] Sound	Water and submerged lands Habitats Species	Contaminated sediments PCBs in shellfish, fish, marine mammals PAHs in fish and shellfish Metals (arsenic, copper, Pb, Hg, tributyltin) Acres available for shellfish harvest Impervious land cover Liver lesions in English sole (PAHs) Lowland habitat loss Eelgrass *Spartina* infestation Species at risk Salmon Rockfish Herring Marine birds Orcas
Chesapeake Bay Program	Land use and people Water quality Bay pollutants Habitats Animals and plants Bay restoration	Land use and pollutant loads Watershed development trends Watershed population Population, households, and development trends Vehicle miles traveled vs. population in watershed Chesapeake Bay partner communities: award status Brownfields redevelopment in basin Preserved lands in watershed Water trails in watershed Public access points to bay and its tributaries River flow into bay Chlorophyll a in bay and tributaries Secchi depth in bay and tributaries

		Bottom dissolved oxygen concentration in bay and tributaries Bay summer dissolved oxygen concentration Phosphorus concentration in bay and tributaries Nitrogen concentration in bay and tributaties Estimated vehicle NOx emissions vs. vehicle miles traveled Simulated nutrient and sediment load reductions Nontidal nitrogen loads and river flow to bay Nontidal phosphorus loads and river flow to bay Municipal N and P delivered loads and population Municipal N and P discharge and population Municipal wastewater flow and population Municipal wastewater flow and municipal N and P discharges Point source N and P loads delivered to bay Sewage disposal and septic tank loads Sources of N and P to the bay Sources of sediment loads to the bay Sediment trends in rivers entering the bay Nontidal sediment loads and river flow to the bay Designated oyster restoration areas Chesapeake basin forests Riparian forest buffer conservation and restoration Acres of bay grasses and changes by zone Density of bay grass acreage Bald eagle population count Trends in waterfowl: black duck and mallard Trends in diving ducks Oyster spat Oyster harvest Blue crab commercial harvest Blue crab mature females Blue crab juveniles Hatchery-reared American shad stocking American shad population trends Striped bass spawning stock Trends in finfish: striped bass Benthic community and habitat condition Acres under nutrient management plans Boat waste pump-out facilities Municipal freshwater flow and nutrient reduction technology Chemical contaminant effects on living resources in tidal rivers Releases and transfers of chemical contaminants from federal facilities Tributyltin concentration levels: Sarah Creek, VA and Hampton Roads, VA Industry-reported releases and transfers of toxins of concern Regions of concern Stream miles opened to migratory fish Wetlands protection, restoration, and enhancement
Chesapeake Bay Foundation	Pollution Habitat Fisheries	Nitrogen and phosphorus Water clarity Dissolved oxygen Toxics

		Forested buffers Underwater grasses Wetlands Resource lands Rockfish Oysters Crabs Shad
Long Island Sound	Water quality Habitats Living resources Public awareness	Nitrogen pollution Hypoxia Toxic contaminants Pathogens Altered landscapes Habitat restoration Shellfish abundance (harvest) Finfish abundance Coastal birds Public participation
Alberta government	Land Water Biodiversity Climate change Air Waste	Wildfires Pesticide use Cleanup of petroleum storage tank sites Parks and protected areas Reclamation of oil and gas wells Reclamation of oil sands mining Timber harvest—actual vs. allowed Groundwater levels Lake level index Lake trophic status River water quality index River nutrient index River bacteria index River pesticide index Groundwater observation wells Groundwater well density Water allocations by sector Water allocations compared to natural flows Waters used for oilfield injection Pulp mill effluent levels Hydrometric monitoring network Reservoir index Volume of water shared Watershed organizations General status of Alberta wild species Species at risk Temperature trends Greenhouse gas emissions Air quality index Benzene Benzo(a)pyrene Carbon monoxide Fine particulates Nitrogen dioxide

		Ozone Sulphur dioxide Acidifying precipitation % of province with airshed zones in place % of air quality monitoring stations that collect and report real-time data Per capita waste disposal Hazardous waste recycling Solid waste diversion
Pacific and Yukon	Freshwater quality Toxic contaminants Biodiversity Marine ecosystems Urban water use and wastewater treatment Climate change Stratospheric ozone depletion Urban air quality	Nitrate levels in groundwater PCBs in cormorant eggs Dioxin/furan levels Pesticide poisonings in raptors Toxins in heron eggs Toxins in osprey eggs Bald eagle Blue brant geese Great blue heron Lesser show geese Porcupine caribou Waterfowl species Trumpeter swan Western sandpiper Sensitive ecosystems Shellfish closures Seabirds Water use and wastewater Temperature and precipitation Stratospheric ozone thickness Fraser Valley smog Central Okanagan Valley smog
St. Lawrence	Water Sediments Biological resources	Changes in water level and flow Water quality in the fluvial section—toxic contaminants and physicochemical and bacteriological parameters Oceanographic processes in the estuary and Gulf Safety of potential freshwater swimming sites Shellfish water quality Toxic contamination in sediments: Lake Saint-Francois Freshwater wetlands and exotic plant species Freshwater fish communities Toxic contamination in freshwater fish Toxic contamination in marine resources Sentinel species for the Gulf—seabirds, great blue heron, Northern gannet Beluga population of the estuary Reintroduction of striped bass
British Columbia	Water Toxic contaminants Biodiversity Climate change Stewardship	Surface water quality Groundwater Surface water use Toxic substance releases Persistent chemicals in wildlife Species at risk

		Habitat Fish Wildlife Greenhouse gas emissions Temperature change Mitigating environmental impacts Linking economy and environment Protected areas

National Indicator Program	Issues	Indicators
Heinz Center—*State of the Nation's Ecosystems* ("Coasts and Oceans" section only)	System dimensions Biological components Chemical and physical conditions Human uses	Area of coastal living habitats Shoreline types At-risk native marine species Non-native species Unusual marine mortalities Harmful algal blooms Condition of bottom dwelling animals Chlorophyll concentration Areas with depleted oxygen Contamination in bottom sediments Coastal erosion Sea surface temperature Commercial fish and shellfish landings Status of commercially important fish stocks Selected contaminants in fish and shellfish Recreational water quality
EPA—*National Coastal Condition Report II*		Benthic index Fish tissue contaminants index Coastal habitat quality index Water quality index Sediment quality index
U. S. Park Service—*Vital Signs* (Northeast eutrophication indicators)	Salt marsh Estuarine eutrophication Geomorphic change Landscape pattern Visitor impacts	Vegetation community structure Nekton community structure Sediment elevation change Water chemistry Water quality Water clarity Seagrass distribution Seagrass condition Sediment organic carbon Nutrient inputs Shoreline position Coastal topography Marine geomorphology Marine hydrography Anthropogenic modifications Landscape pattern Park usage Habitat alteration

		Wildlife disturbance
EPA—*Draft Report on the Environment*	Purer water Better protected land Human health Ecological condition Cleaner air	Waters and watersheds Drinking water Recreation in and on the water Consumption of fish and shellfish Land use Chemicals in the landscape Waste and contaminated lands Health status of the United States Environmental pollution and disease Measuring exposure to environmental pollution Landscape condition Biotic condition Chemical and physical processes Ecological processes Hydrology and geomorphology Natural disturbance patterns Outdoor air quality Indoor air quality Global air issues
Environment Canada—*Environmental Signals*	Human health and well-being Ecological life-support systems Natural resources sustainability Human activities	Municipal water use Municipal wastewater treatment Urban air quality Biodiversity and protected areas Toxic substances Acid rain Climate change Stratospheric ozone Forestry Agricultural soils Energy consumption Passenger transportation Municipal solid waste
NOAA Coastal Zone Management Program (contextual indicators)	Coastal areas Biological features Water quality Land use Human uses Responses/management Hazards	Coastal loss due to climate change Coastal wetland loss Area of coastal watersheds Number of acres of coastal habitats Number of invasive species within coastal watersheds % of water bodies impaired % of impaired water bodies with non-point pollution as primary source of contamination Dissolved oxygen/hypoxia Eutrophic conditions/nutrients Sediment contamination/benthic index Overall national coastal condition % increase in population growth in coastal counties Population density of coastal counties compared to inland % of national employment in or attributable to coastal counties % of national economy attributable to coastal counties Energy and water demand in coastal counties % land use change % change in impervious surfaces

		Freshwater demand % of acres of coastal zone open for public use % of total miles of beach in coastal zone open for public access Number of coastal sites open for public access Number of coastal communities with waterfront areas Total federal and state dollars spent on coastal water quality activities Area within coastal zone management plan coastal zone boundary Area in coastal nonpoint program boundary Number of coastal hazard events per year Number dollars of damage from coastal hazards per year Number of coastal disaster declarations per year requiring state or federal disaster assistance Number of dollars of coastal hazard assistance per year paid by state and federal agencies Number of people in Category 1 storm surge area Number of acres in Category 1 storm surge area Number of acres of residential and commercial land uses within coastal flooding and erosion areas Number of states that have mapped inventories of coastal areas affected by natural hazards
Surfrider Foundation—*State of the Beach*	Beach access Water quality Erosion and erosion responses Beach ecology	Beach access Surf zone water quality Beach erosion Beach ecology Beach fill Shoreline structures Erosion response Surfing areas Quality of state coastal management websites
Statistics Canada—*Human Activity and the Environment*	Human well-being Ecosystems and well-being Natural resources Natural background Driving forces	Human health Waste generation and management Air quality Water quality Soil Contaminants in biota Protected areas Species at risk Invasive species Natural disasters Agriculture Forests Marine Wildlife Water Energy Mineral Environmental geographies Physiography Climate Geophysical and meteorological profile

		Population Economy Science and technology Environmental legislation and non-regulatory initiatives Environmental protection expenditures Environment industry Environmental practices Public participation Recreation Environmental education

Appendix C. Review of monitoring programs to support the GOM regional indicators and reporting effort.

Monitoring programs are necessary to provide adequate data at appropriate temporal and spatial scales to develop regional ecosystem indicators. Fortunately for the GOM indicators effort, a plethora of environmental monitoring activities are already underway within the region. Monitoring is conducted by federal, state/provincial, and municipal government agencies, regional consortiums, academic and research institutions, and citizens' groups. These monitoring programs collect data that can be used to implement many of the proposed GOM regional indicators.

Within the GOM region, Mendelson (2004) identified monitoring programs within state/provincial environmental agencies and commissions as well as multiple federal agencies that hold useful sources of data to implement the coastal development indicators. Regional monitoring programs have been compiled by the Gulf of Maine Council Environmental Quality Monitoring Committee at http://gomc.sr.unh.edu/index.jsp. In addition, state/provincial governments as well as federal agencies in both the United States and Canada routinely collect data that support the proposed fisheries and climate change indicators. Monitoring programs that are relevant to focus issues of the indicators program and documented in the above sources are shown in the table below.

		Coastal development	Contaminants and pathogen	Fisheries and aquaculture	Eutrophication	Aquatic habitats	Climate change
Monitoring program	**Sponsoring agency**	**Monitoring relevant to indicators**					
National Coastal Assessment	US Environmental Protection Agency	X	X	X	X	X	X
Disposal area monitoring system	US Army Corps of Engineers		X	X			
Bioeffects studies	National Oceanic and Atmospheric Administration		X				
Gulf of Maine Ocean Observing System (GoMOOS)	GoMOOS		X		X		
Gulfwatch	Gulf of Maine Council on Marine Environment		X				
MARMAP	NOAA/Northeast Fisheries Science Center				X		
Mussel Watch	National Oceanic and Atmospheric Administration		X				
National Benthic Surveillance Project (ended in 1992, now part of Biological Effects Studies)	National Oceanic and Atmospheric Administration		X	X			
Fisheries and Oceans Canada monitoring	Fisheries and Oceans Canada			X			
National Marine Fisheries Service monitoring	National Marine Fisheries Service			X			
National Estuarine Research Reserves Systemwide Monitoring	NOAA/National Ocean Service	X		X	X	X	
Environmental Quality Data Bank	Environment Canada						
Toxic Chemicals in Canadian Seabirds	Environment Canada		X				
Maritime Shellfish Sanitation Program	Environment Canada		X				
Biotoxin Monitoring Program	Canadian Food Inspection Agency		X				
Dredged Material Ocean Disposal Site Monitoring	Environment Canada		X				
Atlantic Coastal Action Program	Environment Canada, local communities		X		X		
New Brunswick Finfish Aquaculture Monitoring Program	NB Department of Environment and Local Government; NB Department of Agriculture, Fisheries, and Aquaculture		X	X			
Shellfish Fishery Management Plan for Oak Bay	St. Croix Estuary Project and others		X				
Enteromorpha monitoring	St. Croix Estuary Project				X		
Phytoplankton monitoring	Fisheries and Oceans Canada		X		X		
Rockweed study	St. Croix Estuary Project					X	
Estuary Classification Program (St. Croix River estuary)	St. Croix Estuary Project		X		X		
Atmospheric Deposition Monitoring Program	ME Department of Environmental Protection		X		X		
Air Toxics Monitoring Program	ME Department of Environmental Protection		X				
Ozone Monitoring Program	ME Department of Environmental Protection, US Environmental Protection Agency, National Park Service		X				

		Coastal development	Contaminants and pathogen	Fisheries and aquaculture	Eutrophication	Aquatic habitats	Climate change
Monitoring program	**Sponsoring agency**	**Monitoring relevant to indicators**					
Mercury deposition monitoring program	ME Department of Environmental Protection, US Environmental Protection Agency, National Park Service, Univ. of Southern Maine		X				
Casco Bay Estuary Project monitoring	Casco Bay Estuary Project	X	X			X	
Marine Environmental Monitoring Program	ME Department of Marine Resources		X				
Ocean Studies Penobscot Estuary Program	Corning School of Ocean Studies		X		X		
ME Finfish Aquaculture Monitoring Program	ME Department of Marine Resources			X	X		
ME Shellfish Sanitation Program	ME Department of Marine Resources		X				
ME Paralytic Shellfish Poisoning Monitoring Program	ME Department of Marine Resources		X				
Toxic Chemicals in Gulf of Maine Seals	Marine Environmental Research Institute		X				
Surface Water Ambient Toxins Monitoring Program	ME Department of Envrironmental Protection		X				
Marine Phytoplankton Monitoring Program	ME Sea Grant and others				X		
Local water quality monitoring initiatives	ME--volunteers with land trusts, "friends" groups, municipalities		X		X		
ME and NH Gulf of Maine Assessment	US Environmental Protection Agency, ME Department of Environmental Protection, NH Department of Environmental Services		X	X	X		
Deer Isle Partners in Monitoring	Deer Isle Partners		X		X		
Herrick Bay Stream study	Marine Environmental Research Institute		X				
Friends of Medomak Watershed Water Quality Monitoring	Friends of Medomak Watershed		X		X		
Island Monitoring Task Force	ME Sea Grant, ME Island Trail Association					X	
Great Bay Coast Watch	UNH Cooperative Extension, Sea Grant		X		X		
NH Public Beach Program	NH Department of Environmental Services		X				
NH Shellfish Program	NH Department of Environmental Services		X				
UNH Open Ocean Aquaculture monitoring	NOAA CINEMar		X	X	X		
Estuarine juvenile finfish seine surveys	NH Deptartment of Fish and Game			X			
Enhanced ambient rivers monitoring program	NH Department of Environmental Services		X		X		
Harmful algal bloom monitoring program	NH Sea Grant, UNH		X				
Coastal Ocean Observation and Analysis	Center for Coastal Ocean Observation and Analysis, UNH		X		X		
SeagrassNet	SeagrassNet, UNH Jackson Lab					X	
MA Local and regional beach monitoring	Local boards of health		X				
MA Shellfish Sanitation Program	MA Division of Marine Fisheries		X				
MA Ecosystem Assessment Program, estuaries	MA Coastal Zone Management Program		X	X	X		
Gloucester 301(h) monitoring program	Allan D. Michael & Associates		X		X		
Shellfish Clean Waters Initiative	MA Coastal Zone Management Program		X				
Clean Beaches and Streams program	Salem Sound 2000		X				
Circulation and Contaminant Transport in MA Coastal Waters	US Geological Survey		X				
Outfall and Harbor Monitoring Program	MA Water Resources Authority		X		X		
Wetland Assessment Program	MA Coastal Zone Management Program			X		X	
Salt Marsh Monitoring	MA Audubon Society	X				X	
Monitoring Alewife Runs in Northern MA	MA Audubon Society and others			X			
Cape Cod Bay Marine Monitoring	Center for Coastal Studies			X	X		
Baywatchers	The Coalition for Buzzards Bay		X		X		
Friends of Casco Bay Water Quality Monitoring	Friends of Casco Bay		X		X		
Stellwagen Bank National Marine Sanctuary	National Oceanic and Atmospheric Administration			X	X	X	
Lobster Conservancy	Lobster Conservancy			X			
Shore Stewards	Maine Coastal Program		X				

Appendix D. Regional ecosystem goals as inferred from the list of principles developed by the first *Out of the Fog* workshop held by the Gulf of Maine Environmental Information Exchange (Farrey *et al.* 1999).

- Coastal habitats throughout the Gulf of Maine are healthy and support an appropriate abundance and range of plant and animal species.
- The Gulf of Maine is known for its clean marine environment. Its shoreline and waters are free of marine debris and are healthy for people and wildlife.
- The Gulf of Maine has productive fishery resources that meet human needs and maintain ecological integrity.
- Toxic contaminants in the marine food chain of the Gulf of Maine are at levels such that public health is protected and ecosystem integrity is maintained.
- Gulf of Maine shellfish habitats produce shellfish safe for human consumption.
- Public education and involvement is assured by timely, accurate, and accessible information and data on all activities that may significantly affect the watershed and its resources, habitats, and ecological processes.
- Public access to the Gulf of Maine shoreline, water, and its resources is assured and sufficient.
- The Gulf of Maine is a prosperous, diversified region of sustainable coastal communities retaining viable expressions of indigenous coastal and maritime culture and industry.
- The scientific monitoring processes of the Gulf of Maine are adaptable enough to identify and provide scientifically-based recommendations to address anticipated and unanticipated long-term change, such as the effects of overfishing, global climate change, establishment of non-indigenous organisms, human population growth, and changes in coastal settlement patterns.
- The environmental management infrastructure of the Gulf of Maine is prepared to recognize change and respond proactively to protect the watershed.
- Coastal development patterns in the Gulf of Maine are managed to protect ecosystem stability in the long-term by anticipating shoreline changes due to sea level rise, global warming, and other changes in social, economic, and environmental patterns.
- Representatives from all user groups respect one another and are willing to work together for the long-term benefit of the Gulf of Maine.

Appendix E. Expanded framework for selecting a suite of indicators for the gulf-wide indicators and reporting program.

Content borrowed heavily from Rice and Rochet (2005) and California EPA (2006)

A wide variety of indicators could be used to evaluate the condition of and changes in ecosystems. Multiple indicators are needed to adequately characterize the status of an ecosystem—including its physical, biological, social, economic, and institutional dimensions—but these indicators must be chosen wisely. Costs associated with monitoring, analysis, and reporting increase as the number of indicators increases. In addition, tracking and reporting on a large number of indicators may produce an overwhelming amount of information that could create stalemate in decision-making processes.

To ensure that indicators provide clear management guidance in a cost-effective manner, an objective process is needed to identify suites of indicators that are as small as possible while still meeting the needs of users, capturing trends in a range of issues, and conveying information about the overall status of the ecosystem. The framework presented below lays out key steps and specific tasks associated with selecting ecosystem indicators. Although these are presented as distinct steps, it is likely that some steps will be conducted in an interactive and iterative manner in practice; in other cases, the order of the steps matters (e.g., criteria for selecting indicators must be weighted before indicators are scored to preserve objectivity in the process).

1. Determine user needs

The ecosystem issues of interest and relevance to users of the indicator products should form the core from which indicators are developed. Determining user needs first requires identifying the target audience and then directly engaging representative members of this group in identifying ecosystem conditions and activities of particular interest and importance to them. If possible, objectives associated with each ecosystem condition and activity should be formulated in collaboration with users to guide the choice of specific indicators.

2. Develop an issue structure and list of candidate indicators

The issues identified by users as important can be divided into sub-issues and organized into an *issue structure* that relates issues and sub-issues to one another. Using this structure, a list of potential indicators that can be used to measure ecosystem status relative to the conditions and activities of particular interest can be developed. The indicators listed should reflect knowledge of the ecosystem, characteristics of human activities within it, and societal values. If objectives for the ecosystem have been defined, this process may focus on identifying ways of measuring properties captured by each objective. If objectives have not been specified, the list of potential indicators should capture a broad range of ecosystem features that may affect and be affected by the conditions and activities of interest.

3. Determine screening criteria

Common criteria for evaluating indicators include concreteness, theoretical basis, public awareness, cost, measurement, historical data, sensitivity, responsiveness, and specificity. These nine criteria, as well as others that may become important in specific situations, should be considered in evaluating indicators, but they are not all equally important in every case or valued

equally by all users of indicators. Priority criteria may include the indicator's capacity to represent a specific issue, its sensitivity to change, its ability to provide decision support for management, or its usefulness in determining regulatory compliance. To establish an objective screening process for the indicators, the relative importance of each criterion (e.g., ranking its importance on a gradient as high, medium, low or essential, moderate, inconsequential) should be established before the screening process begins.

4. Score indicators against criteria

Two components of indicators must be considered in scoring them against the pre-defined screening criteria. These components include the information content or quality of each indicator itself and the strength of evidence by which information quality is evaluated. A direct quantitative evaluation of the information itself may only be possible for a few criteria (e.g., cost), and many criteria are multidimensional (e.g., evaluating "measurability" of an indicator requires considering its variance, bias, accuracy, and precision as well as other non-statistical factors). A ranked scoring of each indicator against the criteria on a scale with 3-5 ranks offers a sufficient solution to the difficulty of precise quantitative scores. Table 2 in Rice and Rochet (2005) describes the screening criteria and sub-criteria, as well as the endpoints for scoring an indicator against the criteria.

5. Summarize scoring results

After completion of steps 3 and 4, two matrices will be produced: one with the criteria weights and one with the indicator scores against each criterion. A method for data reduction is needed to aid selection of indicators. Rice and Rochet (2005) caution against collapsing the multi-dimensional information that will be produced into misleading aggregated scores, as may result if simplistic techniques such as weighted averages are used, which may:

- Give moderate scores to indicators that scored very well against certain criteria but very poorly against others
- Produce similar scores for indicators with similar properties, thereby supporting selection of redundant, rather than complementary, indicators
- Neglect the fact that scores are comparable within criteria only
- Disregard information on the strength of evidence associated with each indicator.

Graphic techniques, such as radar plots, can be used to display the score of a candidate indicator against multiple criteria, associate criteria with uses desired for the indicator, and reflect strength of evidence providing the basis for each score. Other data reduction methods, such as clustering algorithms or ordination techniques may offer useful ways of displaying and evaluating the multi-dimensional screening scores.

6. Decide how many indicators are needed

This step requires interaction between the ultimate users of the indicators and profiles of how the indicators score against the evaluation criteria. Effective profiling against the screening outcomes should show whether there are a few clusters of indicators with similar attributes, or a broad array of indicators that are relatively distinct in their information and performance. If a few clusters emerge, the number of indicators should be a small multiple of the number of clusters.

If little clustering emerges, indicators with the greatest interest and relevance to public users will serve as a starting point for reporting on the state of the ecosystem. However, attempting to link indicators to management actions in this situation requires careful consideration of the number and types of factors that may affect different indicators. Further analyses (and perhaps even additional data collection) will be needed to differentiate between the role and contribution of each factor to the status and trends observed in the indicators. The more similar the effects of multiple factors, the greater the number of indicators needed to differentiate between causal factors.

7. Make final selection of indicators

The matrices of criteria weights and scores of indicators against the criteria should be used to guide the selection of suites of indicators that perform well on all criteria of importance to each expected use and that cover the spectrum of ecological, social, and economic objectives. Given that all indicators may not perform well on all of the important criteria, some indicators in the suite should perform well on each important criterion, and they should not all perform poorly on the same criterion. A similar balance may be required if the indicator suite is intended to serve multiple purposes, in which case some indicators should be matched well to each use, rather than attempting to compromise among uses and risk not performing well for any of them. The rationale behind the selection of indicators should be well documented and retained to guide interpretation of the indicators and to preserve consistency in future re-considerations of the indicators.

8. Evaluate data availability for development of selected indicators

After the indicators are selected, they should be classified according to data availability to support each indicator. Indicators for which adequate data to support their development are available from ongoing monitoring programs can be classified as *Type I* indicators. These indicators can be developed immediately. *Type II* indicators are those for which full or partial data have been generated by monitoring programs, but a complete cycle of data may not have been collected or further analysis or management of the data is needed before the indicator can be presented. If no ongoing monitoring or data collection programs are in place to support development of an indicator, it can be classified as *Type III.* Type III indicators reveal data gaps that need to be filled to enable tracking of significant issues.