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Research and Monitoring Priorities for Ecosystem-based Management of New York's Oceans and Great Lakes

A report prepared by the Scientific Advisory Group of the New York Oceans and Great Lakes Ecosystem Conservation Council

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I: Introduction

Ecosystem Based Management

Over at least the last century, New York's marine and Great Lakes ecosystems have experienced significant environmental degradation due to increasing population density and development along our coasts. Environmental stressors affect biological diversity and overall ecosystem health, thus impacting local economies, fisheries, and human health. The condition of estuaries in the northeast United States is the poorest in the country according to the EPA, which estimates that 27% of the region's estuaries offer diminished conditions for aquatic life and 31% have damage that impairs human use (US EPA, 2005).

Human activities threaten the continued health and productivity of the oceans and Great Lakes ecosystems, on which we depend for many resources and services (Pew, 2003). Not only do we depend on the ocean and Great Lakes for recreational and commercial activities such as fishing, transportation, energy, military use and homeland security buffers, manufacturing, and waste disposal, but the nearshore also provides buffering benefits, protecting the coastline from storm erosion and the effects of sea level rise (Swanson and Conover, 2006). In addition, technological advances have enabled land-based activities to move offshore, making marine and aquatic environments targets for new—and historically unplanned for—uses, including energy projects and aquaculture. Conflicts often arise between new and old uses for aquatic environments, and the ecology and biodiversity of an ecosystem can be compromised if new endeavors are not managed effectively.

In order to successfully address all of the factors that negatively impact the health and integrity of our marine and Great Lake ecosystems, future management strategies must reflect the complexity of these environments and their watersheds. Historically in New York State, many aquatic and marine management efforts have been reactive, not pro-active. Decisions have frequently been made on a piecemeal basis, not guided by an overall ecosystem plan. This kind of management strategy has been largely ineffective as evidenced by the failure of past management efforts that focused on conservation of a single species or protection of small areas.

There is much scientific consensus on the effectiveness of ecosystem-based management (EBM) in the conservation of aquatic and marine resources. EBM has been recognized worldwide as a key management tool that helps conserve the biological and ecological integrity of marine and aquatic ecosystems, contributes to economic and social welfare, and provides important research and educational opportunities. EBM is an integrated approach to resource management that strives to balance ecological integrity with sustainable development and other human uses of natural resources. Unlike many existing management efforts, it is place-based and focuses on ecological health and the explicit inclusion of humans in the ecosystem (Arkema *et al*., 2006). EBM is guided by science and emphasizes an ecosystem's structure, function, and key processes

(Christensen, 1996; Grumbine, 1994; Arkema *et al.*, 2006). EBM plans include specific ecological, human dimension, and management criteria.

EBM for New York's Aquatic Ecosystems

With the passage of The New York Ocean and Great Lakes Ecosystem Conservation Act, New York became one of the first states in the nation to implement legislation recognizing the need for ecosystem-based management for our marine systems and Great Lakes. This landmark legislation will help New York State streamline coastal conservation efforts and adapt a more holistic approach to marine management.

The New York Ocean and Great Lakes Ecosystem Conservation Act created a New York Ocean and Great Lakes Ecosystem Conservation Council (OGLECC) charged with developing a strategic plan to implement ecosystem-based management in New York's coastal waters. The Council appointed a Scientific Advisory Group to compile the State's research and monitoring agenda. In their role as science and research experts on the Council, the State University of New York (SUNY) led the development of the Research and Monitoring Agenda and supported the work of the Science Advisory Group, with the guidance of the Council's staff in the New York State Department of State Division of Coastal Resources (DCR).

The Scientific Advisory Group

The Scientific Advisory Group (SAG) is composed of 19 scientists from a range of disciplines, including ecologists, physical oceanographers, environmental engineers, biologists, social scientists, and economists. The charge to the SAG through November 2008 was to oversee the development of a research and monitoring agenda. The SAG held its first meeting in November 2007 and produced a preliminary summary report of research and monitoring priorities for EBM in New York's marine and Great Lakes ecosystems in January 2008 (Appendix 1). For this preliminary summary report, each Council agency and place-based aquatic or estuary program in New York was asked to submit their research and monitoring priorities for EBM. These submissions, along with science priorities in relevant literature and reports, including the National Ocean Research Priorities Plan (2007) and the New York Sea Grant (2007) report on the demonstration areas, were included in the preliminary report. Research and monitoring categories and an initial list of 117 priorities were identified and then refined further in subsequent SAG meetings and public workshop into general research and monitoring priorities that could be applied across a range of ecosystems.

In April 2008, the Science Advisory Group (SAG) held a series of four full-day workshops in Stony Brook, Manhattan, Buffalo, and Syracuse to present and elicit feedback on a priorities plan that identified issues in need of further research to enhance EBM in New York's Ocean and Great Lakes ecosystems. Participants, including scientists, resource managers, and agency staff completed surveys that asked them to rank and discuss the SAG's draft research and monitoring priorities, particularly near-term priorities, and estimate the level of funding necessary to conduct the recommended research and monitoring activities. After completing the surveys, participants in the workshops discussed their answers in small breakout groups. The overall sentiment of workshop participants was generally positive regarding the SAG's draft priorities, although there were some suggestions for minor language changes and clarifications. The research and monitoring priorities outlined in this report were shaped by feedback from the workshops and the surveys.

Organization of This Report

The goal of this report is to lay out a new agenda for implementing EBM in New York's marine and Great Lakes ecosystems and develop a New York Ocean and Great Lakes research and monitoring agenda. As required by the New York Ocean and Great Lakes Ecosystem Conservation Act, this research and monitoring agenda identifies broad physical, chemical, biological, and social science issues in need of further research.

The SAG has used the premise of "ecosystem services" to identify a broad template of practical research requirements applicable across all marine and Great Lakes ecosystems. This report describes long-term research and monitoring objectives, near-term priorities, suggestions for Ocean and Great Lakes monitoring and observation systems, and an implementation and funding strategy.

II. Ecosystem-based Management

What is an ecosystem?

Systems are characterized as having boundaries, interacting components, and—in the case of open systems—fluxes of material, energy, and information across the system boundaries (inputs and outputs). Ecological systems, or ecosystems, are physically defined areas having these attributes. Ecosystems may have a well-defined boundary, as in the case of a lake, or the boundary may vary over time, such as when the extent of a wetland changes due to hydrologic inputs. Also, ecosystem boundaries may be functionally assigned. For example a coastal ecosystem may be defined from mean high tide on the landward side out to the 100 m depth on the seaward side.

A key feature of an ecosystem is that the components within the system tend to interact more with other system components and processes than with those components and processes from outside the system. However, some external factors, such as rainfall or isolation, are important driving forces that provide the energy and material basis for structure and functioning of the system.

Coupled natural/human systems

Few natural ecosystems, whether considered regionally or globally, are entirely unconnected from human influences. Human societies, with their physical footprint, cultures, mores, and social institutions, are intimately tied to natural systems. These couplings may be direct, such as the establishment of cities, highways, and other development along New York's coastlines; or the coupling may be indirect, through mechanisms such as globalized markets that bring goods produced in remote ecosystems, including agro-ecosystems, to our doorstep. Recognizing coupled natural/human systems means that we must consider humans in any management scheme.

Over the past decade, ecologists and social scientists have developed the paradigm of "ecosystem goods and services" as a means to communicate notions of value to policymakers, the public, and other stakeholders. Too frequently we lack the ability to assess the value(s) of an ecosystem and therefore neglect this critical consideration when making development decisions or taking other actions that might alter land- and waterscapes. In conventional cost-benefit analyses, ecosystem value has tended to be underestimated or even set equal to zero. Yet when data are available, it is possible to impute economic benefits to the ecosystem, which have proven surprisingly large (Daily, 1997; Costanza *et al.*, 1997). The ecosystem services approach highlights the dependencies of humanity upon nature and the need for humans to practice good stewardship in order to ensure that nature continues to support our existence.

As part of adopting an ecosystem-based management approach, the ability of marine and Great Lakes systems of New York to produce and maintain ecosystem goods ("natural capital") and services should be assessed and stewarded.

The Millennium Ecosystem Assessment defined four broad categories of ecosystem services (MEA 2006):

- **Provisioning services** are those that provide goods such as food and water;
- **Regulating services** are those that control various processes, such as flood control or suppression of disease outbreaks;
- **Supporting services**, such as nutrient recycling, maintain material and energy balances; and
- **Cultural services** are those that provide spiritual, moral, and aesthetic benefits.

We can consider regulating and supporting ecosystem services as "core services" on which ecosystems depend on for their functioning. These can include provision of healthy habitat, water purification, and natural beach replenishment. Further, we can consider the use of waters for transportation, fisheries and other extractive uses, waste dispersal, etc. as human use dependent services. Cultural and aesthetic services include tourism or even the simple appreciation of a coastal seascape; traditional and environmental knowledge; educational and cultural uses; and the importance of an ecosystem to community identity.

Why do we need EBM?

Despite concerted efforts, the health of the nation's marine and freshwater resources continues to deteriorate. In 2006 there were over 650 beach closings and safety advisories issued for New York's Great Lakes and marine beaches. The incidence of closure or advisory events lasting less than six consecutive weeks increased 55 percent from 2005 (NRDC, 2007). Beach closures, which are precipitated by factors such as elevated bacteria levels, unknown sources of contamination, storm water runoff, and sewage leakage or spills, cost the New York economy tens of millions of dollars each year (Cantor, 2007).

Human activities on land, along our coasts, and in our coastal waters are unintentionally, but seriously, affecting marine and freshwater ecosystems. The deleterious effects of human activities can include: polluted waters, altered food webs, changed climate, damaged habitat, eroded coastlines, and environments infiltrated by invasive species.

Although management practices and programs are currently in place to address these problems, the Pew Oceans Commission, the U.S. Commission on Ocean Policy, several "State of the Lakes" Ecosystem Conferences, the Great Lakes Regional Collaborative, and many scientists and nongovernmental organizations have called for a more comprehensive, integrated approach to better protect and restore U.S. marine and freshwater ecosystems.

Many of our current management plans are focused on managing a single issue, whereas our environments are responding to an accumulation of different stressors. For example, tens of thousands of wildfowl in the Great Lakes die due to avian botulism and there are many factors that contribute to the disease's deadliness in this environment. In part, increased phosphorus loading leads to more decomposing vegetation, which promotes the anoxic conditions necessary for growth of the bacterium. Yet, bacterial growth is also stimulated by increased water temperatures due to climate change, while at the same time toxins from cyanobacteria growing in the eutrophic waters may weaken the birds and make them more susceptible to the botulism toxins.

Achieving sustainability in our economies, communities, and natural environment requires rethinking traditional, fragmented approaches to managing complex and interrelated challenges concludes the *Scientific Consensus Statement on Marine Ecosystem-Based Management* (2005), a report prepared by scientists and policy experts to provide information about coasts and oceans to U.S. policymakers.

What makes EBM unique?

Ecosystem-based management differs from existing management strategies in that it acknowledges the interconnectedness of systems and focuses on the way that human activities and ecosystems synergistically affect each other. Unlike Ecosystem-Based Fishery Management, which manages an individual sector (fishing) in an ecosystem context, EBM takes a holistic approach. EBM considers not just the impact of the ecosystem on an individual sector such as fishing, but also the impact the sector has on other sectors and the entire ecosystem.

Just as each ecosystem is different, each ecosystem-based management plan will have different requirements and measures of success. There is no one-size-fits-all ecosystem-based management solution. Yet successful EBM programs share certain key attributes.

First, an EBM plan should define the spatial boundary of the ecosystem and begin with a clear statement of objectives. An initial evaluation of the ecosystem should identify processes important for the system and characterize ecosystem attributes and indicators, including human values, interests, and activities. It should also take into account the effects of long-term ecosystem changes. It is important that broad public participation occur early in the planning process so the community can provide input on its needs and priorities.

After assessing an ecosystem's structure, function, and stakeholder needs, governance structures, at the appropriate scale to manage the ecosystem, should be put in place. It is necessary for an EBM plan to establish cross-jurisdictional, interagency management goals across local, state, federal, and tribal authorities.

EBM requires managers to be adaptive and acknowledge that our current understanding of how ecosystems work is incomplete. A successful EBM strategy allows for scientifically based evaluation and testing of alternate management approaches and demonstrates a willingness to modify management strategies as scientific understanding improves. Most EBM plans include a re-evaluation component at designated intervals; for example the Great Barrier Reef Marine Park revisits its EBM marine zoning plan every 5 years.

How do we define EBM success?

EBM is an emerging resource management approach based on integrated principles, so the processes that characterize it and measurements of success are also evolving. Yet an EBM plan can be considered good if it engenders cooperation from and satisfies the expectations of a diverse constituency of stakeholders, from commercial fisherman to kayakers. How well an EBM strategy balances the needs of a diverse constituency, while keeping in mind the value of ecosystem goods and services, is a determinant of its success (Arkema *et al*., 2006).

Another indicator of a successful EBM strategy is implementation of an oversight system that uses data to constantly assess the effectiveness of management strategies in achieving ecological and economic goals. The goals for each ecosystem and community will be different, but proper EBM involves collecting and evaluating sufficient data through monitoring programs to truly measure the impact of interventions and management decisions (Arkema *et al*., 2006).

Necessary Research Support

The foundation of an ecosystem-based approach to management is a firm scientific understanding of how ecosystems function. Without knowledge of the interconnections and feedbacks between all components of the system, we cannot make accurate predictions of impact, evaluate the risks associated with human-induced or natural perturbations of the environment, or develop and implement management practices and governance systems that will assure the existence of important ecosystem functions and services into the future. There are no ecosystems where such knowledge is fully developed at this time. While we certainly can begin using ecosystem principles to guide management decisions even with incomplete scientific understanding, it is crucial that we improve ecosystem science in concert with the implementation of EBM. Improved understanding is the cornerstone of adaptive management and it is through research, monitoring, and assessment that such knowledge is gained.

III. Marine and Great Lakes Ecosystems in NY

The SAG has identified five marine and estuarine systems and five Great Lakes systems in New York. Each of these ecosystems has defined boundaries and is characterized by distinctive environmental and topographic qualities, ecosystem services, and environmental stressors, and human communities. Each of these ecosystems is affected by its adjacent terrestrial and aquatic watersheds as well as atmospheric interactions.

Marine and Estuarine Ecosystems

- **The Continental Shelf** is an oceanic ecosystem that extends roughly 100 miles from the coast, although New York's official jurisdiction extends out only 3 miles from shore. This region, known as the New York Bight, is geologically distinct as it is bisected by the Hudson Shelf Valley, the remnant valley of the Hudson River. This ecosystem sustains economically important commercial and recreational fisheries and has historically been used as a repository for waste, including both nearshore and offshore dumping.

- **Long Island Sound** is a 3,419 km^2 estuary bounded by Connecticut to the north, Long Island to the south, and New York City to the west. It has two narrow connections to the ocean, distinctive two-layered estuarine circulation, and a unique geological history as a catchment basin for glacial deposits. The Sound provides critical habitat for marine fish, bird, and plant species. It is also a crucial commercial waterway and supports important commercial and recreational fishing, boating, and tourism industries.

- **The Peconic Estuary** is bounded by the North and South forks of Long Island and is designated by the US Environmental Protection Agency as an estuary of national significance. Only 80 miles east of NYC, the Peconic estuary is home to over 100 rare species. It is fed by surface water, is affected by agricultural runoff, has a spawning population of weakfish, and supports an economically important commercial shellfish industry.

- **The Lagoonal Bays** are located on the south shore of Long Island and include Great South Bay, Jamaica Bay, Moriches Bay, Hempstead Bay, and Shinnecock Bay. These coastal lagoons are sheltered from the Atlantic Ocean by barrier islands. Groundwater is a major input, and pollution from coastal development, runoff, and sewage effluent are major stressors to these systems. These bays act as spawning and nursery areas for fish and provide important recreational and commercial opportunities for boating, fishing, and shellfish harvesting. Additionally, the bays play an integral role in protection of the mainland from storm surges.

- **The Hudson River** occupies a large glacially carved valley running almost due North-South. Tides progress over 150 miles from NYC past Albany. The Hudson serves as an integral passageway for shipping and transportation between the Atlantic Ocean and the Great Lakes and it supports a robust striped bass recreational fishery. In addition, it contains nearly its full complement of historic fish species, making it unusual along the East Coast. Coastal development, invasive species, and legacy contaminants are some of the major threats in this system.

Great Lakes Ecosystems

- **Offshore waters** are those regions where the late summer thermocline does not come in contact with the lake bottom. For Lake Ontario and Lake Erie, these are the regions of the lake greater than 20 meters in depth. This region would include both the central (average depth 25m) and eastern basins (average depth 36m) of Lake Erie, and all three basins of Lake Ontario (average depth 86m). Distinctive features of offshore waters are the marginal input from the bottom sediments, and the general improvement in water quality over the past 30 years due to strong phosphorus control measures. These offshore waters now support a strong re-emerging recreational fishery and are considered a restoration success.

- **Nearshore waters** occupy a band of varying width around the perimeter of each lake between the land and the deeper offshore waters. The band (generally < 20 – 30 m in depth) is narrowest where the slope of the lakebed is steep and continuous. Unlike the offshore, the nearshore is generally unstratified and subject to wave/sediment interactions. This ecosystem shows a strong benthic influence in nutrient recycling, and large populations of invasive species, such as the zebra and quagga mussels or attached plants such as *Cladophora*, can have a major influence on water quality in this zone. This nearshore region is also the zone of greatest human interaction with the waters of the Great Lakes.

- **River mouths, drowned river mouths, attached ponds and embayments.** The mouths of major tributaries, such as the Oswego and Genesee Rivers, represent a special ecosystem type. The Lake Ontario and Lake Erie watersheds drain more than 142,000 km^2, an area more than three times the total surface area of the lakes. Therefore surface runoff entering via the major tributaries can be a major factor in the ecology of the lakes. These tributaries are often sites of major human population centers, important in transportation and industry, and may also serve as a source of legacy chemicals and anthropogenic nutrient inputs to the lakes. In addition, the southern shores of Lake Ontario and Lake Erie are characterized by a large number of smaller attached ponds and embayments. These protected waters often have limited water exchange with the main portion of the lakes and often contain an overabundance of aquatic weeds, blue-green algal blooms, increased coliform bacteria, and decreased water quality. Tourism and recreational fishing are usually the main activities in these areas and property values are directly dependent on the health of these ecosystems.

- **The Niagara River** is a 58 km corridor that transports an estimated that 20 percent of the world's surface freshwater into Lake Ontario. It is a region of economic and industrial importance. There are major population centers and industries at Buffalo and in the Niagara Falls region. Past anthropogenic and legacy chemical inputs into the Niagara River, along with historical waste sites, continue to have a major impact on Lake Ontario and nearby sediments. Niagara Falls is also a worldwide tourism destination as well as a major source of hydroelectric power for the region.

- **The St. Lawrence River** is the major point of exit of water from Lake Ontario, passing Montreal before reaching the sea at the Gulf of St. Lawrence. It is a major shipping channel. The completion of the St. Lawrence Seaway in the 1950s allowed modern ocean vessels (and hitchhiking invasive species) to enter the lakes. The St. Lawrence River Hydropower project, which operates a dam spanning the river between Massena NY and Cornwall Ontario, is a major source of hydropower in the region and also the major regulator of water levels in Lake Ontario and the St. Lawrence River. Summer tourism along the St. Lawrence River is an important economic driver for the northern New York region.

IV: General EBM Research Needs and Priorities that Apply to All Systems

While each of the major aquatic ecosystems of New York has unique, place-based characteristics as described above, there are general principles of ecosystems structure and function that apply to all systems. There are also similarities across systems in the services that ecosystems and their adjacent watersheds provide to society such as food, recreation, and transportation. Finally, there are human-induced threats that are common to all ecosystems including pollutants, excess nitrogen inputs, rising CO_2, warming temperatures, invasive species, and overharvesting of living resources. Hence, while there are unique features and geographic contexts that define and shape any given ecosystem, our knowledge will advance more rapidly by taking a comparative approach that stresses general principles across systems while also identifying unique features. We have therefore chosen to articulate a set of generic research priorities necessary to advance EBM across all systems.

The research priorities for New York are organized around four central themes:

1) What are the ecosystem's structures, functions, and services? This will provide a blueprint or model of the ecosystem and its value to society.

2) What are the most important factors and processes driving ecosystem change? This provides an understanding of the drivers of ecosystem change.

3) How do we forecast future ecosystem states? This builds the capability to predict future ecosystem states and, much like models used to predict climate change as a function of carbon emissions, can prescribe corrective actions that must be taken now to avoid undesirable futures.

4) How do we as a society balance competing human uses, foster stewardship of marine and freshwater systems, and create a governance system that can effectively implement EBM? This involves strategies that will enable society to develop sustainable living practices as both an integral part and as a steward of the ecosystem.

<u>Research Theme 1: What are the ecosystem's structures, functions, and services?</u>

To implement EBM in an ecosystem, managers must understand the qualities that make the system unique and identify the qualities that stakeholders value. To characterize the system, it is important to:

Research Priority 1: **Conduct an integrated ecosystem assessment (IEA) for each ecosystem by assessing existing baseline information and identifying key goods and services.**

An IEA is a comprehensive assessment of an ecosystem, including its structure and function, key goods and services, stressors, interactions among components, and potential for change. Various estuary programs and designated management authorities throughout the state have already started or completed much of this work, including defining properties of the system, characterizing the conditions of the ecosystems, and identifying additional data needs.

To address the human impact, an in-depth analysis of key ecosystem goods and services should be conducted, including an evaluation of how they influence and how they are influenced by the sustainability of the system. An evaluation of services should include historical and existing services, as well as an evaluation of what services the community prioritizes in the system. It should also identify which services can actually be restored or conserved. The value of the services should be quantified, not just in terms of economic value, but also in terms of social and environmental value. Communities must also appreciate that every ecosystem has some limited ability to provide services. To maintain an ecosystem's ability to provide desired services, we must understand which ecosystem attributes affect service flows and how those attributes may change in the future. Site-specific ecosystem research objectives will be determined by identifying how these services are affected by environmental factors and which might be threatened by human activities.

Research Priority 2: Identify key species, processes, living resources and socioeconomic benefits for each ecosystem.

There is a strong foundation of general knowledge about the natural history of many of the key species in most of New York's ecosystems, but their roles in the ecosystem context are less well understood. We must improve our understanding of the interconnections among species and their habitats, as well as physical and geochemical processes that characterize the ecosystem. We must implement monitoring programs to track the status and trends in abundance and distribution for key species and processes, including not only those of direct economic value but also those that play a pivotal role in the ecosystem and society.

To account for the complexities of ecosystem structure, we must build models that incorporate both natural components and human-induced alterations of the system, including inputs such as effluents and extractions such as fishery harvests. We must then develop methods of coupling ecosystem models with socioeconomic analyses to identify trade-offs and evaluate alternative management scenarios. The specific objectives are as follows:

i. Understand interspecies relationships and relationships between biotic and abiotic factors in the ecosystem
ii. Identify and understand the status/trends of abundance and distribution for key species (ecologically and economically valuable species)
iii. Build models that incorporate both ecosystem processes and interactions among different components (inputs and outputs)
iv. Couple socioeconomic models with ecosystem models to evaluate impacts of human uses and identify trade-offs

Research Theme 2:

What are the most important factors and processes driving ecosystem change?

Ecosystems are dynamic. Therefore, for any management strategy to be effective, managers must examine and take into account important factors and processes driving change in the system. Research should focus on multiple stressors so that we may better understand the interactions of individual factors with each other and the ecosystem as a whole.

Without an understanding of the processes that drive ecosystem change, we cannot accurately evaluate the risks or predict the impact of human-induced or natural perturbations of the environment. For some systems, we have substantial information about important processes yet there are no ecosystems where such knowledge is fully developed at this time. As part of implementing EBM, it is important to:

Research Priority 3: Identify and quantify the resiliency of systems to natural and anthropogenic hazards/perturbations and episodic events.

Not all systems change at the same rate, nor do they all have the same sensitivity to environmental stressors or other perturbations. For example, not all systems would react the same way to periods of hypoxia, storm events, effluent discharges, or toxic spills. Differences in ecosystem sensitivity need to be reflected in any management plans. It is important to identify risk associated with both episodic and chronic events and quantify both short-term and long-term consequences.

Research Priority 4: Understand how ecosystem structure and function will be impacted by global climate change.

Global Climate change has the potential to change the basic fabric of any ocean and Great Lakes ecosystem. The impacts include but are not limited to:

Effects of temperature
Effects of changing water levels
Effects of changing precipitation and snow pattern
Effects of increased $C0_2$
Effects of ocean acidification

Research Priority 5: Understand impacts and effects of invasive species.

Exotic species can dramatically change all aspects of an ecosystem, influencing—perhaps negatively—everything from the ecosystem's abiotic characteristics to its biotic community structure. An evaluation of current and possible future threats, as well as their impacts on the system, is necessary. Understanding vectors of invasion and consequences of introduction will help us mitigate the impact of invasive species.

Research Priority 6: Determine and quantify the interactions between the human and natural components of the ecosystem

Specific components that must be considered include:

i. Effects of increased/changing anthropogenic nutrient inputs. These can occur through changing land use, increased population, or poor waste management.
ii. Effect of increasing resource demand. Increased population and increased population density place additional pressures on the natural ecosystem.
iii. Effect of land-use and coastal development. Agriculture, industrial, and metropolitan uses all place different demands on the environment. Increased development may exceed the natural capacity of the system to provide needed resources.
iv. Effect of impervious surfaces, which can increase water runoff and decrease the ground water recharge. This can lead to increased erosion and may also serve as an additional source of pollutants to surface waters.
v. Understand effects of anthropogenic pollutants. Many of our legacy chemicals have long lifetimes and may negatively impact ecosystems far into the future. These long-term impacts must be balanced with short-term gains.
vi. Understand the impacts of increased industrialization, including new transportation systems, energy infrastructure, and shoreline development, on ecosystems

Traditional management plans have tended to focus on one or a few of these different components. In reality, no one component can be treated in isolation, as they are interrelated issues and all affect the sustainability of the system. It is the cohesive approach to addressing and balancing multiple components simultaneously that makes EBM unique and effective.

Research Priority 7: Understand sources and processes contributing to aquatic and ocean-related risks to human health.

EBM requires managers to consider humans as a part of the ecosystem. It is important to consider not just human impact on the environment but also the environment's impact on us.

Human health and safety can be put at risk by certain ecosystem changes, including harmful algal blooms, beach closures due to coliform bacteria, potentially hazardous refuse, and the degradation of essential drinking water supplies.

Research Priority 8: Understand the impact of current restoration efforts, regulations, and legislation.

To avoid duplication and wasted efforts, it is important to understand interactions among different efforts. To maximize the success of any EBM program, planners must understand how all restoration and conservation efforts affect one another. In order to adapt to changing environmental and social conditions, it is necessary to continuously evaluate the successes and shortcomings of existing management strategies.

Research Theme 3: How do we forecast future ecosystem states?

In 2000, then United Nations Secretary General Kofi Annan called for a global-wide assessment of the consequences of ecosystem change on human well-being. In an effort called The Millennium Assessment, more than 2000 contributors worked to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems (MEA, 2005). The Millennium Assessment was designed to offer a scientific basis for predicting the consequences of management decisions on ecosystems. The assessment identified options on how to achieve human development and sustainability goals, as well as suggested areas where future research was needed. (See callout box) A similar, though smaller scale, assessment is needed to provide supporting information for New York State's EBM approach.

To be truly EBM, a management plan must not only be able to address multiple factors simultaneously but also must incorporate sufficient flexibility so that managers can adapt to changing scenarios. The ability to forecast future ecosystem states in response to current and proposed changes is essential. Steps that move towards this ability include:

Research Priority 9: Develop appropriate indicators and metrics of ecosystem health.

Many estuary and place-based programs in NYS have begun to identify localized metrics of ecosystem health, yet there are few comprehensive monitoring networks to fully monitor and track these and statewide comprehensive metrics for ecosystem health do not exist. Once appropriate metrics of ecosystem health have been identified, there need to be standardized monitoring networks deployed to measure these abiotic and biotic variables. If standardized, data can be shared statewide across different regions. Also, without baseline data, there is no standard against which managers can examine how the ecosystem is changing in response to different stressors or management efforts.

Research Priority 10: Expand and integrate regional and local coastal observing-system capabilities.

Models and forecasts are often only as good as the information that is used to derive them. In order to forecast future ecosystem states, we need to improve our baseline knowledge of important ecosystem drivers and processes. To obtain this information, New York State needs to expand its regional and local coastal observing-system capabilities. These systems provide the basic physical and biological measurements that form the foundation of many ecosystem models, which are necessary for EBM. Integration of local, state, and Federal monitoring programs is important to ensure data consistency and accessibility. Long-term and continuous data collection programs are necessary to monitor deviations from baseline observations, identify temporal patterns, and reduce uncertainty in modeling efforts.

Research Priority 11: Develop models that couple knowledge of ecosystem structure and function with human use patterns and information from observing systems and indicators/monitoring networks.

To improve our understanding of an ecosystem, it is necessary to develop models that integrate physical, biological, economic, social, and culture aspects of the system. Models can help clarify relationships between natural and social systems, describe the relationships between different parameters, forecast how an ecosystem may be expected to respond to change, and demonstrate potential tradeoffs.

Good models can lead to good decisions when they improve the understanding of a problem by providing rapid, cost-effective mechanisms to test different treatment options, evaluate the importance of different drivers and stresses, and examine interactions, tradeoffs, and feedbacks between ecosystem components and services (Manno *et al*., 2008). They also provide a tool with which to evaluate potential public health issues, predict the effects of continued land use and development, and estimate the danger of reaching an ecological “tipping point,” the critical point at which the effects of multiple stressors cause a sudden shift in structure such that the ecosystem is no longer capable of providing the level of services on which the biological community, including humans, have come to depend. In the absence of such models, resource managers and stakeholders are forced to proceed in an ad-hoc manner, without the maximum benefit of existing scientific information.

To design models with maximal utility for EBM, researchers need to:

- Ensure that the models include ecosystem service flows, socioeconomic forecasting, and adequately describe human interactions and dependences on ecosystem services.
- Link the outcomes of the models with discrete objectives, so that resource managers and other stakeholders can directly use this information to develop what-if scenarios and describe cause and effect relationships. To maximize the benefit and minimize the ambiguity of models, these objectives need to be identified and agreed upon by both modelers and managers up front.
- Build flexibility into a model so it can support adaptive management by being able to incorporate unplanned events and changes to the ecosystem.
- Ensure that planning and managing the modeling process, from its initial conception through dissemination of the model results, involves meaningful public participation. This process can make clear what the model can and cannot provide and provoke a meaningful discussion among stakeholders.

Research Priority 12: Understand and predict the current and future effects of climate change on marine and freshwater aquatic systems.

Global climate change will potentially have a huge impact on New York State's coastal and Great Lakes ecosystems. In 2000, the US Global Change Research Program conducted its first national assessment on the potential consequences of climate change and climate variability. This national assessment is comprised of 16 regional or sector assessments, of which several are directly applicable to New York State. Potential impacts of climate changes as drawn from the Great Lakes Overview, the northeast regional assessment, and the coastal and oceans assessment include:

- Increases in extreme weather events, including ice storms, severe flooding, nor'easters, hurricanes, and severe or persistent drought
- Exacerbated effects of farm and urban runoff on estuaries, bays, and wetlands
- Shifts in the seasonal recreational patterns across the Northeast
- Higher survival rates for deer and mice leading to changed resource demands
- Changes in insect survival rates, which could affect mosquito populations that are vectors for Lyme disease, west Nile virus, equine encephalitis, and *Cryptosporidium*
- Changes in species composition and the introduction and influx of new species
- Reduction of habitat for migratory birds.
- Loss or movement of coldwater fish (Salmon) or shellfish (lobster) species, which may be balanced by increased habitat for warm water species such as Atlantic menhaden.
- Shoreline erosion and disruption of coastal communities due to sea level change and changing frequency of storm surges
- Decreased ice cover in the Great Lakes, with associated changes in the severity of lake effect snowstorms
- Changes in shipping and transportation patterns due to changes in water levels.

Where possible, ecosystem models and forecast scenarios should incorporate current predicative models for global climate change. Plus, a model should be flexible enough to account for the changes in human behavior climate change might provoke. For example, a rise in sea level would not just destroy existing bird habitat but might also shift human activities so that they place additional demands on surviving habitats. At a minimum, forecast models should conduct sensitivity analysis to determine how model results are impacted by these changes in climate.

Research Theme 4: How do we as a society balance competing human uses, foster stewardship of marine and freshwater systems, and create a governance system that can effectively implement EBM?

For an EBM plan to be successful, managers must engender cooperation from and satisfy the expectations of diverse constituencies that might not share the same priorities. To reduce conflict among different stakeholders, it is necessary to:

Research Priority 13: Develop and evaluate EBM management strategies and policy options to resolve conflicts and quantify the economic, social, and economic values of different ecosystem goods and services.

Ecosystems provide many goods and services to humans and have aesthetic and economic values. An EBM plan should manage for human uses and needs within an ecosystem and the viability of EBM initiatives relies on coupling conservation policies with local community needs and regional economic development (Oracion *et al*., 2005). In EBM, current ecosystem services such as recreation, habitat protection, conservation, fisheries, and tourism must be balanced with possible future larger-scale energy, aquaculture, and transportation projects (O'Connell, 2006). In order to design effective ecological management strategies for the future, it is crucial to base policy on sound social and ecological science. Conflict resolution based on measures of competing goods and services will add an objective tone to the debate. EBM is place-based management and it is crucial to develop methods to incorporate local and traditional environmental knowledge and socioeconomic metrics into ecosystem assessments.

Research Priority 14: Determine how to design governance systems at the scale(s) appropriate to the complexity of the ecosystem as well as to the diversity and complexities of the social systems involved. Evaluate the efficacy of different institutional and stakeholder partnership models in achieving EBM goals.

For each ecosystem, it is important to evaluate the effectiveness of various policy decisions and EBM strategies. Scientific research should inform New York State's marine and Great Lakes management policies.

Collaboration and coordination between various levels of government, businesses, community members, scientific institutions, and other stakeholders are important parts of successful EBM. Diverse interest groups must work together to identify common goals and solutions and promote co-management. Management decisions should be science based and interdisciplinary. EBM management tools, such as zoning, can be helpful in creating a framework to help balance and mitigate different uses and interests in marine and Great Lakes ecosystems, as well as promote conservation and effective governance (O'Connell, 2006).

Early in the EBM planning process, it is essential to understand and address the different needs of each stakeholder group. Stakeholder participation is important throughout the EBM planning process – from creation to implementation (Christie *et al.*, 2005). It can help identify points of contention and management alternatives, as well as help justify chosen management strategies (Salz and Loomis, 2004).

Research Priority 15: Develop and evaluate strategies for ecosystem assessment that allow for adaptation and flexibility, as well as account for uncertainty.

The Ocean and Great Lakes are dynamic ecosystems that operate on various spatial and temporal scales. They have complex trophic and habitat interactions, relationships, and feedback loops. Types of ecosystem services, as well as the demand for those services, also change over time. Management plans should include continuing research, monitoring, and adaptive components that account for the complex and dynamic nature of these ecosystems (Arkema *et al*., 2006).

V. Using the EBM approach to design and prioritize site-specific research activities

The unique features of any given ecosystem will shape the way in which the general research themes we have outlined are applied and prioritized for that system. Below are three examples demonstrating how scientists and managers can use the framework described in the general research priorities section of this report to design a customized list of EBM research priorities relevant to their ecosystem of interest.

Great South Bay

Great South Bay is a shallow, coastal lagoon located on the south shore of Long Island. It is about 40 km long, 2.5-8 km wide, and it has an average depth of 1.3 m. It is separated from the ocean by a barrier island, Fire Island, which is 150-750 m wide. The barrier island has moved progressively northward over time, and as part of the natural rollover process, washover is responsible for proving substrate for submerged aquatic vegetation.

Great South Bay's saltwater exchange with the ocean is through Fire Island Inlet and indirectly through Jones Inlet to the west and Moriches Inlet to the east. The major sources of freshwater are rainfall, runoff, stream flow, and groundwater (Ecologic, 1999). These inputs total about 1.2 billion liters per day. Groundwater contributions represent an unusually large proportion (11%) of the freshwater input and can create patchy, low salinity microhabitats. Circulation in the bay is affected by both tidal and meteorological forcing, and while the bay is weakly stratified with depth, physical forcing from winds effectively mixes water from the surface to the bottom throughout the year (R. Wilson and C. Flagg, pers. comm., Marine Sciences Research Center, Stony Brook University).

The major geographic and political subdivisions of Great South Bay are defined by boundaries between the Town of Babylon, Town of Islip, the Bluepoints Bottomlands under the control of The Nature Conservancy, and the Town of Brookhaven. Most of Fire Island is under town, county, state, or National Park Service (Fire Island National Seashore) jurisdiction. About 1.5 million people live within the watershed (South Shore Estuary Reserve Council, 2000).

GSB provides a number of core and human use dependent services. Some of the more visible services include recreational boating, protection of the mainland from storm surges, fishing for species like the bluefish, *Pomatomus saltatrix*, and winter flounder *Pleuronectes americanus*, and shellfish harvesting of the blue crab *Callinectes sapidus* and the hard clam *Mercenaria mercenaria*. About 3,000 businesses and 30,000 jobs are dependent in some way on Great South Bay (South Shore Estuary Reserve Council, 2000). The bay and surrounding intertidal habitats also serve an important ecosystem role in nutrient recycling, nutrient removal, food and organic matter production, and as spawning and nursery areas for fish.

The Great South Bay ecosystem has changed in the last decades due to overharvesting of commercially fished species, habitat loss, changes in inlet configuration, decline in water quality, increased occurrence of harmful algal blooms, climate change, disease, increased predation, changes in the types and loading of nutrients, shifts in plankton structure, loss of filtration by suspension feeders, and increased shoreline hardening. Impacts are typically not attributable to a single factor but stem from a variety of interconnected issues that reflect the complexity of the system. In fact, causes of many changes in the ecosystem are generally poorly understood.

To implement EBM in the Great South Bay, key research is needed to help managers:

***Monitor changes to the system**

A high resolution (spatial and temporal), long-term physical, chemical, and biological monitoring system—providing real-time or semi-real-time data where possible—will provide managers information on system response with respect to events such as brown tide and storms, and will provide parameters essential for ecosystem modeling.

While the biweekly-monthly measurements of temperature, salinity, nutrients, brown tide, and chlorophyll conducted by Suffolk County are valuable, these data, along with the annual hard clam surveys conducted by the Towns and The Nature Conservancy, an annual seining survey, and annual commercial landings data represent the only long-term monitoring historically available for Great South Bay. There is no regular spatial or temporal sampling of critical biological components such as phytoplankton, zooplankton, benthic fauna, and adult fish. Meanwhile, most physical, chemical, and biological parameters are not sampled frequently enough to characterize the small-scale, short-term dynamics critical to understanding the system

***Understand the sensitivity of the system**

Because of their large surface area and small volume, lagoons are more sensitive than estuarine and coastal systems to physical forcing from winds, groundwater and surface freshwater flow, nutrient inputs from land, short-term and seasonal changes in solar heating, and inlet configuration. Additionally, lagoonal systems are not highly stratified vertically and water is mixed from surface to bottom throughout the year. This results in a much tighter coupling between biological processes on the bottom and in the water column than one finds in strongly stratified estuaries and coastal systems. Research is required to understand the exchange of water, nutrients, and organisms between subregions of the bay, groundwater, and the ocean; to determine and quantify the sources and sinks of nutrients and evaluate how various nutrient loading rates, both natural and anthropogenic, impact the ecosystem; and to understand food web interactions, especially indirect and feedback effects.

***Create models evaluating all ecosystem services**

Research that supports creation of an ecosystem model or suite of models will allow managers to examine a variety of options and assess the costs and benefits to resources in the future. For example, the model could be run under different nutrient loading scenarios, under enhanced shellfish stocks, restored eelgrass beds, and/or various dredging schemes to examine effects on other parts of the ecosystem and on the services they provide.

The Hudson River

The Hudson River and its valley have been important culturally, as a source of natural resources, and commercially for well over half a millennium. Its geographic location and low relief have made it a valuable transportation and military corridor. The Hudson River is of moderate size in terms of discharge but occupies a large glacially-carved valley running almost due North-South. Because of this geomorphology, tides progress over 150 miles from NYC to beyond Albany, with tidal ranges greater than 1 m over most of this length. In an average summer, brackish water extends for about 50 miles north from the Battery (southern tip of Manhattan). In the past, the Hudson River has supported significant commercial fisheries for shad, sturgeon, and striped bass. Presently, there are smaller commercial fisheries for shad and blue crab. Yet opportunities for viable commercial fishing have been severely reduced through a combination of overfishing and contamination by PCBs discharged into the Hudson above the Federal Dam in Troy, NY. There is a robust, recreational fishery targeting the spring migration of striped bass.

Due to the Hudson's relatively wide and shallow cross-section and significant tidal range, there are several important fringing habitats throughout the Hudson River. Tidal wetlands occupy roughly six percent of the River area and vegetated shallows make up about eight percent of the littoral zone. The actual shoreline of the Hudson River has been extensively modified by human activity intended to stabilize the shore and help maintain a navigation channel.

Water quality in the Hudson has improved dramatically over the past half-century, with very low incidences of hypoxia and rare blooms of noxious algae. Plant growth in the river is strongly limited by light availability, which in turn is almost completely controlled by the abundance of suspended inorganic particles. Inorganic nutrient concentrations are moderate so any improvement in water clarity would lead to greater primary production. The major water quality problems in the Hudson are legacy contaminants, primarily deposits of PCB contamination above the head of tide. Occasional combined sewer outflow (CSO) discharges prevent human contact recreation at some locations of the river near Albany and in the southern reaches.

There is high biodiversity for some taxonomic groups in the Hudson, its tributaries, and Valley, while at the same time invasive species have caused numerous and wide spread changes in the ecosystem. The Hudson is currently recognized as an extremely valuable resource for support of a high diversity of fishes, other animals, and plants.

Ever since the Hudson River School of painting there has been strong appreciation for the scenic qualities of the Hudson River Valley. There is tremendous development pressure throughout much of the region, often concentrated along the river itself. The Hudson River also supports numerous human uses, including drinking water, power plant cooling, and recreation.

It is a major management challenge to allow for human uses of Hudson River resources while protecting or restoring the natural resources. Research is required to address conflicts among Ecosystem Services. For example, there is increased human desire to live and recreate along the Hudson and have good access for fishing and boat launching, but many important nearshore habitats may be compromised by heavy human activity in the littoral zone. Research is required that will enable us to quantify and assess these trade-offs.

To implement EBM in the Hudson River, key research is needed to help managers:

***Evaluate strategies for coping with the impact of climate change**

In the face of climate change, public pressure to strengthen shoreline structures for protection from storm surges and higher water levels will likely increase. Research is required to find shoreline modifications that can provide both the needed protection and high habitat value.

***Reduce the threat from invasive species**

Invasive species continue to be a significant portion of both the fauna and flora in the Hudson River, with new threats—including several recent reports of Chinese mitten crabs—imminent. Research is required to better understand the ecological effects and options for control of invasive species.

***Understand the effects of contaminants**

Residual contaminants still represent a serious impairment of resource use by humans. Even after the upriver PCB removal, research is required to identify other contaminants in the Hudson River and monitor their impacts over time.

***Create and calibrate models**

Given the unknown conditions in the future, well-grounded models and current environmental observations are key to predicting future status and managing proactively to the extent possible. There are now and have been substantial investments in hydrodynamic and water quality models for the Hudson, but progress has often been limited by scarcity of calibration data. It is a key research priority to maintain and expand the current network of observing sites along the Hudson.

Lake Ontario Nearshore Zone

Lake Ontario's large nearshore zone encompasses 1,020 km of shoreline (537 km Canada; 483km USA) and is a transition zone influenced both by the waters of the offshore zone and by land use and drainage from watersheds. The nearshore zone occupies a band of varying width around the perimeter of the lake between the land and the deeper offshore waters to a depth of 20-30 m.

The structure and function of the nearshore zone is complex and is influenced by the proximity of the shoreline and localized sources of meso-scale variability, such as tributaries, land-use in the watershed, embayments, geology, and effluent pipes. There are also geographic and temporal variations in the current regime, influenced by wind direction and upwelling. The currents control transport and distribution of temperature, nutrients, contaminants, and planktonic organisms, as well as bottom shear stress and erosion potential.

The Nearshore Zone is valuable as a source of drinking water and for industrial usage, recreational boating, fishing and swimming, tourism, and wastewater processing. The ecosystem is a key asset in the economies of upstate New York and the Province of Ontario and is necessary to support the state's human and wildlife populations. As economic growth in other areas of the United States is impacted by the availability of fresh water, the abundance of freshwater in Lake Ontario and Lake Erie represents a key resource available for economic growth of upstate New York.

Despite significant water quality improvement in the open waters of the lake over the last three decades, Lake Ontario's nearshore waters and associated wetlands are suffering from many impairments that severely limit their recreational use and ultimately affect the economic development of the region (Makarewicz, 2000). These impairments include invasive species, habitat destruction, algae blooms, erosion, turbidity, navigational impairments, beach closings, property loss, sedimentation and associated nutrient enrichment, as well as fish consumption advisories due to toxicants. These impairments affect drinking water quality, shoreline property values, and the attractiveness of the lakeshore to shoreline residents and the public using the beaches, walking the shoreline, or boating (Lake Ontario Coastal Initiative).

Recent data indicate the nearshore waters of Lake Ontario have greater sediment loads; have higher levels of nutrients such as TP, TKN, and nitrate; have greater amounts of Cyanobacteria and algae; and have higher levels of cyanotoxins than offshore waters (Makarewicz and Howell, 2007). Large pods or mats of *Cladophora* algae, often several meters in diameter, float into beaches, in association with scouring during wind events and seasonal die-back.

Research and remediation efforts of the coastal zone continue to be fragmented, with projects, communities, and counties competing for limited funds and attention from state, provincial, and federal agencies. Information gaps are readily apparent. The water quality and biological data that do exist are spatially limited and often not comparable due to different sampling designs between Canada and the U.S. Plus, measurement regimes are generally focused on the offshore region rather than the nearshore zone of the lake.

To implement EBM in the nearshore zone of Lake Ontario, key research is needed to help managers:

*** Monitor nearshore zone ecological status**

EBM requires data to monitor ecosystem health and evaluate the consequences of management decisions. Therefore a unified sampling framework for monitoring physical and biotic variables in the nearshore zone of Lake Ontario is needed. The sampling design should be spatially extensive to stratify natural habitats, anticipated scales of variability in water quality, and types of anthropogenic influence.

*** Understand spatial and temporal trends in nutrient concentrations in the nearshore zone**

To undertake EBM in the nearshore zone, we need to understand the mechanisms that drive the nearshore to offshore movement of materials in Lake Ontario. A key question is to what extent the retention and accumulation of nutrients, particularly phosphorous, has increased in the nearshore, and whether nutrient supply to the offshore has declined. It is important to determine whether mussel beds and *Cladophora*, which is still present at elevated levels despite the apparent success of the phosphorous abatement program, are acting as biological filters, removing and retaining phosphorus in the coastal zone, thereby reducing the amount transported to the offshore.

*__Quantify the losses of materials (nutrient and sediments) from major and minor watersheds to the nearshore zone and identify sources of pollution within watersheds__

While point source pollution has been identified and managed, nonpoint source pollution is poorly understood. Evidence suggests that nonpoint sources may have a detrimental and substantial impact regionally on the nearshore zone.

*__Develop an integrated model, which incorporates the economics of social systems and the ecological relationships of the natural system__

A unique opportunity exists to improve science-based forecasting capabilities; to integrate human, economic and ecological factors with investigations of the physical environment; to synthesize environmental knowledge across disciplines, systems, and space; and to test hypotheses on causes and management strategies.

VI. Monitoring and Development of Infrastructure

Importance of monitoring and observation systems

Long-term environmental and social monitoring is essential to detect changes in an ecosystem and properly evaluate the success of any EBM program. EBM forecasting models and adaptive management plans require a continuous stream of information. As New York State marine and freshwater ecosystems suffer increasing pressure from a rising human population, as well as potential threats due to global climate change, the best way to evaluate the impacts and effects of stresses is to examine historical and contemporary patterns of ecosystem change. Data collected at the appropriate temporal and geographic scale by continuous monitoring systems and on-ground physical, chemical, biotic, and social/economic surveys is needed to create ecosystem models and forecast systems that can be used to predict how specific changes and management plans will impact future ecosystem states. Efforts are needed to assess periodically the effectiveness of EBM strategies to achieve ecological, social, and economic goals.

While the data provided by monitoring systems is critical for the managers of New York’s oceans and Great Lake waters, the resulting information will also be of importance to community development officials, fishermen, water providers, scientists, and a number of other end users. One of the prime examples of how real time continuous monitoring and “on-the-ground” observations can be used for the public benefit is the national weather forecasting system, which uses a series of remote weather stations, Doppler radar, and human observations to predict and forecast future changes in the weather. These forecasts are critical drivers for everything from the weekend barbeque to the national transportation infrastructure.

Integrating and building on local, state, and federal monitoring systems and the monitoring efforts of research institutions and estuary or place-based organizations could create a statewide monitoring system that encompasses coastal waters, as well as the providing watersheds, that would allow the state to track critical factors such as those listed below (USCOP, 2004).

- Concentration of industrial, municipal, and agricultural contaminants including nutrients, sedimentation, and particulate matter
- Conditions of natural, cultural, and economic resources
- Quantity, quality, and timing of storm water flows
- Presence of pathogens and chemical toxins in organisms, including fish and seafood consumed by humans
- Rates, locations, and composition of atmospheric deposition
- Impacts of flooding, coastal hazards, and sea-level rise
- Status of coast habitats to support conservation and restoration efforts
- Impacts on ecosystem and human health from pollution
- Introductions and spread of invasive species
- Impacts of offshore activities
- Performance of marine and freshwater protected areas
- Sources and quantities of marine and freshwater debris
- Extent, productivity, and functioning of benthic communities

Monitoring systems

Modern monitoring generally falls in one of two categories: observing systems, which provide a continuous flow of information about environmental conditions, or chemical, physical, biotic, and social surveys, which take regular discrete measurements in order to detect changes in the studied variables over time.

Most existing **observing systems** measure physical properties such as temperature, currents, and salinity. However, soon newer sensors capable of detecting harmful algal species and petroleum spills in the water in real time will be available. Sensors can be deployed from a stationary platform, such as a buoy or pier, or from mobile systems, such as ferries, ships of opportunity, or remotely controlled vehicles. Several of these observing systems are currently being developed on a national scale as part of the integrated oceans observing system (IOOS) and New York needs to embrace regional associations such as the Great Lakes Observing System (GLOS) and the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA).

Chemical, physical, biotic, and social surveys are needed to chart changes in environmental variables, biotic abundance, and the human systems with which natural systems are coupled. Surveys are often spatially limited and manpower intensive, but they can provide a very detailed snapshot view of the state of the ecosystem. Biotic surveys can ether be direct measures of biological abundance, such as the annual Christmas bird survey, or indirect measurements of ecosystem health using indicator species, such as the State of the Lakes Ecosystem Conference (SOLEC) indicators. Biotic surveys are most valuable to management when they extend over long periods of time, particularly if they take place before and after perturbations to the environment, such as a hurricane or a change in management policy.

As part of these biotic surveys, there is a need to maintain specimen banks and historical archives. These archives can serve as the “reference points” which resource managers and scientist can use to examine historical events and thereby better understand current and future ecosystem change.

Integrate, Maintain, and Develop Monitoring Infrastructure

To support new and existing projects in EBM, New York State’s monitoring infrastructure needs to be dramatically increased. Building on existing systems, we recommend investment in installation and maintenance of equipment such as buoys, stream gauging stations, tidal and current meters, and sensors for traffic flow. Funds should be available for survey work in offshore waters, which may require access to large research ships that are capable of reaching these systems safely. EBM forecasting models and adaptive management practices require a continuous stream of information. It is essential that funding for the maintenance and continual operation of these sensor systems be incorporated early in the budget planning.

Infrastructure needs extend beyond simple collection of information. One of the main challenges in coordinating multiple observing systems and statewide studies of biotic and chemical systems is physical handling of the data once they are collected. While physical sensors that measure parameters such as temperature and current speed often have a uniform format, data from historical observations or individually designed physical, biotic, chemical, or social surveys may utilize any number of formats.

Data Management and Communications (DMAC) issues were identified as an area of critical priority by IOOS. In order to facilitate the distribution of data and information between different observing systems, nationwide DMAC standards are being developed to ensure a uniform format for data. A uniform format is essential to obtain a broad level of data sharing between different regions and to maximize access to the information by the largest number of users. It will also facilitate incorporation of information into the ocean and coastal resources atlas (New York Ocean & Great Lakes Atlas www.nyoglatlas.org) as called for by the NYOGLECC.

VII: Near-term Timeframe Research Priorities

The following four research objectives should have top priority for immediate implementation.

1. **Develop an integrated ecosystem assessment (IEA) for each ecosystem including identification of baseline information, data gaps, and appropriate metrics for ecosystem health –** Each of the major ecosystems within NY should undergo an integrated ecosystem assessment which would bring together baseline information and assess present status. Place-based programs such as the Long Island Sound study, the Peconic Bay Estuary Program, the South Shore Estuary Program, the NY/NJ Harbor Estuary Program, and the Hudson River Estuary

Program have done much of this for some of NY's ecosystems. In other areas, such as NY's continental shelf waters, no comprehensive analysis exists.

2. **Develop metrics of ecosystem health and status including parameters that could be incorporated into an observing or monitoring system –** It is vital that we be able to track shifts in ecosystem health and also be able to communicate such information to policy makers. Currently we lack a set of consistent measures or guidelines for doing so. Technology now exists for continuous monitoring of a variety of biotic and abiotic factors that can track the shifting baseline of ecosystem health. We must incorporate this technology into routine annual assessments of ecosystem status. While place-based and estuary programs throughout New York state have begun to develop long-term assessments and measures of ecosystem condition, these indicators need to be incorporated into coordinated observation and monitoring programs for each ecosystem.

3. **Develop and initiate models integrating best available data and conceptual frameworks –** It is imperative to move quickly from qualitative system description to a quantitative model-based understanding of each of NY's ecosystems. Without a model based approach, there is no way to accurately predict the consequences of various alternative management scenarios. While sector-specific models currently exist for some ecosystems, there are no **comprehensive** ecosystem models that integrate structure, function, and services for any of New York's marine and Great Lakes ecosystems.

4. **Identify and conduct a valuation of ecosystem services –** To further motivate stewardship of ecosystem structure and function, it is very helpful to demonstrate the economic and other benefits that ecosystems provide to society. While environmental economists have developed techniques to do this, they have only applied these analyses to certain sectors of NY's aquatic and marine ecosystems, such as commercial fishing. It is crucial to conduct a thorough, comprehensive evaluation of services, including all core and human-use dependent services mentioned in section two of this report.

VIII. How to Connect Research to EBM and Policy-making

Create Scientific Advisory Committee

It is recommended that a science advisory committee (SAC) be established as a permanent component of the New York State EBM program. Careful integration of scientific information by resource managers, public policymakers, and individual citizens is essential. In some cases, information may be incomplete or conflicting, requiring evaluation of the current state of knowledge and identification of research needs. The SAC will provide guidance in understanding conflicting information, help identify future research needs, and help identify those areas where EBM can be rapidly implemented. The SAC will also support policymakers as they evaluate and incorporate alternative management methods and evaluate alternative governance approaches, by providing scenario evaluations, integrated analysis, and alternative analytical approaches. In addition the SAC will play a role in developing indicators of EBM success and performance measures. The SAC will need to have a permanent executive director and staff support.

Fund Research that Supports EBM

A successful EBM strategy allows for scientifically based evaluation and testing of alternate management approaches and demonstrates a willingness to modify management strategies as scientific understanding improves. By supporting work on the research priorities outlined by the SAG, the Council will help researchers give managers the tools they need to make management decisions.

EBM spans wide geographical and temporal boundaries; therefore research priorities and implementation programs must also span a range of scales. To ensure maximum benefit, highly targeted, single-issue research projects should be balanced with larger, more regional efforts. Since many existing programs, infrastructure, and efforts can and do address research priorities, an appropriate balance of sustained existing efforts and new projects must be fostered. Sufficient support for maintenance of existing EBM efforts must be included in the programs' operating budget.

The SAC can help facilitate independent peer review of new projects and EBM efforts, ensuring that all projects receive rigorous and objective treatment. Independent merit-based review is the best mechanism to ensure that the New York State EBM projects couple the best ideas with those participants who can carry them out most efficiently. The SAC must work closely with the Oceans and Great Lakes working group to provide input and review of request for proposals (RFP's) and the selection of demonstration projects.

Partnerships among local, state, academic, non-governmental, tribal, regional, federal and international agencies and organizations will maximize limited resources, provide leverage for matching funds and efforts, and promote the interchange of ideas and communication between the different organizations. When at all possible, EBM programs should use existing mechanisms in order to reduce redundant organizational efforts, streamline collaborations among diverse parties, and help ensure that the majority of funds available are dedicated to addressing the research and implementation needs of the projects.

New York State is encouraged to investigate novel methods for funding EBM projects, such as the use of appropriate contracting agencies that can respond rapidly to emerging issues. Mechanisms must be developed to move funds quickly from the granting agencies to the recipient research partners, as delays in contracts can often result in the loss of entire years worth of efforts. Similarly, funding must be sufficient to sustain existing efforts, while still providing for growth and development of new programs.

EBM can be successfully implemented only with improved understanding of New York's ecosystems. An initial annual investment of $10M in basic research, and increased yearly thereafter, is the minimum necessary to build the fundamental knowledge needed across the 10 ecosystems identified above. These funds must be above and beyond mission-driven research that has been funded historically by individual state agencies.

Facilitate Communication Among Scientists, Managers, and the Public

A successful EBM strategy is characterized by an oversight system that uses data to constantly assess the continued effectiveness of management strategies in achieving ecological, social, and economic goals. Therefore, fostering communication among scientists, managers, policy makers, and citizens is critical. One key role of the SAC will be to translate scientific research into decision support and information products for resource managers and the Council. The SAC will support informed discussion of ocean and aquatic issues by providing scientific synthesis and assessment. To enhance technology transfer, the SAC will issue reports, maintain a website, and produce a newsletter to keep managers and the public aware of the research outcomes and breakthroughs.

We further suggest that the Council, through the SAC, sponsor annual conferences at which scientists, stakeholders, and managers discuss current research, its practical applications, and EBM implementation in New York's marine and Great Lakes ecosystems. We recommend that there be two conferences each year, one focusing on research and management on one of the five marine ecosystems outlined above, and another focusing on one of the Great Lakes ecosystems. We further suggest that the New York Marine Sciences Consortium and the Great Lakes Research Consortium be asked to host these conferences. Each year, one of the five ecosystems in each region would be the focus of the conference. In this way, the research community will assist decision makers and managers in communicating and disseminating results to stakeholders, local municipalities, the media, and the general public.

We further recommend that the Council establish mechanisms to facilitate communication between the scientific advisory group, the agency working group, and the stakeholder working group. Transparent and frequent communication will help an EBM plan engender cooperation from and satisfy the expectations of a diverse constituency of stakeholders. One way to foster such communication would be to establish an "executive roundtable" consisting of the Chairs of all working groups that report to the Council.