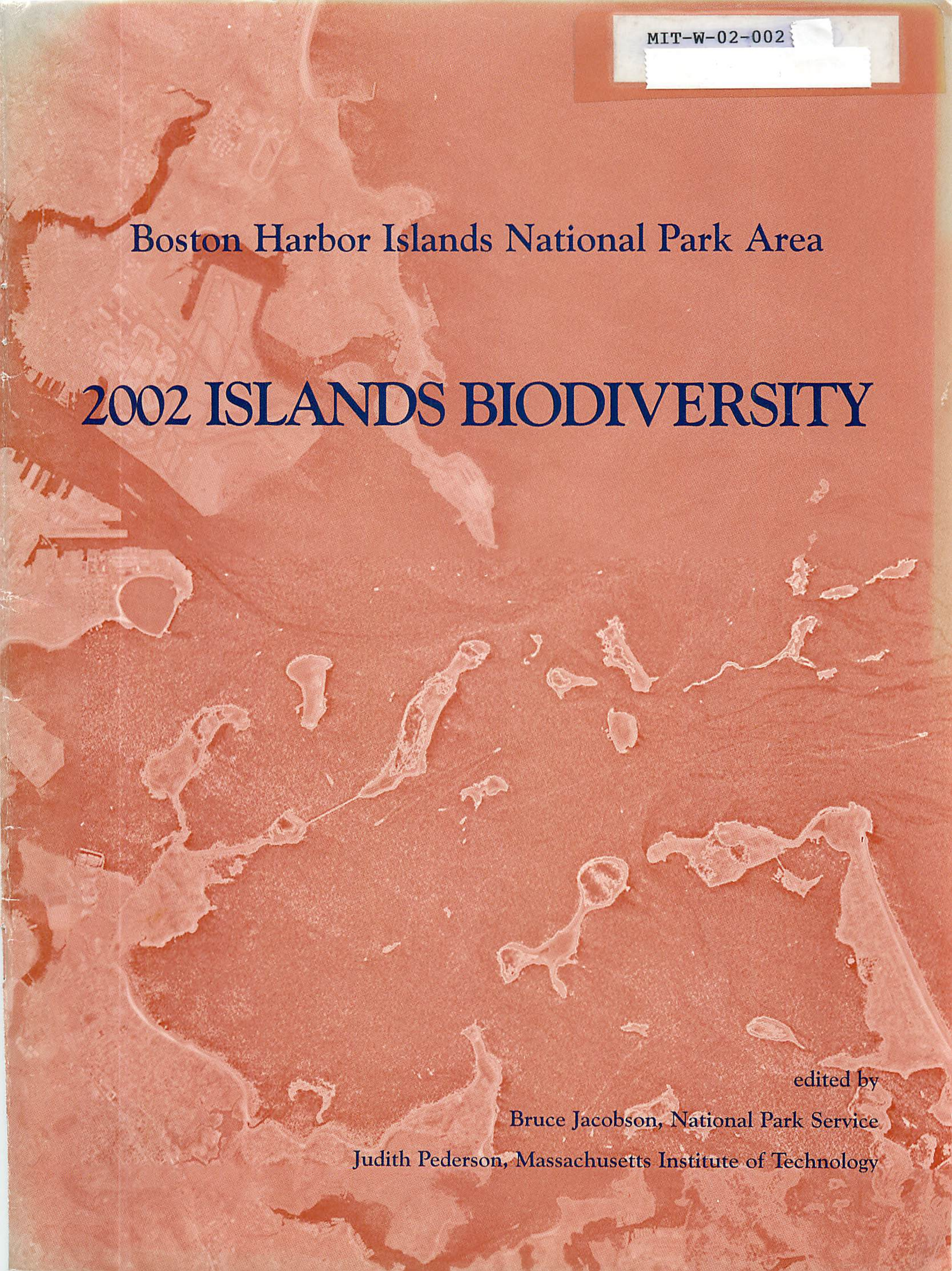

Boston Harbor Islands National Park Area

2002 ISLANDS BIODIVERSITY

edited by

Bruce Jacobson, National Park Service

Judith Pederson, Massachusetts Institute of Technology

Boston Harbor Islands National Park Area

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Proceedings of a Seminar

May 30, 2002

edited by

Bruce Jacobson, National Park Service

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Preface

Management of Boston Harbor Islands national park area is coordinated by the Boston Harbor Islands Partnership, which represents a range of federal, state, city, and private agencies named in the Boston Harbor Islands enabling legislation. Twelve members are appointed by the Secretary of the Interior, one member is appointed by the Secretary of Homeland Security. The Partnership agencies are:

- National Park Service
- U.S. Coast Guard
- Massachusetts Department of Conservation and Recreation (2 seats of former Department of Environmental Management and Metropolitan District Commission)
- Massachusetts Port Authority
- Massachusetts Water Resources Authority
- City of Boston
- Boston Redevelopment Authority
- Thompson Island Outward Bound Education Center
- The Trustees of Reservations
- Island Alliance
- Boston Harbor Islands Advisory Council (2 seats)

During 2002 the Boston Harbor Islands Partnership and other cooperators (see page vi) conducted research and a series of activities to explore the rich diversity of life on the Boston Harbor Islands. These activities included school programs; public field trips; natural resource inventory and monitoring; and the Islands 2002 Biodiveristy Seminar, which was the culminating event.

The Biodiversity Seminar took place on Thursday, May 30, 2002, in Cambridge, Massachusetts. The seminar provided a forum for scientists and land managers to present and exchange information about the Boston Harbor Islands' diverse natural resources. The Partnership's goals were to identify critical research and management needs, identify opportunities for collaboration, and strengthen the network of individuals with interest in the islands.

The National Park Service and the Island Alliance organized the seminar on behalf of the Boston Harbor Islands Partnership. It was hosted by Massachusetts Institute of Technology Sea Grant College Program.

The 2002 field trips began in January when the Boston Harbor Islands Winter Wildlife Cruise enabled 350 participants to discover birds of the harbor and islands. During June, more than 100 people participated in field experiences aimed at familiarizing citizens with the wealth of animal and plant species on the Boston Harbor Islands. The park organized these Biodiversity Days 2002 trips in cooperation with the Massachusetts Executive Office of Environmental Affairs (EOEA).

More than 620 students explored the native plant and animal species living on the Boston Harbor Islands during May and June 2002. Island field experiences, such as tide pool explorations, were conducted as part of curricula at a dozen Boston area schools. In connection with Biodiveristy Days 2002, students from Rogers Middle School and South Boston High School examined inhabitants of the island shore environment with the Secretary of Environmental Affairs and divers from the New England Aquarium.

The overarching mission of the Boston Harbor Islands Partnership is to conserve unimpaired the natural and cultural resources and values of the islands for the enjoyment of this and future generations. We are unable to do this job effectively without scientific information about the nature and condition of resources in the park and how they are changing over time. Lack of knowledge weakens our ability to make sound management decisions that support the park mission. During 2002, the Boston Harbor Islands Partnership continued a five-year Natural Resource Inventory and Monitoring Initiative to collect basic information about the physical environment of the park and the plants and animals that inhabit it. By 2006, a monitoring program will be in place to keep track of the health of the Boston Harbor Islands. Inventory and Monitoring is one initiative, among six adopted by the Partnership, that relates directly to understanding island biodiversity. Four primary goals will be accomplished during the initiative:

- Sensitive habitats and species of special concern are identified on digitized maps for 30 Boston Harbor Islands.
- Presence or absence is known for 90% of the vascular plant and vertebrate animal species expected to occur on the Boston Harbor Islands, presence is physically documented.
- Surficial geology and coastal processes are evaluated on 30 Boston Harbor Islands, appropriate processes inventoried, and human influences that affect those processes are identified.
- Park *vital signs* are identified and the first monitoring of Boston Harbor Islands natural resources is complete using professionally accepted protocols.

A comprehensive survey of plants and animals on all 34 harbor islands was begun in 2001 when the National Park Service and the Island Alliance took the lead for the Partnership, in cooperation with the Natural Heritage & Endangered Species Program of the Massachusetts Fish & Wildlife Department, the New England Aquarium, and others. Assessment work completed during 2002 in upland habitats focused on island vegetation including lichens, aquatic invertebrates, and macrolepidoptera and other insects. In 2002, the US Fish and Wildlife Service National Wetlands Inventory Unit completed a comprehensive survey of all coastal, brackish, and freshwater wetlands in the park. The New England Aquarium and US Geological Survey Biological Resources Division conducted a survey of the biotic communities in the intertidal zone of the harbor islands. Their 2002 final report presents a comprehensive species list, GIS database, and narrative description of intertidal zone habitats, identifying habitats and species of concern. University of Massachusetts-Amherst researchers traced the history of natural vegetation and land use on the Harbor Islands from the time of European settlement in the 1600s. A water resources study, completed in 2002 by National Park Service Water Resources Division, identified and analyzed major water resource issues and management concerns, summarized existing hydrological information, and developed management recommendations for the Harbor Islands. The Islands 2002 Biodiversity Seminar offered the chance for researchers involved in the park natural resource overview and assessment to present and discuss their preliminary findings.

Bruce Jacobson

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New England Aquarium
North Atlantic Coast Cooperative Ecosystem Studies Unit at University of Rhode Island
Urban Harbors Institute, University of Massachusetts-Boston

SEMINAR HOST

Massachusetts Institute of Technology Sea Grant College Program

BOSTON HARBOR ISLANDS 2002 BIODIVERSITY SEMINAR

INTRODUCTION

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Why are we here? I draw your attention to the Boston Harbor Islands Partnership Phase I Initiatives. This represents our thinking in broad terms–what do we want to do over the next five years in order to improve the management, to improve public access, and to improve the visitor experience on the Boston Harbor Islands? There are six broad areas that the Partnership wants to highlight. The six initiatives are:

- resource stabilization & remediation
- natural resource inventory & monitoring
- cultural resource baseline
- visitor access
- interpretation & education
- partnership effectiveness

Today we are focused on the Natural Resource Inventory and Monitoring Initiative. Our goal here is to try to understand more about the natural resources. When we use the term natural resources we are including all biota, we are including the geology, we are including the soundscape, the visual landscape, and the air above us. So natural resources is a very broad category, everything that is living and pretty much everything it is living on. We want to improve our overall understanding of the Harbor Islands.

Much of the work that you will be seeing today will be to understand a general natural resource overview and assessment. The overview and assessment is a very broad brush approach, it is very quick. It is a general idea of what is out there. Our next step would then be to conduct detailed inventories. We now have a general idea of the species that are there, but not where the major populations are, or the composition of the habitats that support those species and how the system functions as a whole. To gain a clearer understanding, we need to do detailed inventories. So that is the next step in our five year initiative. Then the third part of the five year initiative is—once we have identified generally what we have and learn some more specifics about individual populations or individual habitats—then we want to focus on monitoring. If our goal is to maintain a healthy environment in perpetuity, which is our charge, how are we going to keep track of that? What aspects of the natural environment do we need to monitor in order to maintain good health? And so that is the third step. The first was to do a broad overview, second to do inventories, and then third to decide what it is we need to monitor and to begin monitoring it over time. This is the broad framework that we have in mind over the next five years regarding natural resources. In our management plan there are more specific objectives for the natural resource program over the next five years for the Boston Harbor Islands.

As part of introducing keynote speaker Gary Davis and to provide background on how the work at Boston Harbor Islands fits into the national effort of environmental inventory and monitoring, I wish to show a portion of the National Park Service video "Vital Signs." Following is a transcript of Part III: Gathering the Information.

Vital Signs
A National Park Service Video

A Partial Transcript

NARRATOR: Information about the ecology and health of our national parks is crucial. As an example, Yosemite National Park has very little information about its wildlife. The park's most complete wildlife survey is more than 80-years old. The good news is that the National Park Service is working to help parks gather the information they need. There are two parts to this process. First, parks need basic inventories of what they contain, like types of plants, and sizes of animal populations. Next parks need to monitor these elements in order to detect problems at an early stage. The Park Service has defined the basic inventories that all parks need for resource protection and management. These inventories are now being carried out through partnerships with other agencies. The inventories include bibliographies that will list all scientific studies, maps and records relating to park ecosystems. Scientists are creating maps of park soils and park geology. Each park will have inventories of plant species and maps showing where various plant communities are located. Scientists are also mapping the populations and distributions of animal species. Finally, each park will have basic assessments of air quality and water quality. At the current rate the Park Service plans to complete all of these inventories over a period 10 years. The Park Service also is setting up monitoring programs for all parks. This is a huge task that poses many questions. What should be monitored in each park, individual species or entire communities? What methods work best with collecting the data? To learn how to address these questions in all 250 national parks, several parks and clusters of parks have been chosen as prototypes in a variety of biomes. These parks represent the broad spectrum of biogeographical regions contained in the national park system. Research scientists and resources managers are working together to design monitoring programs in these pilot parks.

GARY DAVIS: When we have worked out the techniques, we have figured out how to go about doing this, how to give your park its annual checkup, then we will be able to expand that technology in a very cost effective way to many other systems. So we are just in the beginning stages of this where we have prototype monitored programs in a few parks. But very soon we will be able to expand this experiment to include most of the parks in the system.

NARRATOR: Channel Islands National Park represents one of the pilot groups. Their intertidal monitoring program is an example of how these programs are working.

GARY DAVIS: So we use photographs, where we go out and photograph the same plot every spring and every fall to look at the changes in the abundance and the distribution and the size of the mussels, of the barnacles, of the major algae, the kelps that grow there, of the abalone, and that allows us to gather a lot of information in a short period of time. Then we can bring the photographs back into the laboratory where we have all the time in the world, to project those into life-size images and measure those characteristics of the populations that we are interested in.

NARRATOR: This monitoring program led to a surprising discovery. Although black abalone appeared to be abundant, monitoring revealed that they were actually dying off from disease. Very few abalones were resistant. And in some areas entire populations were lost.

GARY DAVIS: It allowed us to predict what was going to happen in other areas of the state as the disease spread from a center at Annapa Island and Santa Cruz Islands; south on to Santa Barbara Island, and San Clemente Island, and St. Nicholas Island; and north along the mainland coast along Port Conception. And that allowed us to see our failure to recognize that there was going to be a big problem with black abalone repopulations and if they allowed harvesting to continue, then harvesting would take the last of the survivors, the last of the resistant animals. And so the fishery was closed as a precautionary action to protect those large reproductively active individuals that are going to be resistant to the disease.

NARRATOR: Monitoring the health of our parks is now more important than ever. Information gives parks a tool to defend against external threats. And only vital signs can warn us of dangers that would otherwise go unnoticed. With adequate information we can hope to protect the life, the breath, and the heartbeat of our national parks.

Know, Restore, Protect and Connect: The Cornerstones of Park Stewardship

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Introduction

Gary Davis is a marine ecologist who serves as Visiting Chief Scientist for the National Park Service. His role in this temporary assignment is to coordinate ocean programs, looking at marine parks in the national park system all over the country. Mr. Davis has worked for the National Park Service since 1964, starting out as a park ranger. He has explored the coral reefs as an aquanaut in the Man in the Sea Project in the Virgin Islands National Park. In the 1970s he helped found the National Park Service South Florida Research Center and conducted studies on the effects of fishing and lobster management on coastal ecosystems in the Everglades, Biscayne, and the Dry Tortugas national parks. Since 1980 Mr. Davis has led efforts to monitor and understand the ecological equivalent of human health *vital signs* in national parks, and continued investigating the roles of marine protected areas in ocean stewardship, primarily from Channel Islands National Park and the coast of California. Mr. Davis is a certified fishery scientist and has served as president or director of several professional associations and societies including the American Academy of Underwater Sciences, Natural Areas Association, and the George Wright Society. In addition he has authored more than 130 scientific articles including the 1996 book, *Science and Ecosystem Management in the National Parks*, co-edited with William Halvorson.

Together, we are planning the future of the Boston Harbor Islands. I'm pleased to be here because I enjoy talking with people who share my passion for taking care of special places on the coast. Today I would like to provide some context for our discussion of this special place and talk with you about how we take care of our national parks. We call that stewardship. Specifically, I want to describe the structure and function of stewardship programs in the National Park Service and discuss how monitoring the ecological equivalent of vital signs helps to preserve our common heritage.

We all have visions of national parks. For most people, the vision involves vast landscapes of mountains, canyons and forests, often in the scenic western United States. The idea of a national park in the ocean is a bit beyond of the park stereotype. Nevertheless, the current 385 units of the national park system, the special places saved by the American people so that all may experience our heritage, include more than 60 coastal parks. Those parks contain 34 million acres of prime coastal habitats and over 4,000 miles of ocean and Great Lakes shoreline. Forty of those parks contain 2.5 million acres of submerged lands.

These ocean parks are not a recent development; some have been in the national park system for more than 60 years. The idea of ocean parks started with Olympic National Park in 1909, Acadia in 1916, Glacier Bay in 1925, Isle Royale in 1931, Dry Tortugas in 1935, and Channel Islands in 1938. The Antiquities Act of 1906 provided the System with National Monuments on the coast, beginning with Cabrillo in 1913, Buck Island Reef 1961, and the latest at Virgin Islands Coral Reef in 2001. More than a dozen special places along the coast have been designated National Seashores or Lakeshores, adding Apostle Islands, Assateague Island, Canaveral, Cape Cod, Fire Island, Indiana Dunes, Padre Island and Point Reyes to the list. Tropical parks in Hawaii at Haleakala and Hawaii Volcanoes and the Virgin Islands balance coastal preserves in the cool climes of Alaska at Aniakchak, Bering Land Bridge, Katmai, and Wrangell-St. Elias. Americans enjoy national recreation areas on the coast from Gateway in New York, to the Golden Gate and Santa Monica Mountains in California. The nation's diverse maritime history is captured at national historical parks as diverse and widespread as Castillo de San Marcos and DeSoto in Florida, Ebey's Landing and Fort Point in the Pacific northwest, Kalaupapa, Kaloko-Honokohau, Pu'uhonua o Honaunau in Hawaii, and Salt River Bay in the Virgin Islands. In the Pacific, American Memorial in Saipan, War in the Pacific in Guam, and the U.S.S. Arizona in Hawaii all memorialize ocean connections of our more recent history. Table 1 shows a complete list of the coastal units of the national park system.

Boston Harbor Islands recently joined the national park family of special places on the coast. National parks on the coasts and in the water serve many millions of Americans every year. As more and more people move to the coasts, recreational demands for parks and opportunities to connect people to their ocean heritage in parks both increase. Many Americans first encounter nature in coastal parks. It is often their first connection with wild things—untamed, untrammeled, and unimpaired. The Boston Harbor Islands offer wonderful opportunities to connect Americans to their wild heritage.

The national park system contains a wide variety of sites, established to capture the diversity of the nation's natural and cultural heritage, yet every unit of the system is valued and treated equally. The Congress directed the National Park Service to "Promote and regulate the use of ...national parks...to conserve the scenery and the natural and historic objects and wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Congress further declared in the General Authorities Act of 1970 "that the National Park System, which began with the establishment of Yellowstone National Park in 1872, has since

Table 1. Ocean Units of the National Park System

Unit Name	Year Est.	State	Size (acres)	Submerged land (acres)	Coast Line (miles)
Aniakchak National Monument & Preserve	1978	AK	609,750	0	60
Bering Land Bridge National Preserve	1978	AK	2,818,750	0	400
Cape Kruesenstern National Monument	1978	AK	667,500	0	75
Glacier Bay National Park and Preserve	1925	AK	3,264,500	601,600	900
Katmai National Park & Preserve	1918	AK	3,759,500	0	210
Kenai Fjords National Park	1978	AK	677,750	0	430
Lake Clark National Park & Preserve	1978	AK	4,091,500	0	120
Sitka National Historic Park	1910	AK	100	50	1
Wrangell-St. Elias National Park & Preserve	1978	AK	13,200,000	0	115
Biscayne National Park	1968	FL	175,250	168,666	50
Buck Island Reef National Monument	1961	VI	19,015	18,839	3
Canaveral National Seashore	1975	FL	60,500	39,680	24
Castillo de San Marcos National Monument	1924	FL	20	0	1
De Soto National Memorial	1948	FL	27	0	1
Dry Tortugas National Park	1935	FL	65,500	64,661	4
Everglades National Park	1934	FL	1,416,000	625,000	155
Fort Matanzas National Monument	1924	FL	228	0	1
Salt River Bay National Historic Park & Ecological Preserve	1992	VI	912	600	1
Timucuan Ecological & Historical Preserve	1988	FL	46,500	38,000	1
Virgin Islands Coral Reef National Monument	2001	VI	12,708	12,708	3
Virgin Islands National Park	1956	VI	14,750	5,650	22
Apostle Islands National Lakeshore	1970	WI	42,750	27,232	1
Grand Portage National Monument	1951	MN	710	0	1
Indiana Dunes National Lakeshore	1966	IN	12,857	436	25
Isle Royale National Park	1931	MI	578,750	438,009	81
Pictured Rocks National Lakeshore	1966	MI	73,750	9,770	47
Sleeping Bear Dunes National Lakeshore	1970	MI	72,000	12,000	47
Gulf Islands National Seashore	1971	FL & MS	136,250	115,189	76
Padre Island National Seashore	1962	TX	164,750	32,500	66
Haleakala National Park	1916	HI	28,655	?	1
Hawaii Volcanoes National Park	1916	HI	229,177	0	43
Kalaupapa National Historic Park	1980	HI	11,000	2,000	1
Kaloko-Honokohau National Historic Park	1978	HI	1,250	?	2
National Park of American Samoa	1988	AS	10,750	2,500	1
Pu'uhonua o Honaunau National Historic Park	1955	HI	182	0	1
Puukohola Heiau National Historic Site	1972	HI	80	0	1
U.S.S. Arizona Memorial	1980	HI	0	0	1
War in the Pacific National Historic Park	1978	GU	1,960	1,000	4
Acadia National Park	1916	ME	38,000	11,900	52
Boston Harbor Islands National Recreation Area	1996	MA	0	0	1
Cape Cod National Seashore	1966	MA	44,000	16,523	50
Fire Island National Seashore	1964	NY	12,500	4,411	52
Gateway National Recreation Area	1972	NY	27,000	17,989	1

Unit Name	Year Est.	State	Size (acres)	Submerged land (acres)	Coast Line (miles)
Ebey's Landing National Historical Reserve	1978	WA	0	0	1
Fort Clatsop National Memorial	1958	OR	125	0	1
Olympic National Park	1909	WA	949,250	15,186	57
San Juan Island National Historic Park	1966	WA	1,750	0	1
Assateague National Seashore	1965	MD & VA	40,000	31,411	86
Cape Hatteras National Seashore	1937	NC	30,750	3,993	153
Cape Lookout National Seashore	1966	NC	28,750	19,674	56
Cumberland Island National Seashore	1972	GA	36,750	10,262	30
Fort McHenry National Monument & Historic Shrine	1925	MD	43	0	1
Fort Sumter National Monument	1948	SC	198	0	1
Cabrillo National Monument	1913	CA	250	125	1
Channel Islands National Park	1938	CA	252,500	125,000	176
Fort Point National Historic Site	1970	CA	29	0	1
Golden Gate National Recreation Area	1972	CA	75,000	3,657	28
Point Reyes National Seashore	1962	CA	72,000	17,162	180
Redwood National Park	1968	CA	111,500	5,939	36
Santa Monica Mountains National Recreation Area	1978	CA	150,000	0	41
TOTAL			**34,136,026**	**2,449,322**	**3,985**

grown to include superlative natural, historic, and recreation areas in every region...and that it is the purpose of this Act to include all such areas in the System...." and "that these areas, though distinct in character, are united through their interrelated purposes and resources into one national park system as cumulative expressions of a single national heritage; that, individually and collectively, these areas derive increased national dignity and recognition of their superb environmental quality through their inclusion jointly with each other in one national park system preserved and managed for the benefit and inspiration of all the people...." Congress amended this Act in 1978 to add "...the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the national park system and shall not be exercised in derogation of these values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

To achieve this mission through most of the 20th Century, park stewards made policy and management decisions based largely on limited personal experiences and their beliefs about how ecosystems function. They anticipated what they thought park visitors wanted and expected, and they worked diligently to provide it. Science was not a guiding principal of early park stewards. They generally believed that people came to parks to view wide expanses of forest and canyons, to see vast herds of wildlife, and to catch fish. They saw that fires burned down the trees, wolves ate the deer and elk, and pelicans ate the trout. To protect the parks for visitors, they suppressed the fires and killed the predators. Without science as a way of knowing, we nearly lost the parks in the process of learning how park ecosystems work.

Today, we know how important fire is for renewing and sustaining forests. Though science, we've learned that predators sustain diverse prey assemblages, rather than extirpating them. As our knowledge of ecosystems improves, our stewardship becomes more effective, more efficient, and more certain.

Modern park stewards face a suite of ecosystem stresses in and around parks that include:

- fragmented landscapes and populations;
- polluted and altered air, water, and soil;
- unsustainable uses-such as fishing; and
- invasions of alien species.

The stewards need more information and understanding than they have ever needed before to deal with these onslaughts. As land and seascapes become evermore fragmented, polluted, depleted, and overrun by alien species, it becomes clearer that parks are connected to everything around them, no matter how large and remote they may have once seemed. As we learn more about the ecological connections among environmental forces and biological populations, we recognize how difficult it will be to sustain parks unimpaired for the enjoyment of future generations.

In nature, form follows function. Effective human-devised systems do the same. Before we explore how science can inform and provoke better stewardship, let's examine the four major functions of stewardship in national parks and the organizational structure that follows from those functions. The mantra of National Park Service stewards is: *Know, Restore, Protect and Connect.* Park stewards must know and understand the parks, restore impaired resources and sustain them once restored, protect parks and mitigate threats to them, and connect people to parks deeply. These four functions are the cornerstones of park stewardship.

Effective environmental stewardship, like medicine, requires specialization and a division of labor. Park stewardship is like environmental health care for ecosystems. Three groups of people work together in separate, but complementary, ways to assure healthy parks. Park rangers and other field personnel provide emergency medical services for park visitors. They also provide equivalent services for natural resources. While patrolling parks, they survey resources for abnormal conditions, such as oil spills or fires, and they take immediate actions to prevent further damage and stabilize conditions. Rangers also act as public health officials for the environment, e.g., explaining how invasive species threaten natural systems and why they must be controlled. The second group of people working for healthy parks is the natural resource managers. They act as family physicians for parks. They monitor status and trends in resource conditions, diagnose abnormal situations, prescribe treatments, and evaluate treatment efficacy. The third group is the research community. Just as medical researchers discover new facts of human physiology and genetics and use that knowledge to develop new vaccines and other treatments, research ecologists discover new information about ecosystems. They develop and test better ways to measure ecosystem health, to restore lost functions, and to mitigate threats to system integrity. All three groups work together on all four functions to assure healthy parks. A matrix of form and function shows how the groups complement each other (figure 1).

FORM & FUNCTION	RESEARCH SCIENCE	APPLIED SCIENCE	FIELD OPERATIONS
KNOW & UNDER-STAND	Design Monitoring Protocols	Monitor Resources	Observe Conditions
RESTORE & SUSTAIN	Develop Techniques	Apply & Test Techniques	Explain Needs for Intervention
PROTECT & MITIGATE	Evaluate Efficacy	Mitigate Impacts	Enforce Laws
CONNECT	Test Communication Methods	Diagnose Issues	Describe Effects of Environmental Stress

Figure 1. Form and Function of National Park Service Stewardship Program.

Monitoring the ecological equivalent of medical vital signs is the key to knowledge and understanding of park ecosystems and to cost-effective stewardship. Knowledge of resource conditions helps set goals, determine normal conditions and evaluate performance of restoration and protection actions. Understanding how resources and people interact helps to predict ecosystem behavior and to project consequences of intervention or *laissez-faire* strategies. Knowledge helps connect people to parks. The aphorism that *people love what they know, and care for what they love* is as true for parks as it is for other facets of life. Monitoring park conditions also helps frame the right questions and form useful hypotheses, among the most difficult tasks in science and conservation. As Charles Darwin noted "*You would be surprised at the number of years it took me to see clearly what some of the problems were which had to be solved...looking back, I think it was more difficult to see what the problems were than to solve them.*"

Design of a park monitoring program can be a daunting task. It requires decomposing an immensely complex ecosystem into tractable elements, selecting parameters to measure, figuring out how to measure, record, and report observations of resource conditions, analyzing the results, and sustaining the fiscal and human resources needed to do the work. Many parks have used a four-step design process: 1) Set Program Goals, 2) Construct a Conceptual Model of the Park, 3) Develop Monitoring Protocols, and 4) Prepare an Implementation Plan, as described in detail in Davis 1993, 2002 (figure 2).

The most important step is the first one: setting program goals. Properly set program goals answer the question, *Why Monitor?* Those answers will greatly help to determine such details as what, when, where and how to measure things, the accuracy and precision of data needed for decisions, and how and to whom to report results. All park stewards are faced with basically the same kinds of challenges. Parks are embedded in land and seascapes increasingly fragmented, altered by contaminants, invaded by alien species, and used unsustainably. To guide stewardship, monitoring programs need to achieve several goals, including:

- identify status and trends in park ecosystem health,
- define normal ecosystem dynamics,
- provide early warnings of abnormal conditions to reduce costs and increase probability of successful treatment,
- suggest remedial treatments and frame research hypotheses, and
- determine compliance with laws and regulations.

Conservation is fundamentally health care for the environment. Unfortunately, ecology at the close of the 20th Century had advanced about to the point medicine reached in the 17th Century, when William Harvey discovered the human heart was a pump driving a circulatory system. Ecologists know the names of most parts of ecosystems, have some idea of how the individual parts function, and understand that the parts are connected. Ecology is not very good at predicting how ecosystems will respond to stresses or how the rippling effects of those responses will cascade through the systems over decades and centuries. Defining a *healthy* ecosystem is still rather rudimentary, having progressed little since Aldo Leopold described a land ethic as "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise". (*A Sand County Almanac*, 1949). A healthy ecosystem has all of its parts (e.g., missing no species), has no *extra* parts (e.g., no alien species), responds normally to perturbation (i.e., does not collapse after extreme natural events such as hurricanes or El Niño events), and is resilient (e.g., resists invasions by alien species).

Ecologists use several approaches to study and understand ecosystems that are amenable to monitoring. Some reduce system elements to common denominators, such as energy, nutrients, or constituents. Measuring and tracking the flow of energy in systems, or the cycling of carbon or nitrogen, facilitates comparisons among ecosystems and change within systems over time. Measurements of these features of ecosystems generally require complex procedures with quite sophisticated instruments and comprehensive *a priori* understanding of system structure and function. Monitoring the amount of carbon or energy stored in forest root systems is important, but difficult to measure as routinely as *vital signs*. Biodiversity is another powerful descriptor of ecosystems that also functions well at

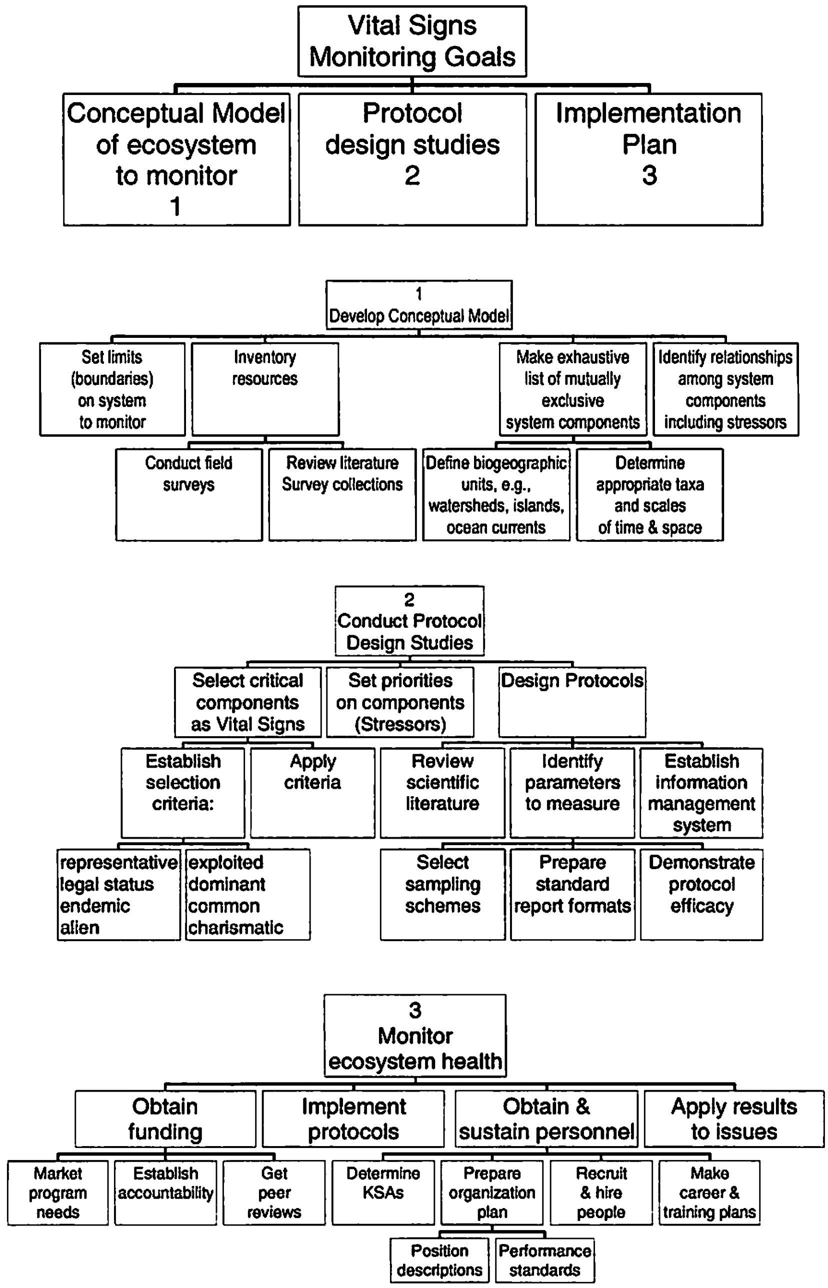

Figure 2. Step-down plan for park vital signs monitoring design.

many scales, from genetics and populations to species and landscapes. Comprehensive inventories of species are underway in all national parks, in part to help lay a foundation for long-term monitoring. Repeating those inventories periodically may be a useful form of monitoring. However, repeated inventories for biodiversity do not provide reliable early warnings of impending extinctions or invasions of alien species, and biodiversity is difficult and expensive to measure. The taxonomic expertise required to survey the average park would be difficult to sustain for routine monitoring. However, measuring population dynamics of selected plants and animals is relatively easy. Demographic information on abundance, distribution, population age structure, reproductive efforts, juvenile recruitment, growth rate, and mortality rate integrates and reflects environmental conditions of whole ecosystems. Measures of reproduction, recruitment and population age structure provide glimpses of the future-early warnings of population collapse. Growth rates and reproduction are sensitive to chronic, sub-lethal, stress, and therefore also useful as sentinels. Interpreting efficacy of remedial actions with demographic data is relatively direct and understandable by many people. The best *vital signs* programs for parks combine some aspects of all of these approaches, but the most successful early efforts in parks have come from monitoring population dynamics.

Given the relatively primitive state of ecological knowledge, the best strategy for design of monitoring programs is a *Delphi* method of asking experts their best judgment in an iterative fashion. Using adaptive management, the design can be refined over time to meet a wide variety of needs and take advantage of changes in technology. Once the experts have developed their best first approximation of a conceptual model of the park, they can then turn to development of monitoring protocols in the same way. For biological components of the system, it is useful to give them some selection criteria to assure that the selected *vital signs* include:

1. Species that are representative of the entire ecological diversity in the system
2. Species that are common, dominant, or provide structural habitat elements
3. Species with special legal status, e.g., endangered
4. Endemic species
5. Species legally exploited in the park
6. Invasive alien species
7. Charismatic species with extant political constituencies
8. Practical, e.g., reliably identifiable in the field

Monitoring environmental *vital signs* reduces uncertainty and cost, and increases likelihood of effectiveness and success in conservation endeavors. These advantages are clear in examples from Channel Islands National Park and Cabrillo National Monument in California, where *vital signs* monitoring began 12-20 years ago. The California Channel Islands have been heavily impacted by invasive alien species, pollution, unsustainable uses, and regional landscape fragmentation. Information from *vital signs* monitoring there has guided the removal of alien pigs, rabbits, cats, burros, horses, sheep, and cattle from park islands. It has also helped document and evaluate the recovery of native species and communities; and provided early warnings of invasive plants. Marine ecosystems in Channel Islands National Park were heavily contaminated with DDT dumped into the nearby ocean. Monitoring California brown pelican reproduction provided an early warning of impacts that led to a national ban on DDT, but not before some species, such as bald eagles and peregrine falcons were extirpated.

These extirpations led to a dramatic decline in endemic island fox populations in the late 1990s, which also revealed an unintended sequence of cause-and-effect events triggered by human actions that has cascaded through park ecosystems for more than 150 years. It all began when ranchers introduced sheep, horses, cattle, and pigs to the islands in the 1840s. The subsequent grazing relegated native shrubs to steep cliffs and disturbed the ground so often that alien annual grasses eventually replaced the native perennial bunch grasses. The resulting low veneer of vegetation and bare soil, in turn, halved the islands' capacity to capture fresh water from fog, greatly accelerated erosion, and exposed foraging foxes to potential aerial predators. The next chapter in this sad saga began when DDT was introduced into coastal ecosystems by agricultural runoff and industrial dumping in the 1940s and 1950s. By the late 1960s, the accidental side effects of DDT were clear: predatory birds that ate fish and fish-eating birds had accumulated so much poison they could no longer reproduce on the islands. California brown pelicans and peregrine falcons came dangerously close to disappearing, but today are recovering slowly. The fish-eating bald eagles did not survive on the islands. Their departure in the 1950s left an empty ecological niche that was partially filled in the 1990s by mammal-eating golden eagles, which could survive on feral piglets, augmented by an occasional island fox. The incidental take of foxes was enough to drive island fox populations to the brink of extinction by 2000. Timely information about island fox demographics from monitoring ecological *vital signs* averted disaster, but restoration will be expensive. A captive breeding program for island foxes on three islands holds extinction at bay, while pigs are removed, golden eagles are live-trapped and relocated, and bald eagles are reintroduced to the islands.

Another example shows how expensive blind stewardship can be. Traditional 20th Century fisheries management relied primarily on monitoring the amount of fish taken from the sea as a surrogate for knowing how much and what kinds of fish were left. This strategy assumed that if lots of fish were taken easily, there must be many more to be taken, i.e., the fishery was sustainable. For many fisheries this was like managing a bank account by only recording the checks written, but never monitoring the deposits and balance. Monitoring ecological *vital signs* of juvenile recruitment and population demographics is like monitoring the account's deposits and balance to provide an early warning of balance depletion, when withdrawals exceed deposits.

California's abalone fisheries were once the state's most valuable. They supported hundreds of commercial divers, who received $30-$100 for each abalone they landed. Abalone also provided recreational opportunities for hundreds of thousands of sport divers every year. The fisheries were managed with species-specific size and take limits, seasons, gear restrictions, and limited numbers of divers, all based on the best scientific data available on species biology and fishery landings. Abalone landings rose quickly after World War II, and remained high for nearly 20 years before collapsing suddenly in the 1980s. Eight abalone fisheries were closed statewide in the 1990s (sport and commercial fisheries for white, pink, green and black abalone), and two more fisheries (sport and commercial) for red abalone south of San Francisco along the southern two-thirds of the coast. Only one fishery remains open, and that is for red abalone only taken by breath-hold sport divers on the far north coast. In 2001, white abalone was federally listed as an endangered species, the first marine invertebrate on the list. What went wrong? Monitoring only fishery takes did not provide an early warning of collapse. Traditional management tools (species-specific limits on size, season, take, etc.) did not protect adequate reproduction and replacement capacity. Landings data masked the serial depletion of five abalone species and then red sea urchins and consequently the nature and extent of resource depletion by the commercial diving fleet. *Vital signs* information on abalone and sea urchin demographics from Channel Islands National Park finally verified the resource depletion and helped California decide to close abalone fisheries before the species were lost and while there was still some hope of their recovery. The costs of not monitoring ecological *vital signs* were the loss of multimillion dollar fisheries, forgone recreational opportunities and the businesses they generated, and the greatly diminished capacity of abalone and sea urchin populations to generate value for the public. The huge capital value of these natural resources and its ability to generate benefits, supposedly held in trust for the public, was lost.

Denial that changes were needed in fishery management was one of the greatest challenges to overcome. Long after abalone populations collapsed, commercial divers testified to the California Fish and Game Commission that the reason abalone landings had declined was not because few abalones survived, but because sea urchin collection had become more profitable than abalone collection so the fleet shifted its effort to sea urchins. That was partially true, since there were so few abalone it was more profitable to collect sea urchins worth $0.25 each rather than abalone at $32-$100 each, but with only fishery landings data (checks written) it was impossible to tell what was left in the account. If the Commission had not known abalone populations were depleted, fisheries would have remained open and the last few abalone taken. As it is, restoration of abalone, and eventually abalone fisheries, will take many decades and millions of dollars of public funds.

One last example from the tide pools of Cabrillo National Monument in San Diego shows how useful *vital signs* monitoring can be for connecting local communities to parks, and how such monitoring can prevent unnecessary and deleterious litigation. In the winter of 1992, San Diego's wastewater treatment plant effluent pipe into the ocean broke near shore adjacent to the monument. During the 60 days it took to repair the pipe, 16 billion gallons of treated effluent were discharged into the monument, and the tide pools were closed to visitors to protect human health. When the tide pools were reopened, many people expected to find damage from the polluted water and to launch litigation to mitigate the damage. Surprisingly to many, *vital signs* monitoring before and after the spill showed that many aspects of the tide pools were healthier after the event than before. The sediments and nutrients in the treated effluent re-nourished a system apparently starved by decades of flood control on southern California rivers and respite from thousands of daily visitors trampling fragile algae and overturning rocks allowed tide pool communities to flourish. When members of the local community who were intimately involved in helping monitor tide pool *vital signs* saw the changes, they immediately realized that Pogo was right when he said, "We have met the enemy, and he is us." With leadership from the community, one third of the monument's tide pools were closed to visitation to determine how long recovery would take and to develop sustainable strategies to assure that future generations would have the same options to enjoy this inspirational window on the sea. More volunteers are now engaged daily to explain to their neighbors and visitors from afar during low tides why the area is currently off limits and what is being done to protect the nation's heritage here. Any thoughts of litigation were quickly forgotten and the bonds of trust among affected agencies actually grew stronger as a result of the shared experience of making informed decisions.

Monitoring the ecological equivalent of medical *vital signs* won't resolve all stewardship issues. It will reward perseverance, and help communities move beyond the denial that changes are needed. It will reduce the costs of stewardship and improve the likelihood of successful conservation of special places like the Boston Harbor Islands. If we can know, restore, protect, and connect the Boston Harbor Islands, we can pass them on unimpaired for the enjoyment of future generations.

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UNDERSTANDING THE BOSTON HARBOR ISLANDS: A WORK IN PROGRESS

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The Boston Harbor Islands came into the national park system at a really good time in terms of natural resource preservation. The National Park Service is in the middle of a major budget initiative that has funded our ability to really tackle some of the natural resource issues of the system. The Boston Harbor Islands Partnership is also really fortunate to have an abundant source of scientific expertise that we have been able to draw on to focus our efforts. We are really just getting started, so instead of having a major presentation we have asked a sampling of some of the scientists to come and present their work. They are prominent regional scientists and will be able to put the Boston Harbor Islands in more of a regional context. Each speaker will form a panel and respond to questions.

Geology and Coastal Processes of the Boston Harbor Islands

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PANEL PRESENTATION

I would like to introduce the team of investigators that is helping out with this study. First of all, there is Emily Himmelstoss, my graduate student who is really heading up our field program. Peter Rosen is chairman of the Geology Department at Northeastern University. He has spent over 15 years studying the Harbor Islands and has published on Thompson Island, the formation of spits tombolos, and the two till problem. Final member of the team is James Allen. He is associated with the US Geological Survey (USGS) and also the National Park Service, and he is an expert on shoreline erosion. The subjects of my presentation today cover the following. I will be talking about first of all the evolution of Boston Harbor and the formation of the drumlins, which comprise the islands. I will be talking about a pilot study that we began last January. And I will be going into some detail about a study that we are proposing and are currently being considered for funding. And throughout I will be talking about the processes affecting the shorelines and one of the major impetuses for this project; that is the impact of boat wakes.

First of all, we can ask the question, why is Boston Harbor there? You can see on a map (figure 1) that along this coastline we have a major retrenchment, which comprises Massachusetts Bay and Boston Harbor. This is really a function of the geology of this area. On either side of this retrenchment are plutonic rocks, granites, which resist erosion, and in the middle we have sedimentary rocks, things that you may have heard

*Paper prepared by Emily A. Himmelstoss and Duncan M. Fitzgerald of Boston University; James R. Allen, U.S. Geological Survey and National Park Service; and Peter Rosen, Northeastern University.

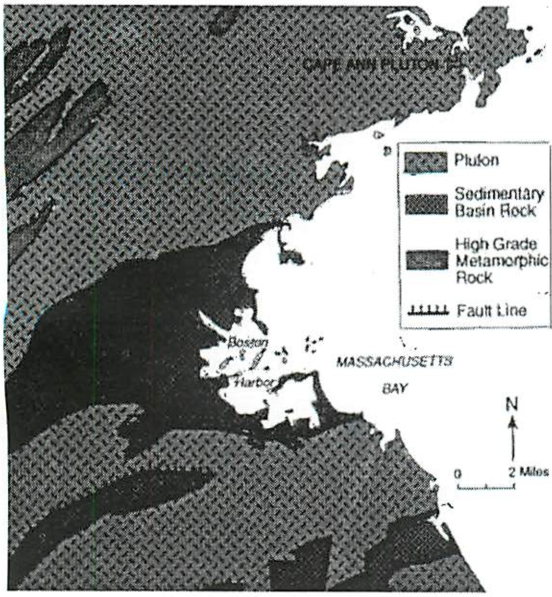

Figure 1. Formation of Massachusetts Bay.

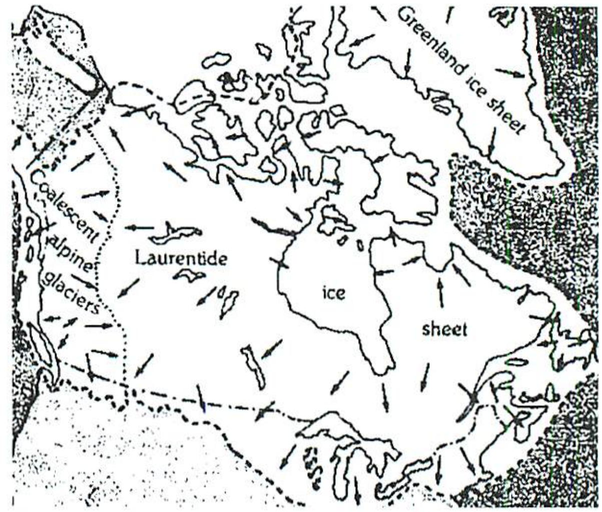

Figure 2. The Southern extent of the Laurentide ice sheet.

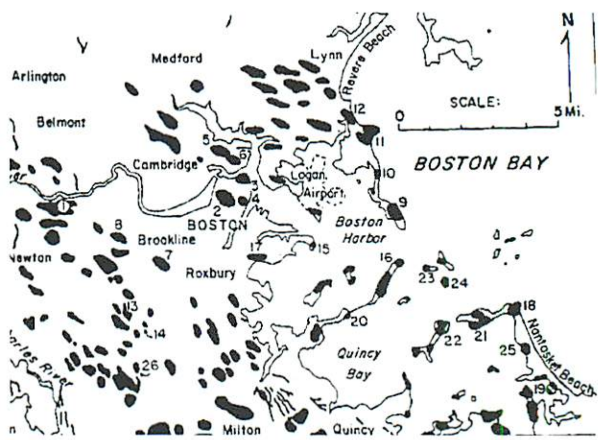

Figure 3. The distribution of drumlins around Boston.

in the news, the Cambridge Argillite, the Roxbury Conglomerate. These are much less resistant to erosion, so over the last tens of millions of years, this area has eroded preferentially and thus become Massachusetts Bay and Boston Harbor, whereas the resistant rocks stand out as promontories.

Anybody who has spent any time in the Boston area knows that Boston is rather flat, except for these knobby hills that are known as Beacon Hill, Bunker Hill, and Breeds Hill. These are actually drumlins. Drumlins are anywhere from a few meters in height to up to 40 meters in height, and they are several football fields long. To understand the development of drumlins, we have to go back about 18,000 years. Figure 2 illustrates that the high latitudes were covered by a series of a coalescing ice sheets. The ice sheet that was affecting us was the Laurentide ice sheet. It emanated from Hudson Bay and moved out readily, all the way to the Canadian Rockies, eastward to the Scotian shelf, and as far south as Martha is Vineyard, Nantucket, and westward into Long Island. The drumlins (figure 3) formed underneath this ice sheet. Drumlins, they have been referred to in Gary Davis's talk, I visualize as a basket of eggs. I like to think of them as upside down spoons. They have a blunted end, where the ice was advancing and they have a streamlined end, where the ice smoothed that form out to a trailing edge. There are several theories about how the drumlins form. One theory envisions a thick carpet of till infused with water, giving it plastic-like qualities, and then as the ice overrides that, it forms a series of bed forms, in this case drumlins, in a manner similar to water flowing across a sandy bed, forming ripples. I like this theory because drumlins do occur in fields just like ripples do along the seashore.

Another theory envisions the drumlins being actually erosional remnants. We start out with the same blanket of till but we erode the sides of it, forming stream-like forms. Regardless of what theory you want to accept, when the ice

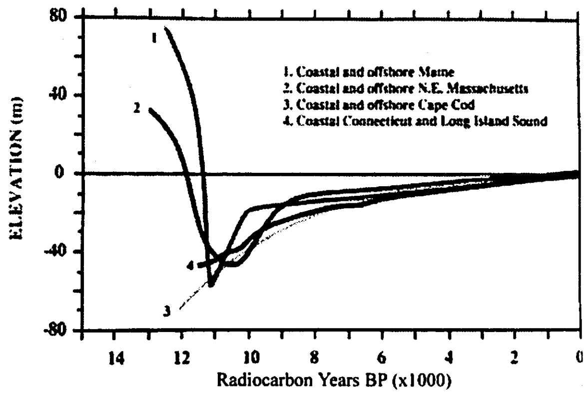

Figure 4. The local relative sea level for four New England areas.

retreated from this area, we were left with drumlins, which were situated high and dry. The shoreline was many kilometers offshore at this particular time. To understand the transformation of these drumlin forms into islands, we have to know something about the sea level, and the history of this region. Figure 4 illustrates four different sea level curves for the New England area. The one that is pertinent to us is the one that is labeled as number 2.

If we begin about 10,500 years ago we can see that sea level was approximately 40 to 50 meters lower than it is today. As the ice retreated northward and as that water was given back into the ocean basins, sea level lowers first of all precipitously and then it leveled off. About 4,000 to 5,000 years ago, sea level reached within about four to five meters of its present day position. This inundated the Boston Harbor Islands, producing the present day form. Although the Boston Harbor Islands are unique to the United States, we do find other drowned drumlins in other parts of the world. For example an area in Donegal, Ireland, Clew Bay, has drumlins similar to Boston. I think if we got rid of the mountains in the background of Clew's Bay and put a few structures and causeways, I might be able to convince you that this Irish bay was Boston Harbor. Another area with drowned drumlins can be found along the eastern shore of Nova Scotia. In fact, most of the eastern shore has a number of drowned drumlins.

Now that you know something about the origin of Boston Harbor and the formation of drumlins, I will tell you a little bit about a pilot project that the National Park Service (NPS) is funding. The major objective of the study was to learn something about the surficial processes, which are affecting the Boston Harbor Islands. We are focusing primarily on erosional processes, so we are determining the impact of storm waves; local waves, and of course, waves, which are generated by boats. A major goal in this study is to create a model of bluff evolution. Helping us out with this study is a pervious effort that was taken on by Paul Panay and his colleagues at Colgate University in which they studied the Ontario Bluff, a glacial bluff shoreline. What they found is the primary agent in affecting those bluffs were slumping and gulling. Those processes, in turn, were a function of the exposure of wave energy and then far down on their list were the composition of the bluffs. We find many areas that adhere to this basic model in Boston Harbor. We also find that there are islands in which this does not adhere at all. For example, in Thompson Island, it is not the exposure to wave energy that affects the shoreline. Rather it is the composition of the till. Sandier tills erode at a much more rapid rate, and I will be going into this in more detail in a few minutes. Our pilot study is giving us qualitative ideas about shoreline processes, but it is the potential funding of our comprehensive study that will yield quantitative results. We will be able to determine quantitatively how fast shorelines have accrued and how fast they have eroded, what has happened to that sediment, and the processes that are accomplishing erosion of sedimentation. What I would like to do now is go through the following items in more detail, so I can give you an idea of what the study is all about:

- Assess role of storms, tides, sea-level rise, and mass wasting processes in shoreline (bluff) erosion;
- Quantify rates of shoreline retreat;
- Determine significance of boat wakes on shoreline erosion;
- Delineate sources, sinks, and sand/gravel transport pathways of coastal sediments; and
- Determine influence of engineering structures on shoreline processes.

One of the things that we realized in our initial study of Boston Harbor is that different processes dominate different portions of the harbor. For example, some portions of Boston Harbor are rather sheltered. This area is affected mostly by wind-generated waves, local winds. When we move out of this sheltered area, open ocean processes affect other areas. If we look at a wave energy flux diagram of this area (figure 5), we can see these telescoping arms indicating that the dominant wave approach for this region comes from the northeast and east. This, of course, is associated with the passage of extra-tropical storms, Nor'easters. These occur on the frequency of about anywhere from 10 to 15 per year, and they last for anywhere from one to two days. They generate waves that are in the neighborhood of 10 to 15 feet. When we look at the outer islands e.g., the Brewsters, Calf Island, and so on, we see that much of the sediment has been eroded from these areas. It has been removed by these large waves generated from Nor'easters. As we move on shore into Gallops Island, Georges Island, and Lovell Island, we see that there is a little bit more sediment that has been protected here. The dominant wave approach in this area has also had an important effect on the formation of the drumlin shorelines of Winthrop and also Nantasket Beach.

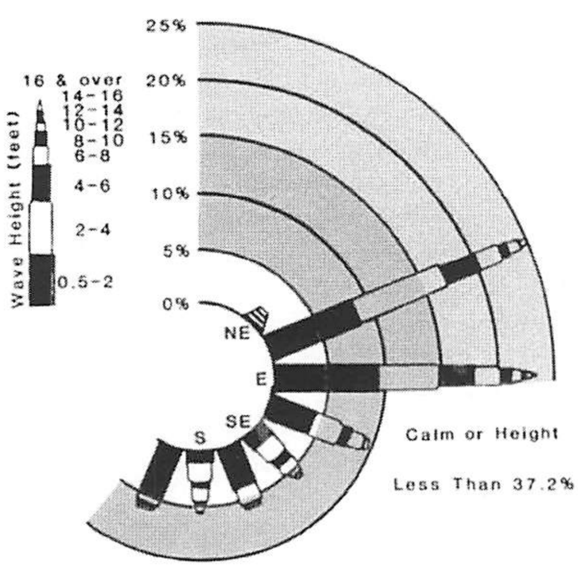

Figure 5. The wave energy flux for the Gulf of Maine. The measurements were taken off Penobscot Bay, Maine.

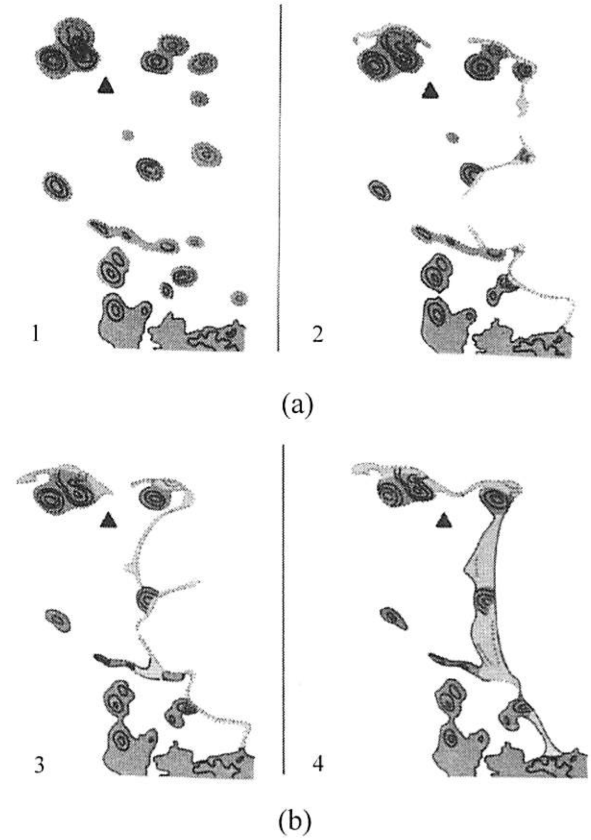

Figure 6. The above sequences, numbered 1-4, depict an evolutionary model of Nantasket Beach (D.W. Johnson, 1925).

In fact, if we look at this evolutionary model (figure 6) that was first put forth by D.W. Johnson in 1925, we can envision how this shoreline built through time. Beginning about 4,000 years ago, rising sea levels encroached upon these drumlins. Because they consist of till, easily eroded sediment, the drumlins retreated. The large boulders were left behind. The fine grain sediment has even moved into the harbor off shore, and also, we have the formation of sand and fine gravel spits, which trended in a northwesterly and a southwesterly direction. Further erosion of the drumlins caused the connection of these individual spits in a peninsula-like form, the area of Nantasket Beach. The width of the areas is certainly due not only to the adjacent erosion of drumlins, but perhaps the entire consumption in the orange field (color not shown in figure 6b) movement of that sediment through time.

The northeast shoreline of Boston Harbor includes the Winthrop shoreline (figure 3), blackened drumlin areas 9 and 10, and the light gray area are the spits, which have connected these individual drumlins. When you fly into Logan airport from the ocean, look out on your right-hand side, and you can see the standpipe that sits on top of Winthrop head. This was certainly one of the drumlins, which was eroding, providing sediment to the intervening beach to the south and Winthrop beach to the north. Now it is fronted by a 15-foot high sea wall and that sediment is now lost to the system and so there is some evidence for the erosion of Winthrop beach being attributed to the cut off of this sediment source.

We understand why these islands here are devoid of sediment in some respects, how the large peninsula formed. As we go into the harbor area, there are really no shoreline features, which are similar to this, that have the breadth of these intervening spits. This is because this area is much more protected. It is affected by local, wind-generated waves. If we look at a rose diagram of winds taken at Logan Airport (figure 7), again we see the dominance of the northeast storms. These areas are impacted with very strong winds, but they do not occur very often. When we look at the most frequent winds, seen by the darkest portion of the diagram, we can see that we have very frequent winds coming

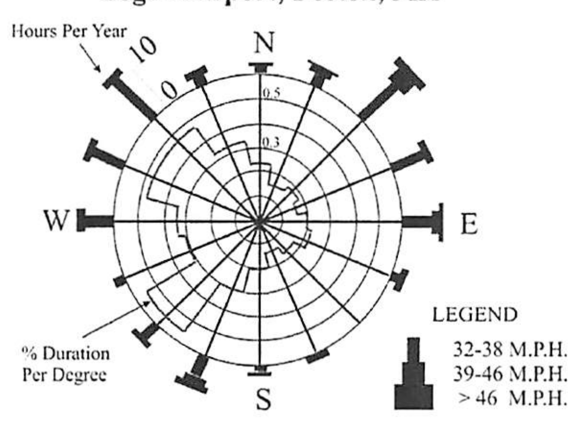

Figure 7. The role of dominant winds is shown.

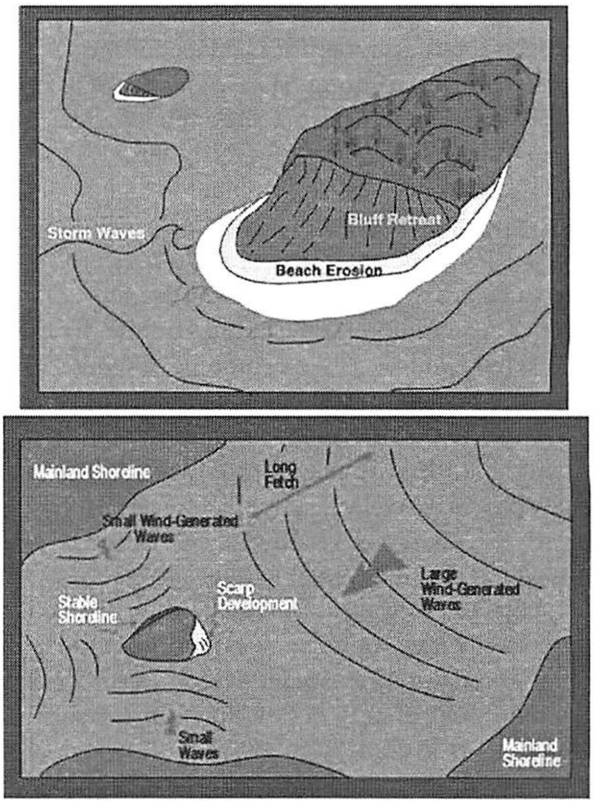

Figure 8. The various factors affecting drumlin erosion include storm waves, along with regular large and small waves.

here from the northwest, west, and also from the southwest. These are all prevailing winds. The southwesterly winds are the winds we are experiencing now in May. They occur from the spring through the early summer. The westerly and northwesterly winds are the winds that we experience during prevailing conditions during the fall and winter. So it is important to understand the local winds, because they are going to affect the areas inside the islands. So if we look at a cartoon (figure 8), we can expect that the drumlins will form bluffs, where they are exposed to the storm waves, but inside the harbor, we have to look at not only the prevailing winds, but also the distance over which those winds can blow and transfer their energy to the water surface. So if there is a prevailing wind which coincides with a large fetch, than we can generate some good sized waves and we can expect that that area of the island will erode, whereas even if we had prevailing winds, if there is a very small fetch that will not generate waves large enough to form scarps. We can understand the formation, for instance, of the southwest portion of Long Island. This faces to the northwest. There is also a large fetch there, so we get the development of a fairly large scarp. And also Princess Point, there is a very large scarp that extends along the entire length of this particular drumlin. Princess Point is eroding because it has a large fetch towards Quincy Bay. It also is eroding because it has a fairly large fetch down towards Weymouth. Another important criterion in whether a shoreline, or bluff, is eroding is the composition of the till. In this particular till, it is called a boulder till. It consists primarily of large boulders in a matrix of mostly clay. Clay is a kind of a cementing agent, which does not erode very easily, even when subjected to waves. But what you can also observe as the large boulders weather out of this; they act as a natural revetment, which can expend the wave energy before the bluff is really eroded. This is in contrast to a sandy till, which erodes very readily. Often one can see a large slump block, which has fallen off from a portion of a bluff. Sand is inherently incompressible and so it does not form that cementing agent and can be eroded very easily by breaking waves. When we see a slope with rills and gullies, we know that waves are not important at all. Rills and gullies are due to overland flow of water, either through ground water or water coming directly over the top. Then as the water cascades down, it erodes small channels. They become larger toward the base of the slope, because those areas are carrying more water with a greater velocity and are capable of carrying more sediment. Through time, we get even greater rill and gully development. Again, this is an indication that waves have little effect in this area. Eventually, we can even reach large chasms. In contrast to that are areas in which we find large slump lots. When the slope itself is undercut by waves, these areas produce these large slump lots. The supporting mechanism is gone in some cases; large trees fall down the slope. Indications of a steady state condition, an equilibrium condition, are seen where we have a beach and no sort of slump development.

One thing that we want to do in our study is quantify the rates of shoreline retreat. And we want to quantify that from the standpoint of what is happening today and what has occurred through the history of this region. We will be looking at Moon Island and Long Island. At Moon Island, we set up a station in which we have been monitoring since January. We do this with the total station and over this three-month period of time during which we have an average of about 20 centimeters of retreat. Some of this may be error due to the roughness of the slope. That data will give us an idea of what is happening on present day trends, and then through the analysis of vertical area photographs, which is the subject of Emily Himmelstoss' poster presentation we can have an idea of historical trends. Over this 55-year period, the Boston Harbor shoreline has retreated about 40 meters. If we really want to know something about shoreline retreat, we can take a trip to Sheep Island. In the mid-1600s, Sheep Island was some 25 acres in size. Obviously, they had sheep out there and they were grazing. Its present-day size is only about three acres, which in terms that we can understand, is the loss of about 24 football fields. We predict in about 40 years, the whole island will disappear.

Another thing I want to do is determine the influence of boat wakes on shoreline erosion. We have seen large rooster tails, which are produced by ferryboats. During commuter rush hour, these boats go by every 5 to 10 minutes. The waves that they produce are anywhere from 30 to 60 centimeters, sometimes even higher. And when they move on shore, they last for about anywhere from 15 to 20 seconds. While they are breaking at low tide here, they are simply moving sediment along the shoreline. But when they break at high tide, or during storm high tides, they can cause a great deal of erosion. The major traffic route from Hingham here to downtown Boston passes by a number of islands (figure 9). We have been monitoring these areas. In one area here, we observe major erosion. Most of this erosion is perhaps due to wind generated waves, but when we get down to Grape Island and Web State Park, these areas are rather

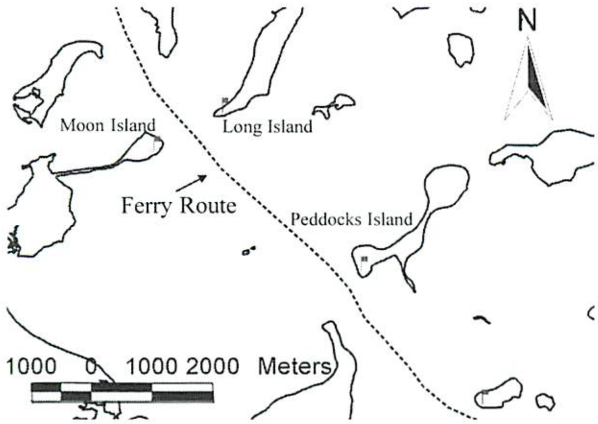

Figure 9. The ferry route from Hingham to Boston travels near many of the Boston Harbor islands.

protected, and the erosion that we have been monitoring in this area is perhaps a direct reflection of the commuter boat traffic. We not only want to know about the erosion of areas, but we want to know what has happened to that sediment. When we look at an area like Princess Point, we know it is smaller outline than its former size.

As sediment has been moved in the general direction towards Peddocks Island and it has formed a triangular foreland. We can also observe from the morphology of this island that once upon a time, one drumlin was separated from another drumlin. The lagoon is evidence of open water that once existed in this area. That was cordoned off by the formation of spits in front of it. So by looking at the geomorphology of an island, we can tell something about its evolution.

Finally, we want to know about the influence of engineering structures in this area. There are a variety of engineering structures, which are found throughout the island. There are gabions. There are also revetments and seawalls. Some of them are in a state of disrepair, and the question becomes should these be rebuilt? In some instances they are preventing sediment from moving along the shoreline, causing erosion. In other areas, they are protecting valuable structures on shore. So there has to be some sort of give and take and an understanding of the coastal processes that are being affected by these coastal structures. That is the end of my presentation. I do not have any conclusions to go over, because we are just initiating this study.

Avian Surveys of Boston Harbor Islands: Preliminary Results

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Panel Presentation

We just started our pilot survey last year. Becky Harris is doing all the survey work this year, and we are doing much more intensive surveys this year. I imagine most of you are not ornithologists, so what I wanted to do today is give you a brief introduction to the birds of the park and what we found last year.

If you have a bird's-eye perspective on Boston Harbor, the first thing that is probably obvious to most birds flying out of the region is it is very urbanized. [He shows a color, infrared photograph, where blue areas are urban and red areas are forest.] What you see in lands around Boston Harbor is a lot of blue [urban areas] with some red [forest areas] mixed in. If you pick out the Boston Harbor Islands, the other thing that is relatively evident is that you have a lot of small islands in Boston Harbor. The large islands in the area are Nantucket and Martha's Vineyard. If you go down to Narragansett Bay in Rhode Island, you get some larger islands. So what species might you expect to find on these relatively small islands? A blow up showing Boston and the harbors and a little greater blow up of the region, showing some islands with a fair amount of forest as we just learned (figure 1).

I am going to focus today on the Outer Brewster Islands. There are a few bird species that are somewhat unique to Boston Harbor; you find them out on the Outer Brewsters. The Graves is an island that, during high tides or during storms, is always inundated with waves and so there are not any birds that nest on the island. You see birds only roosting on The Graves. One of the most common species you find out on the Outer Brewsters is the Double-Crested Cormorant (figure 2). Most of you have probably seen cormorants, but you have probably never seen the double crested species. They may only get that crest during their reproductive plumage. It is a big issue. They eat a lot of fish, and fisherman think that they compete with them, so a lot of Double-Crested Cormorants get shot. Their population has really declined during the middle of the century. Since we have outlawed shooting Cormorants for the most part, the Double-Crested Cormorant populations have increased in the region. There is a huge issue right now in the Great Lakes region, where they want to do a lot of control of Double-Crested Cormorants.

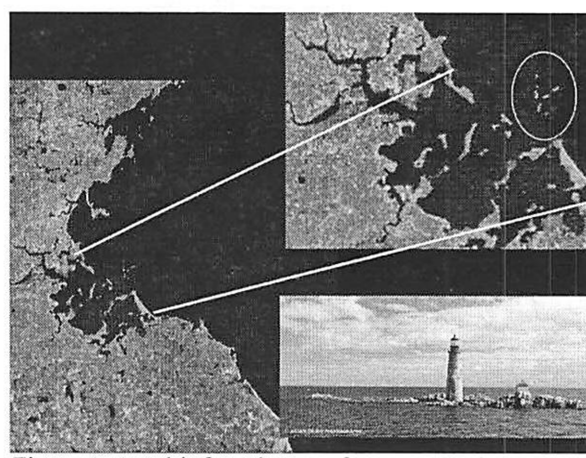


Figure 1. Aeral infrared map of Boston Harbor Islands.

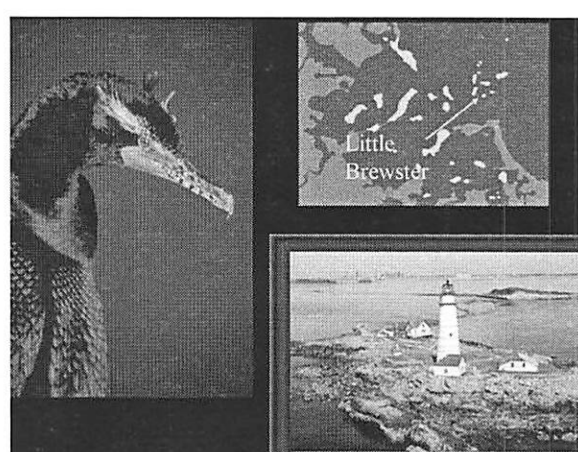
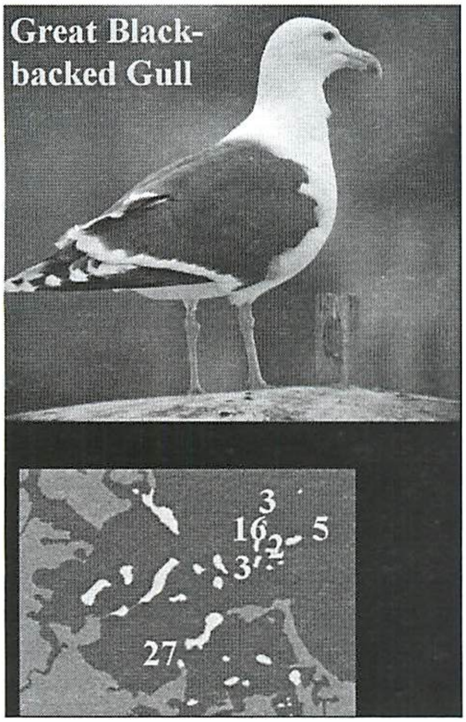


Figure 2. Double-crested cormorant



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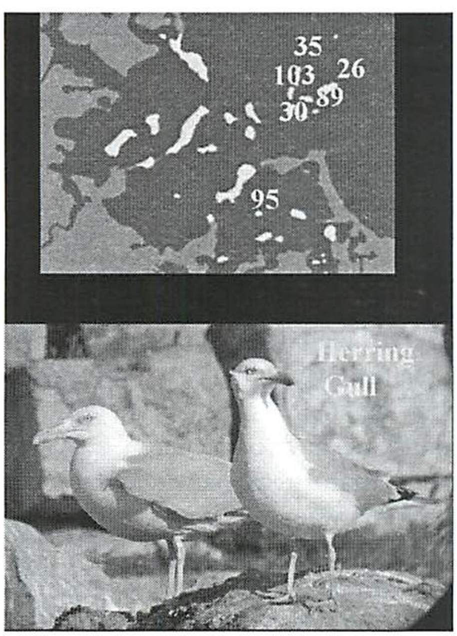

(b)

Figure 3. The distribution of the Herring Gull far exceeds that of the Great Black-backed Gull.

And if you go to the Outer Brewsters, there is only one island in Boston Harbor that is named after wildlife, namely Shag Rocks. If you go to Britain and you meet British birders, they call cormorants *shags*. I am sure that when the first people from Britain came over here and they saw all the cormorants nesting on Shag Rocks, they decided to call it Shag Rocks. Shag Rocks is infamous to people if you study the history of the islands. The Boston Harbor Light, which was established in 1716, is near by Shag Rocks. It is just a small, walkable island, and in the late 1700s and the early 1800s, several ships crashed into Shag Rocks and a number of people were killed. If you look at the number of cormorants that are nesting in the outer islands, the numbers represent the number of nests that I found last year. There are about 1,300 to 1,400 pairs of Double-Crested Cormorants that are nesting in the Outer Brewsters.

You cannot go around New England, along the coast, without seeing gulls. The interesting thing is that if you were to come to Boston at the turn of the century, a gull would be a rare sighting. Gulls were very uncommon at the turn of the century, and they have just become common recently, within the last 50 to 60 years. The Great Black-Backed Gull is one species that nests out in the outer islands. The Great Black-Backed Gull is actually the largest gull in the world, and last year, I only counted about 60 pairs of Great Black-Backed gulls nesting in the harbor and most of them were scattered throughout the Outer Brewsters (figure 3). There is a small nesting colony also on Hangman Island. The other species of gull that is relatively common in the outer islands are Herring Gull. You can tell these two apart by the dark back Great Black-Backed and light gray back Herring Gull, if you are interested. The Herring Gull is much more abundant in the harbor, about 400 pairs nesting mainly in the outer islands and then also another 95 pairs on Sheep Island, which was just mentioned. So they are a relatively common species here.

One of the most interesting findings that we had last year was common Eider Duck. Jeremy Hatch did surveys of Boston Harbor in 1981 and he found one pair of nesting Common Eider out on Green Island. When I went out there, on May 29 of last year, I saw about 450 Eiders out on the outer islands. I found a female on the nest, and a large number of chicks in the water. Common Eider, of course, are very famous because of eiderdown. In northern latitudes, people harvest the down, what I found last year was over 200 Eider chicks on the outer islands. Eiders form crèches, that is all the young form these large groups and the females all hang out with the young. So it is pretty exciting. There really was no record of this large number of Eiders nesting this far south along the east coast of the U.S. The only other large area where Eiders nest in the region is in the Elizabeth Islands. So this is one of the more startling findings we had last year. There were about 20 to 25 pairs, and Becky just recently counted 13 nests on Calf and three on Great Brewster. She has not gotten to Green yet. So there are probably at least 30 or more pairs nesting out there. And I am sure it will continue to increase.

A number of species of wading birds nest on the outer islands. One species that maybe you have seen is the Black-Crowned Night Heron. There are about two to 300 pairs of Night Herons that nest in the harbor. You do not normally see this, because they are mainly active at night, when they forage for fish.

A common species of wading bird that nests in Boston Harbor are Snowy Egrets. There are not nearly as many Snowy Egrets, probably nearer to 100 pairs nesting. The three main sites where you find wading birds nesting are Calf and Sheep islands, and then Sarah Island. Sarah is the largest breading colony for wading birds in the harbor. So, if you have ever had the chance to take a boat around Sarah that is a pretty spectacular place to go.

Another species that was actually persecuted by hunters is the American Oyster Catcher. At the turn of the century, lots of shore birds were harvested for the markets of Boston, and one of those species was American Oyster Catcher. Since that period of extensive hunting, the populations increased and recovered (figure 4). In the last decade or so, Oyster Catchers have started to rebound, particularly in Boston Harbor. There are at least six islands that have one to two nesting

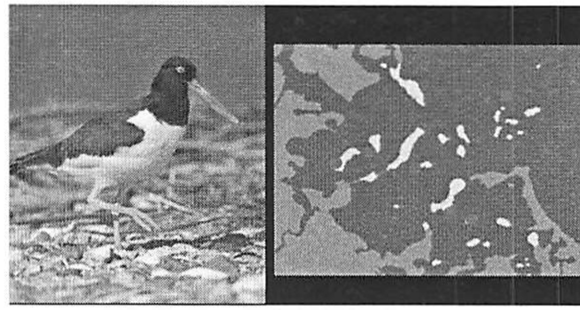

Figure 4. The American Oystercatcher

pairs now and that is fairly exciting news. Least Tern is a state threatened species. Last year, we saw about 30 pairs on Rainsford Island.

Spectacle Island is an easily recognizable Island. At one time it was a dump for the city of Boston but now it has been rehabilitated. The island has been capped and they have planted a great deal of vegetation on it. There is a fair amount of grassland and shrub habitat. They are also in the process of planting trees on it. Because it is grassland habitat, there are Red-Winged Blackbirds that are nesting on the island. There are a lot of grassland birds in the area that people would like to restore to the area. I was noticing there is a poster in the hall about Worlds End and grassland restoration and trying to bring back Bobolinks to Worlds End. And they are successful there. The issue at Spectacle right now is that it is being invaded by muskrats, and they have planted over 3,000 trees on the island. The issue is—another poster talks about this—the muskrats have come onto the island and are eating all the trees. Now maybe from my standpoint, if you want to restore grassland habitat, maybe the muskrats eating all the trees is not a bad thing, but I do not think that people who are doing all the forest restoration on Spectacle like that.

[He shows a slide that is a view of North and South American night.] I bring this in because we have not just resident birds that are using Boston Harbor Islands; we have quite a few Neo-tropical, migrants that are coming to Boston Harbor too. I do not know if you can see the bright lights of Boston right here [reference to the slide]. It is this beacon. I do not think it is necessarily the beacon that is attracting all the birds to Boston; it is fairly obvious that the large forest tracts of Canada are what are really attracting a lot of Neo-tropical migrants. But we still get Neo-tropical migrants to Boston Harbor Islands. One of the more common species you all probably recognize is the Barn Swallow. You see lots of Barn Swallow on quite a few of the islands. These are a species that breed throughout North America and winter throughout South America. The warbler is a visitor that is flying a long way to breed on Boston Harbor islands. Two of the more common species of warblers that you see on virtually all of the islands in Boston Harbor are the Yellow Warbler, the Common Yellowthroat. As I just mentioned they are on most of the islands and are very common. If you go to Peddocks Island—Peddocks is one of the largest islands, has the most forested habitat—you see American Redstarts on Peddocks Island. American Redstarts, especially the males are fairly flashy with an orange tail. Their foraging behavior is to flit through the trees and flash their tail. That bright flash of orange startles the insects nearby, scares up the insects, and they eat it. A pretty good strategy.

Also if you go to Peddocks, there are Chimney Swifts that are nesting in the buildings. They are a species that also winter in South America. The Chimney Swift nests inside of the side of a chimney where the nest is glued to the side of the chimney. Their saliva acts as glue. If you have eaten Bird Nests soup, e.g. as you can in Guam and other areas. The soup is actually made from edible nests; you are eating bird's saliva when you eat that soup. I have never had it. Then if you go to other areas on the Islands you may see, the Baltimore Oriole, which is fairly common on some of the islands. Also the nondescript bird, a Willow Flycatcher, which is fairly common on Grape, and Slate, and Bumpkin too.

These are some examples of the birds that make it here. One, a game species, is the Northern Bobwhite. They are not very strong flyers. They did not make it out there on their own, but people have introduced them to Peddocks also. So just an example of the game species that are being introduced to the islands. One species that you are probably all familiar with is the Black-Capped Chickadee. You might think that the islands would be thriving with Black-Capped Chickadees, but actually they have an aversion to flying over water, like a lot of birds do. The only place I saw Black-Capped Chickadees so far was on Bumpkin. So even though there is forested habitat that might be suitable and large enough for chickadees, for the most part, chickadees do not make it to the islands and survive or breed out there. I want to end this talk with the species that you find on every single island in Boston Harbor: a Song Sparrow. I think it is appropriate to end the bird talk by showing a picture of a Song Sparrow and make you aware that they should be the champion of the Boston Harbor Islands.

Historical Vegetation of the Boston Harbor Islands Natural Recreation Area

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PANEL PRESENTATION

It is a pleasure to be here, coming in from western Massachusetts; it is an interesting opportunity to get involved in this project. I am a forest ecologist, and I have a particular interest in forest change, change through time. My own favorite quote related to ecology is one by a fellow named Frank Egler, a very wise and active forest ecologist, who worked in western Massachusetts and central Connecticut, through the mid-20th century. I use this quote quite often in trying to explain to undergraduates why they are having such a difficult time learning ecology, because they have this idea that it is romantic and neat and it should be easy to understand. But Frank pointed out somewhere that ecology may not only be more difficult than we think, difficult to understand, but it may be more difficult than we can think. And the idea here is that it is a pretty complicated interaction of a number of factors. Certainly, one of those factors is time, especially when it is true, or when you apply it to forests.

Forests change on a time scale that is beyond what most of us can comprehend. I find that—I grew up in Hingham not too far away—I go back to places that I knew 30 years ago, and they do not look the same. I understand that, but I would not have predicted when I was a budding young forester back in the 1960s that things would change as much as they have. So this talk is about change, change on a time scale that is probably quite a bit longer than most of us can comprehend, 400 or more years. I would like to acknowledge the cooperation of Julie Richburg, a Ph.D. candidate at the University, who has helped work on this project. She has a poster out in the outer hall that covers some of the same material. We, as the other speakers, are in the middle of our project, and so what I am going to do is give you a quick overview of what we are trying to accomplish, how we are going about it, and perhaps guess a little bit at what some of our results might be. But we do not definitely have results at this time. Our project is not to explain what the vegetation of the islands was like 400 years ago, not to pose that as an ideal that we could necessarily return to.

I think we do know and understand that 400 or more years ago, the vegetation was changing. We know a good bit about what Native Americans were doing in the Boston Harbor area before contact with Europeans, and certainly, they were altering the landscape, perhaps not as rapidly as we with our larger population, but certainly, they were altering it. Our objective is not also to describe what is there today, or what was there in the past with the idea that that was something that could be preserved as we might preserve a painting, or a piece of furniture, because, again, vegetation changes through time. I work with a lot of historians, pure historians at areas like Saratoga Battlefield, where I helped them initiate a prescribed burning program to maintain their landscape as they thought it looked in the 1770s, at the time of the battle. And the hardest thing that I have had to deal with in dealing with pure historians is the idea is that we can make it look like it was in 1777, let us say, and then we will just let it go. It will be like it is forever. Things never stay the same. So really what we are trying to do is provide a historical context, what was there in the past, what do we have today, so that in the future, when we see change, we will have some idea of how that change compares to the change that has gone on in the past, and also perhaps identify some of the factors that have contributed to the change in the past and that might be important in the future.

Some of the methods we have used, we have looked at written and historical accounts and maps, historical and modern air photos, and fossil pollen analysis, and I will discuss briefly some of the advantages and disadvantages of each of these and what we have found out as they apply to understanding the history of vegetation on the islands.

There are a number of accounts from the 17th and 19th and not too long ago in the 20th century that describes the isles. One warning that we have to keep in mind is one of Emily Russell's, an historian who has also trained as an ecologist and works at Rutgers. She pointed out in a very important paper in the early 1980s that we cannot take these accounts, whether they are essentially of what we might think the natural community was like in 1616, or even as long ago as 120 or 110 years ago in 1891, as being the same kind of objective observation that we might like to have of what the vegetation was like at sometime in the past. In fact, even the earliest explorers had ulterior motives in describing the landscape. They came from Europe. They were encouraging, or expected to encourage, other Europeans to come to North America, and European landscape was a largely settled landscape. We know that Europeans had been clearing land and burning it back to the Stone Age, 5,000 or more years ago. So it was very much of a pastoral landscape and if you were trying to encourage other people to come to New England, you would not describe the mosquitoes.

You would not describe the black flies. You would not describe a dark, foreboding forest full of wild beasts. You would describe it as something perhaps somewhat romanticized, or in terms that those who might follow you could understand. So we have to be a little bit careful about some of these very glowing descriptions of islands full of vegetation and fruit and open landscapes. I am not saying some of them were not, but I have studied New England landscape long enough to know that it is real hard to keep a landscape in New England open for very long without working very hard at clearing it and clearing it repeatedly. In some areas, we certainly know that Native Americans were doing that. On all of the Boston Harbor Islands probably they were not.

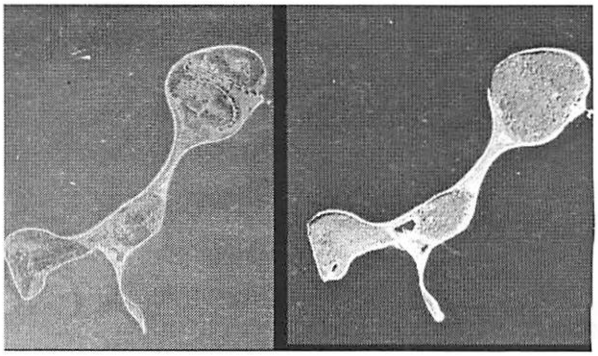

Figure 1. Peddocks Island in 1952, left photo, and in 1999, right photo.

On a different time scale, we actually can look fairly objectively at the change that has occurred since around the 1930s; I think these are the earliest photographs that we have. Figure 1 compares Peddocks Island, an air photo in 1952 with 1999, a period of only 40 years, 1/10th the period of time that I have been talking about, the last 400 years. But we can see dramatic change. An island that was for the large part open, to now one that appears, except for the spits, to be largely forested. The structures that were evident in the early 1950s are almost completely obscured by the change in the vegetation that has occurred. You are just now getting, in fact, yesterday; I spoke with the woman who is comparing the photos from the 1930s and 1950s with those of the 1990s about the results that she is getting. We know, for example, that approximately 70% of Long Island, about 70% of the area that has shown as either wooded or shrubby vegetation in the early 1950s was much more open, either grassland or very low shrub vegetation (figure 2). Again, this provides us with a context, a realization that in four decades we

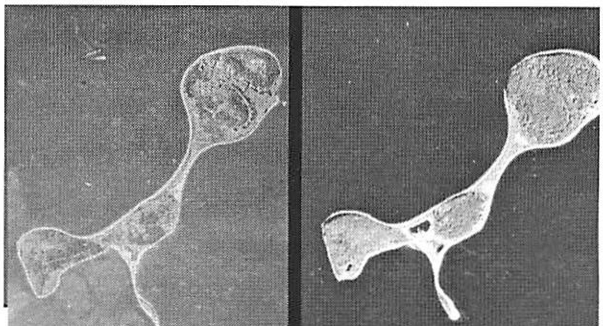

Figure 2. Long and Rainsford Islands, showing the change in vegetative cover.

have had very rapid change on the island, and it probably humbles us a bit to think about how well we might describe the changes that have occurred over a 400 year period, perhaps going from forested to completely barren of woody vegetation to now perhaps almost entirely forested again. The one method that we do have that is at least somewhat objective in terms of describing the vegetation of 400 years ago, and certainly of the time before that, is by looking at pollen that is preserved in wetlands. This is not a very good picture of Calf Island (figure 3), but it illustrates a small marsh in the Calf Island from which we obtained a sediment core last fall and are again working on.

Figure 3. Calf Island, showing site of wetland.

The marsh on Calf Island today is a mixture of sumac in the uplands, almost tidal wetland. We have got some *Phragmites* and there is quite a bit of grass in the area. I think about half of the species that occur on Calf Island today are alien, or exotic species, species we would not have expected to have seen there naturally. We are studying a site as shown in figure 4. Our pole that we are using to probe in the peat extends upward. We have got about two meters of peat and recovered a core from this site. We also use a coring rig that we drive down into the peat and

Figure 4. Extracting a peat-core from marsh study location.

raise up material. From that we can sample currently at about 10 centimeter intervals. We could sample more precisely if we wished to.

We take these samples back to the lab; treat them with a number of chemicals to dissolve silicates, some of the non-pollen organic material, any calcareous material that might be there, and humic acids. And what is left behind is a residue of fossil pollen grains (figure 5). We observe birch, elm, ash and I think there might be grass pollen green. We can distinguish perhaps 80 or

Figure 5. Magnified pollen grains.

100 different pollen types that occur on the New England landscape representative of the several hundred species. So, for example, we cannot tell the four or five species of birch that we have in New England, but we can tell birch from pine. We cannot tell red pine from pitch pine, but we can tell white pine from those.

Among the grasses, we have to measure the diameters of the pollen grains. These grains, as you can imagine if you look out on the hood of your car these days, are very tiny. But for a scale, this is about 100 microns or so, about 20 microns or so for the birch. If we measure the diameter the grass pollen grains, we can get some idea of some of the general groups of type cereal grains. *Phragmites*, it turns out, has a very small pollen grain. But, on the other hand, the elm, we can tell pretty much the species from the pollen. So there are a few types that we can tell the species. We also find in our samples, charcoal as evidence of past fires and that helps us reconstruct one of the important disturbances that we know from studies elsewhere on the south New England coast was present before Europeans arrived. Native Americans burned for a variety of purposes and kept some habitats open, including perhaps some of the Boston Harbor Island areas.

Table 1 is just a summary of a few of the samples that we have looked at so far, and I will use this as an example of how we might be able to interpret a few things from these admittedly very imprecise data both with respect to the vegetation that exists and also with respect to time. We can tell post-settlement from pre-settlement materials. We know at 10 and 37 meters into the sediments that we have quite a bit of ragweed as an evidence of agricultural activity of the Europeans. This is the culture horizon which would be somewhere between 30 and 60 centimeters here. And we see throughout North America, at least in the fairly settled areas of North America, it is a time transgressive horizon. Here in the Boston Harbor areas this probably represents some time before about 1600 in here and sometime after 1600 over here. Get out to Minnesota or to California and that time frame

Table 1. Fossil Pollen Analysis

Preliminary Fossil Pollen Analysis
(percent of total pollen)
Calf Island – 2002

Depth below surface (cm)

	Post-settlement		Pre-settlement	
	10	30	60	90
Oak	0.6	3.8	11.9	17.6
Pine	9.1	4.1	2.5	4.0
Grass	4.6	49.9	27.8	42.1
Chenopods	17.7	0.9	3.3	0.2
Ragweed	4.0	4.3	0.3	0.8
Unidentifiable	50.3	21.5	33.7	22.3

might be only 100 or 150 years ago. We have a long period of time that we have had settlement here and agricultural activity by Europeans. And so we see a sharp increase in ragweed pollen as evidence of that. We can also look at some of the other things that are of interest here. Chenopods, the Lamb's Quarters (20 or 30 different species, which are now common garden weeds) seem to increase dramatically very recently and we know that although there are a species or two of native chenopods on island, there are also alien chenopods. The chenopods, with a little bit of difficulty, can be identified. Their pollen can be identified into species or groups, and one of the things we would hope to be able to do in the next few months is determine whether this increase is the result of a native, or an exotic, species. My guess would be an exotic species, but we need to look at that carefully.

Perhaps the most dramatic change that is evident here is the decline in grass pollen to very low levels here and higher levels both perhaps several decades ago to a century or more ago, back to the pre-settlement time. And again, we would like to look at that and see well, is this just a change in some of the salt marsh grasses that were occurring in this wetland, or does that reflect a change in the vegetation in the uplands surrounding the wetland. And, in particular, we could ask, for example, the question is the *Phragmites* that we see at the wetland today what is apparently now nearly extinct native *Phragmites* throughout New England, or is it the strain that was imported and is taking over many of our wetlands. Again, if we find that we have very small grass pollen grains here in the pre-settlement, than that is pretty good evidence that there may have been native *Phragmites* in this wetland even before the exotic strain was brought in.

There is some indication here that there may have been more wooded landscape on the island. Calf Island is in the Outer Brewsters, north of Hull. And this level of oak pollen in the local pollens would suggest that there might have at least been some oak trees on the island at the time. Today, to my knowledge, there are not any oaks, or they are not obvious at all. And certainly that is reflected by the very low value here at the near surface sample, compared to the region, which has quite a bit of oak remaining in the area around it. So I suspect that just for this particular island we may be able to say something about the change in the upland vegetation, the change in what is going on in the wetland and also perhaps something about what has gone on with respect to invasion by alien, or exotic, species. We will hope to finish this up by about the end of the calendar year and have results by this time next year that we can share with you.

Recovery of Boston Harbor's Ecosystem

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PANEL PRESENTATION

It is a real pleasure to be here to talk about the part of the park that is not part of the park. But without the water we would not have the islands. I am really happy that I was invited to talk. Today I am going to focus on the part of the monitoring that we have done that has taken place over the period of time up to when the new long ocean outfall was commissioned. There is a really interesting story there. There is a poster, which we have done together with Dr. David Taylor that details some of the water quality changes that we have observed in the harbor after the discharge from Deer Island treatment plant was moved 9.5 miles offshore.

First of all I want to give you an idea of what has been going on the most expensive island in the park, Deer Island, where the greater Boston waste water treatment facility is located, which is actually something more than $4 billion worth of construction (figure 1). I am going to first give you a brief overview of how improved treatment at our new treatment plant has been changing what the Massachusetts Water Resources Authority (MWRA) has been discharging into the harbor over the years. Figure 2 shows, in millions of gallons per day of discharges, the change in primary treated flows, which is simply physically removing solids from the wastewater and discharging the effluent to secondary treated flows, which undergo biological treatment and removes up to 95% of the contaminants from the water. You can see that beginning in 1997 secondary treatment started to come on line and progressively more and more contaminants were taken out of the water. Even before that happened some early changes were made really at the very beginning of the Boston

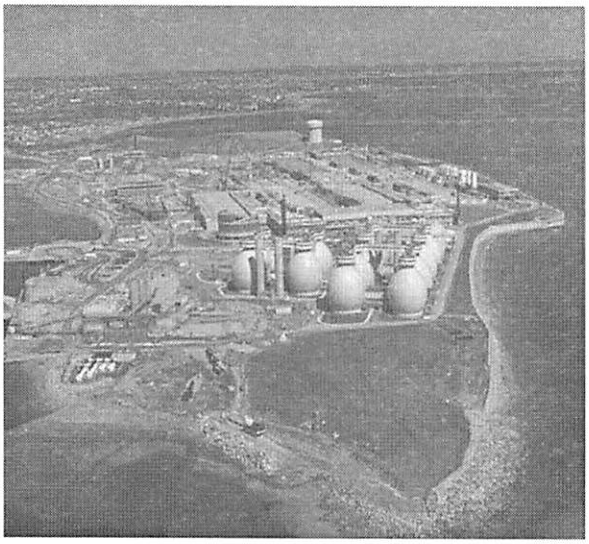


Figure 1. The Massachusetts Water Resources Authority sewage treatment plant on Deer Island.

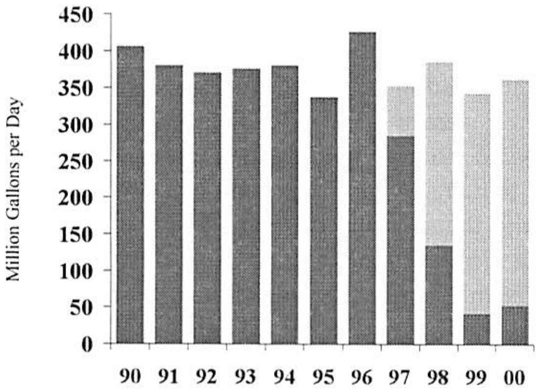


Figure 2. The Massachusetts Water Resources Authority Primary flow (darker color) and Secondary flow.

Harbor Project. One of the first things that we did was fast track some upgrades to the treatment plant, to just make the treatment plant work more effectively and improved disinfection was one of the most dramatic things that we did early on. Figure 3 shows the number of days that we measured effluent with high bacteria counts in 1988. At that time 140 days out of the year had counts that actually exceeded the water quality standards and many of those samples had counts with more than 10,000 fecal coliform per 100 milliliters and the permit limit was 200. We thought one of the first things we needed to do was attack the disinfection system. Since the

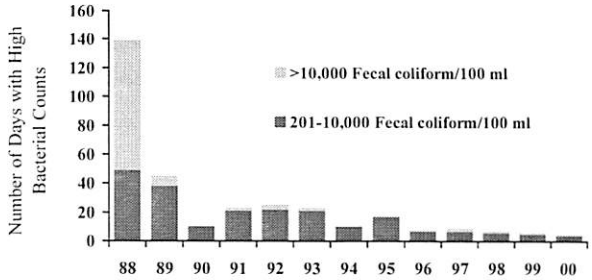


Figure 3. Decreased bacteria levels in Deer Island effluent.

early 1990s, the disinfection has been very effective, with only I think two or three days a year when the counts have exceeded 200.

Likewise the solids discharges to Boston Harbor have decreased from 1988 to 2000. This is measured in tons per day. [On a slide the colors of the bars showed the sources of the solids.] The light blue is from Deer Island treatment plant. The medium blue is from Nut Island in the southern part of the harbor. The yellow is the sludge. In the old days we actually would take the sludge out of the wastewater and then after having it undergo some digestion put it back in the harbor. That was not really one of our better activities. The sludge discharges ended in 1991 when palletizing plant was completed and so that was really the first major drop in solids discharge to the harbor. Secondary treatment came on line at the end of 1997; the solids discharged were even more, so in 1988 we were discharging almost 170 tons per day of solids. By the year 2000 we were down to 40 tons per day. Of course now the discharge is offshore, 9.5 miles offshore, the amount of solids being discharged from MWRA to the harbor itself is zero. That is important not only partly because the solids themselves are a pollutant but also because toxic contaminants are attached to the solids.

Toxic contaminants discharge in metals is one of the things that we measure, and they have changed over the period of time that we have been monitoring. Actually, one of the earliest efforts that was made, even before the Boston Harbor project came online, was to really try to control industrial discharges to our sewer system.

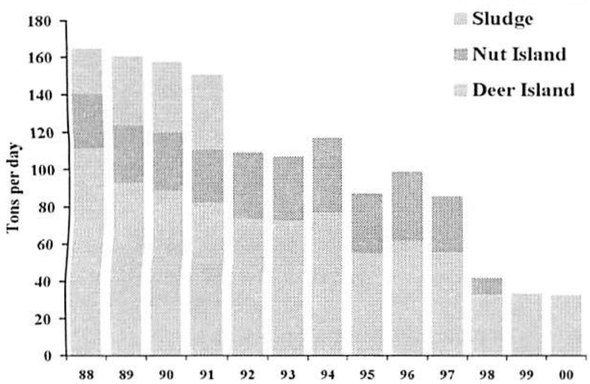


Figure 4. Massachusetts Water Resources Authority solids discharges to Boston Harbor, 1988-2000.

So early, really early on, inroads were made in the amounts of metals that we discharged. Then the decrease after that really parallels the implementation of secondary treatment. So it is a combination of source reduction and improved treatment that have dropped the metals from 1100 pounds per day discharged to the harbor to now more around 200 (figure 4).

The monitoring that we do at MWRA is organized to respond to public concerns and we look at four different areas, four different basic questions. One is, are resources being protected? Is it safe to eat fish and shellfish? Is it safe to swim? And also protection of the aesthetic quality of the harbor is important.

One of the best places to look for the health of the harbor is in the sediments. The reason for that is that the pollutants that we discharge end up in the sediments. So we actually have quite an extensive program for looking at animals in the sediments and that has been done in conjunction with Battelle Ocean Sciences, also the Woods Hole Oceanographic Institution. That program is run by Ken Kay of my staff. One organism that increased in population is an amphipod, *Ampelisca abdita* (figure 5). It is not as pretty as some of the birds, but it is a great little guy. He is a tiny tube-dwelling crustacean. It is interesting because it is moderately pollution intolerant and it is easy to find because it builds tubes into the sediment. One of the ways we look for the sediment quality is working with

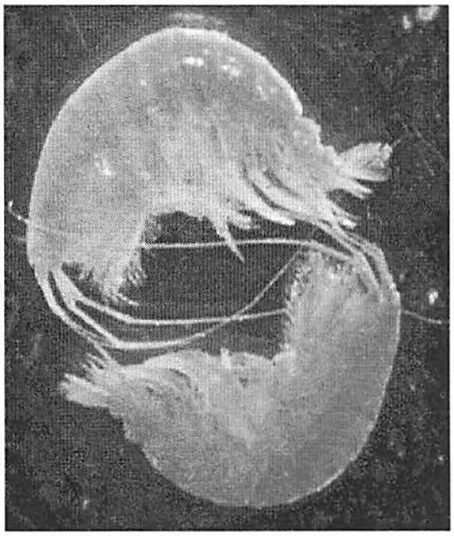


Figure 5. *Ampelisca abdita* is a crustacean that is moderately intolerant and builds tubes in sediment.

Bob Diaz at the University of Virginia. He uses a sediment profile imaging (SPI) camera that he has developed that penetrates right down into the sediment and then will take a picture of a vertical cross section of the sediment (figure 6). It allows me to very quickly get an idea of the animals that are living in the sediment. You can identify them, count them, and also get an idea of the visual sediment quality itself. Every year we use this camera at about 50-odd locations all throughout the harbor, so we can get an idea of

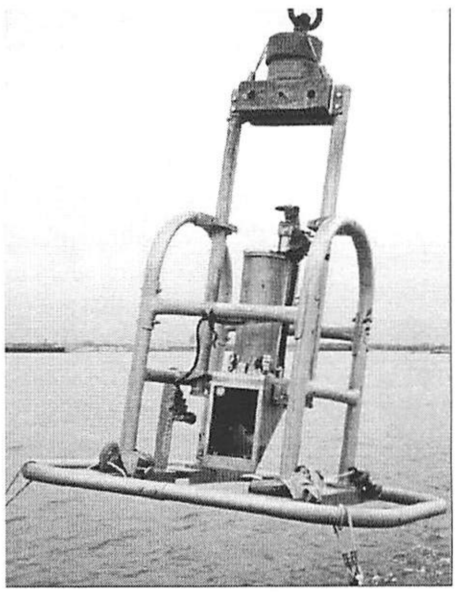
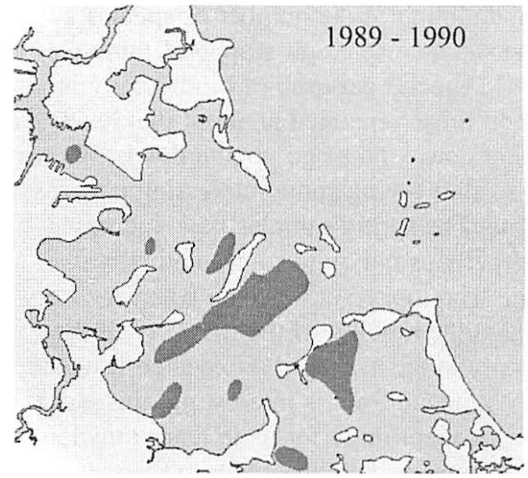


Figure 6. The sediment profile imaging (SPI) camera.

what the sediment quality is like. So using the SPI camera we have identified areas where we found *Ampelisca* tube mats on the harbor floor. When we first started doing this, the tube mats covered an area primarily into the central harbor and the southern harbor, which are generally the more pristine areas. The northern harbor was the most affected by discharges from the Deer Island treatment plant, which were coming out near the discharge. Using a picture that was taken by that camera at the location where we were actually discharging sludge from the Nut Island treatment plant, and another image off the tip of Long Island, we can observe differences in impacts. She identifies the areas on a map. In 1990 at that discharge location, the sediment/water interface is near the top of the image. There was almost nothing living in this sediment. An oxidized region of the sediment is a lighter color and was very, very thin, compared to the anoxic region, which is darker and thicker. By 1996 the images of a thin oxygen layer was visible at the location where we were still discharging sludge. In 1996 after the sludge discharges had stopped, the *Ampelisca* coverage has expanded to cover almost all the harbor (figures 7a and b). Photographs from a cross section of the sediment in exactly the same location show the little tubes of the Ampeliscid amphipods. These are tubes that *Ampelisca* builds. In some places on the image you can even detect some worms. The *Ampelisca*, partly because of its tube-building, is starting to aerate the sediments. This oxygenated layer is about 5 centimeters deep now and thus has increased greatly from the early 1990s. So that is a really dramatic and gratifying thing to see, in a very short space of time.

A measure that we use of species diversity in harbor sediment communities is a simple count of numbers of species per sample. In 1991, we did this survey two times a year, in the spring and the summer, in the summer of 1991 on average we were getting about 17 species per mud sample per grab in the harbor (figure 8). And of course remember in December 1991 was when the sludge discharges to the harbor stopped. It was really quite amazing. These are harbor-wide averages. Almost immediately, in the next summer, we had a very dramatic increase, really



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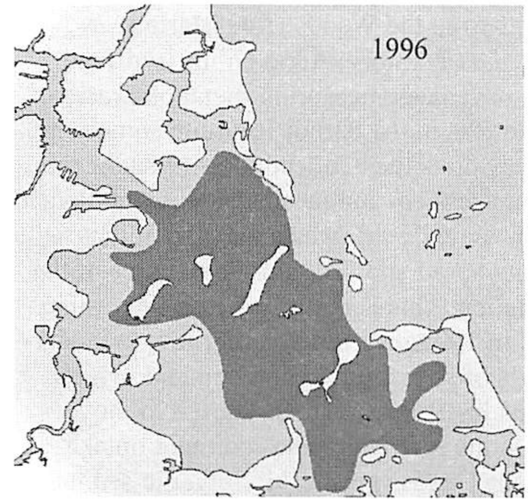


(b)

Figure 7. Ampelisca tubemats on the Boston Harbor floor expanded rapidly after the sludge discharges ceased..

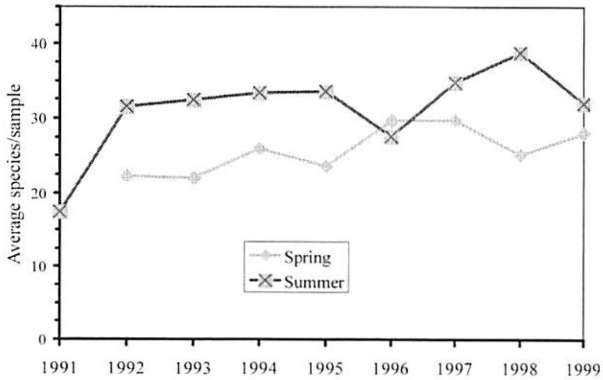


Figure 8. The average number of species collected in each mud sample grab has increased since the sludge discharges stopped.

almost a doubling of the number of species. After the sludge discharges stopped I think we counted 32 species per grab of biodiversity in the harbor. It has remained at about that level, although it does kind of go up and down. We are starting to start seeing some interesting patterns in the data. The spring samples have increased also, but perhaps not quite so dramatically. Everyone who looked at this data was very, very surprised at the rapidity of the recovery of the biodiversity in the harbor. We expected it would take much longer. So it is interesting, this is really a unique opportunity for us to learn how long it takes an impacted environment to recover from the effects of pollution.

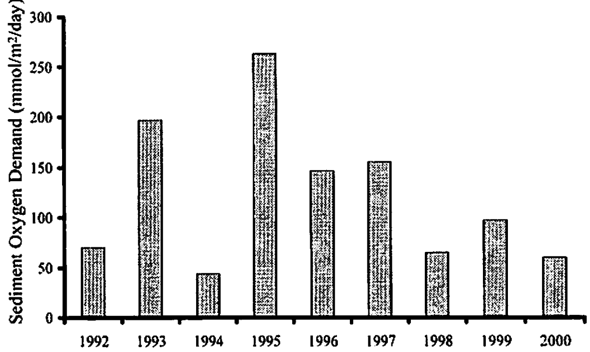


Figure 9. Sediment oxygen demand at the former sludge discharge site in Boston Harbor.

Scientists from the Woods Hole Marine Biological Laboratory; Anne Giblin and Jane Tucker, have been measuring metabolic rates in the sediments in the harbor for quite some time. What they do is they collect cores of sediment and incubate them and measure sediment oxygen demand. Actually this was done also at that same location where I showed you the pictures of the cross section. This is really quite an interesting pattern. In 1992 they noted rather low to moderate levels of sediment oxygen demand, which increased in 1993 as animals started to move back into the sediments, the sediment uptake increased. This is very heavily organic sediment. Sediment oxygen demand is important because generally speaking highly impacted sediments use a lot of oxygen. It is not necessary a desirable attribute. In 1994 the levels went down again, presumably as a lot of the organic material had been used up by the communities living in the sediment. But then in 1995 it shot up to levels, this was like 260 micro milliliters of oxygen per meter square per day, which Anne and Jane say is the highest level of metabolism they have ever measured anywhere. This occurred as more animals were moving into the sediment and enabling the bacteria colonies to move deeper and deeper into the sediments and mine more organic material out. Since that time, the metabolism in those sediments has been gradually decreasing and now in the year 2000 it is really back to what you might call normal estuarine levels, about 60 millimols per meter square per day (figure 9).

The other variable that we looked at is disease in flounder. This spring we had a really successful flounder fishing trip off Deer Island. This is the first time this has ever happened. It used to take us several days to collect the 50 fish that we use for our survey. Just this spring we collected an amazing net full of flounder. So that also was interesting and somewhat encouraging. Flounder are a useful indicator of the health of the ecosystem because they live in contact with the sediments and also consume the little organisms that live there. They can actually absorb contaminants directly through their skin and also they bio-magnify contaminants, which then can be metabolized in their livers and cause liver damage. So we look at liver disease. In the early to late 1980s Boston Harbor was actually made pretty famous by a paper in Science by Bob Murchalano et al. that found the highest levels of centrotubular hydropic vacuolation, which is also an early liver disease in flounder that they had ever seen. They found that actually up to 80% of the flounder in Boston Harbor were affected by early liver disease. Since that time, the percent of fish affected has dropped off (figure 10). There is some variability and the values go up and down. But it is now at around 40% to 50%, where before it was 80%. The more serious condition of actual liver tumors was up around 20% in 1988 and then decreased to about 10% 1989 and 1990, to 0% throughout the 1990s. I think they had one fish in 1996 that had a liver tumor and since then there have not been any flounder with liver tumors. There is about a three-year lag between, when there is a change

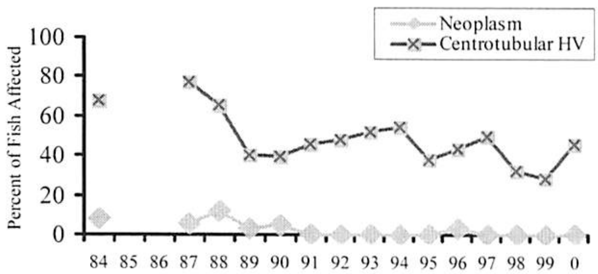
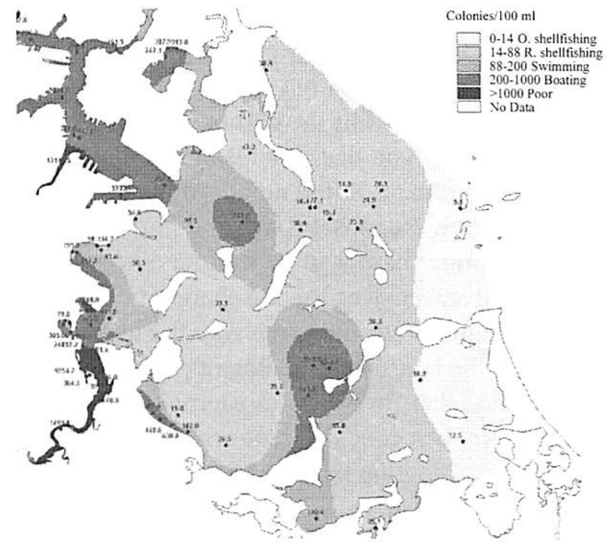


Figure 10. The drop in liver disease incidence in Boston Harbor flounder.

in the environmental quality and that actually shows up in the fish liver. So that also is an interesting indicator of the health of the harbor.

The other thing that we look at as an indicator is whether it safe to eat fish and shellfish? We look at contamination levels. Of course we use mussels because they absorb and concentrate toxic contaminants from the water into their tissues. [A slide shows mussel cages being deployed near the site of the Deer Island discharge.] One of the things that we like to look at in mussels is PAHs, polycyclic aromatic hydrocarbons. Those have really shown a very dramatic decrease in mussels at Deer Island, 1991 to 2000 they have dropped to probably about ¼ of their former levels. So that is also a useful indicator of water quality.

Swimming is another important value to the public. Of course, we looked at bacteria levels, to determine whether it is safe to swim. This is a contour plot done by Dr. Shegan Lang in my office, who took data that we had gathered from a number of different sources, including beach monitoring by the Metropolitan District Commission, data that had been gathered by the New England Aquarium, as well as our data, from the time period 1973, actually going all the way back to 1973, up to July of 1998, which was the date when this Nut Island treatment plant was shut down. The light area (figure 11a and b) is the region that would meet the most stringent water quality criteria required for open shell fishing, which are less than 14 colonies per hundred milliliters. The next darker area would meet restricted shell fishing. The medium gray would



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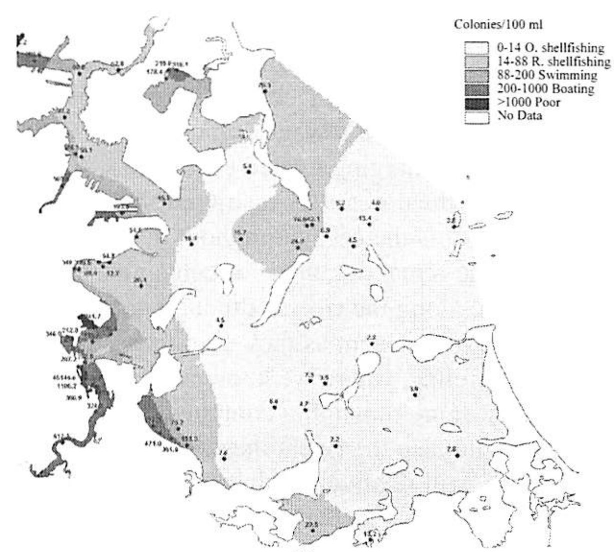

(b)

Figure 11. The fecal coliform counts in Boston Harbor. The top figure (a) shows the pre-interisland tunnel period (June 27, 1973 - July 8, 1998), whereas (b) depicts the post-interisland tunnel period (July 9, 1998 - August 2000).

meet swimming standards. The darker area would meet boating standards. Then the darkest area would not meet any water quality standards at all. The pattern is that the most affected areas are around the old Nut Island treatment plant discharge locations, as indicated on the map. There is an area which actually seems to represent the combination of factors from the Deer Island discharge, which was indicated on a map, the Nut Island discharge, which was indicated on a map, and coming out of the inner harbor. It is an interesting thing because we have got this little bull's eye, which actually corresponds, well to a model that we had of the harbor. But I am not going to show you that. We also have high levels of contaminants at the mouth of the rivers, the Mystic River, Neponset River and Fort Point Channel, the inner harbor in general, and near an old *combined* sewer overflow discharge in Savin Hill Cove. Figure 11b shows the way the harbor looked after the Nut Island treatment plant was shut down and that flow was transferred over to Deer Island for a secondary treatment. Up to the point, not including the point, where the flow was transferred offshore. Because we do not have enough data yet to fairly contour that condition. You can see that virtually all of the outer harbor now around, and that includes around the islands, meets the most stringent bacteria criteria. Even around Deer Island, which is still discharging treated sewage, which at this time was still discharging treated effluent sewage; it met the criteria for restricted shellfishing. In fact, that is the case throughout most of the harbor. The remaining areas of contamination really are along the rivers, although not quite as serious an extent as they used to be, and along the shoreline, where we know we have storm drains, some remaining combined sewer overflows. And also the rivers themselves are unfortunately still relatively polluted. People do swim! The annual swim that takes place off the South Boston beaches is a pretty exciting picture. There is a really nice beach on Lovells Island that is gorgeous. Underwater aesthetics can be seen in photographs of a lobster, many of which live off of one of the rocky coast islands. It could have been around Calf Island, in the outer harbor. There are crabs, kelp beds (which shelter young fish and crabs) and a diversity of organisms that are signs of a recovering harbor. If you go to the Charles River in the spring you will see herring. These are anadromous fish that migrate through the harbor and up the Charles River and up the freshwater rivers, to spawn. The Charles River has the biggest herring migration in the state. I do not know how they do this. Another fish the smelt, attaches its small eggs to rocks at the mouth of the Neponset River (and others) where the water actually tumbles over a dam. It is very well aerated, which is what smelts like. She shows smelts schooling in the Neponset River and calls it her sunset slide. It is just really beautiful a nice sandy bottom and the light coming in from the top.

Panel Discussion

AUDIENCE QUESTION: One of the things we have been talking about is the success story of the harbor cleanup. Is it a success story for everybody? Are there any other examples of a harbor having this much of a rapid transformation?

ANDREA REX: Not that I know of. [She asks Dave Taylor from MWRA who also responds that he does not know of any at this rate.]

AUDIENCE QUESTION: Are there any other harbors that are attempting to do this type of a transformation?

ANDREA REX: I do not think so. New York harbor has had similar upgrades, but we were unusually bad in the beginning. But that was a long time ago. It is much better now.

AUDIENCE QUESTION: Is there any sort of tertiary component plan for the effluent?

ANDREA REX: No. Not at this time. That is an interesting question though, because if there were a tertiary treatment plant for the Boston discharge, it would likely be to do a nutrient removal. We have a really extensive marine monitoring program in Massachusetts Bay to look at the effects of pollutants on the ecosystem; mostly it focuses on the effects of nutrients on Massachusetts Bay. And right now we have not found any deleterious impact, although it is relatively early, since the discharge started, the outfall was commissioned in the fall of 2000. So it has really been only one and a half years. We can see a signature of ammonia, which is in the effluent, in the area around the discharge, but it is quite limited and quite confined. But we do look. We monitor algae, species composition, zooplankton numbers and composition, as well as a whole suite of nutrients, actually throughout the Bay and into Cape Cod Bay. So we have not found anything yet.

AUDIENCE QUESTION: This is directed to Duncan Fitzgerald regarding your surveys of the harbor islands and the boat wakes. Do you intend to extend that to any of the land beaches, specifically the Hough's Neck, or possibly the Wollaston Beach area?

DUNCAN FITZGERALD: Well, right now we are just planning on getting our study funded. When it does get funded we plan to monitor all potentially impacted areas. So if Wollaston Beach is impacted, we certainly will put some instrumentation there. We plan to put wave and current meters in these localities to measure the wind generated waves and also the waves that occur during the boat traveling.

AUDIENCE QUESTION: I was curious. One of our problems is that the perception by the public is that the harbor continues to be dirty, and it is one of the criticisms that people make when they say they do not come to the islands. I was wondering what monitoring unit can we use to market the cleanliness of the harbor on a continuing basis, similar to the flag program for the MDC beaches? Is there a way that we can start to utilize a monitoring agent that we can publicize maybe on our website and in our materials?

ANDREA REX: That is an interesting question. Of course, we use a lot of these, the kinds of indicators that I have shown you. We also measure water clarity, which has improved measurably since the outfall was moved offshore. I think the thing that feeds the public perception that the harbor is still in poor condition is that we do still experience beach postings, and that is really the function of it being an urban environment for the most part. The harbor, as shoreline, is where storm water gets discharged, and that carries a whole freight-load of urban pollutants with it. So it is unfortunate, but that is where people want to be at the shoreline, and it is also where the pollutants get discharged. But water clarity is good, as well as these other indicators that I mentioned. So that is one thing we can use. Do you have any other ideas?

AUDIENCE QUESTION: I have a question for Gary Davis. The Boston Harbor Islands obviously are in a very urban environment. I am wondering how that compares to other island systems that you are familiar with in the United States or in the world, and just your thoughts about trying to understand a natural system in what some consider an urban location.

GARY DAVIS: It is not unique. I think there are other island systems that are becoming urbanized. Certainly, the few islands in San Francisco Bay are in a similar setting. San Diego has a number of island settings as does the Virgin Islands and South Florida, in Biscayne Bay. Miami is growing around the upper Florida Keys and in Biscayne National Park. So, a lot of folks are facing the same kinds of issues. All of the islands themselves are facing the same kinds of development pressures. There are a lot of other places where people are going through these kinds of things. As a comment on the idea of how you would get the public engaged in understanding that things are getting better, the thing that has worked really well in San Diego is that the public has been engaged in the monitoring so that they are actually doing it in communities, and they are organizing themselves to get engaged in that. And so, it is not an agency telling them that things are better or showing them a graph, but it is they themselves actually out picking up things, measuring, using cleanup days, counting fish, doing things like that. There is an effort called the Great Annual Fish Count that is like the Audubon Christmas Bird Count, where people go out and count fish in their neighborhoods to see if things have gotten better. So they are engaged in the process.

AUDIENCE QUESTION: Duncan, I have a question for you. Will you talk about sea level rise; rates of sea level rise in Boston Harbor Islands, and what impact that may have on erosion patterns?

DUNCAN FITZGERALD: Yes. The rate of sea level rise right now is about 30 centimeters per century. With global warming this may increase to 60 to 90 centimeters per century, which is going to bring the level of the breaking waves up closer to the base of the slope. So we can certainly expect with increased rates of sea level rise to see increased rates of erosion. A graduate student of mine some time ago did a study of Sandy Neck in Barnstable on Cape Cod, Massachusetts, and what he showed was the growth of Sandy Neck. He followed the growth through time by looking at ^{14}carbon records of the marsh and was able to show that the growth of the spit was greatest when sea level rise was the greatest. So, it was the fact that the waves were able to break at a higher level up onto the bluffs of the south shore, where the sediment was coming from, and that created a greater sediment supply for the spit system. So the spit was not growing at a rapid rate when sea level was rising relatively slowly. Rather, it was building at the most rapid rate when sea level rise was at its greatest, which is an indication of how quickly the bluffs will erode as well. So sea level is of great concern. It is what is driving the erosion, and we can expect with increased global warming to see increased rates of bluff loss.

AUDIENCE QUESTION: Would you have any recommendations about whether we should try to save the islands from sea level rise?

DUNCAN FITZGERALD: Well, that is a management issue. Whether we want to save the facilities, whether we want to save islands, like Sheep Island, or whether we want to keep them in a natural state. Do we want to build revetments and sea walls and cordon off the islands from the water, or whether we want to maintain natural systems? And I think that is an issue that everyone has to deal with.

AUDIENCE QUESTION: Two questions for Peter. One is, why have the gulls become more common than in the past? And the other is about the Chimney Swifts and that might be for everybody, which is, if they nest in chimneys, do we want to make sure there are still some chimneys around rather than tearing them all down?

PETER PATON: Well, before chimneys were here, Chimney Swifts nested in snags. There are not a lot of large snags left around here. So if you want to have chimney swifts around here, you are going to have to maintain some structures for sure, we could start to build artificial snags if we wanted to maintain swifts around here. Why have gulls become so common? Well, humans have a lot of refuse and gulls like dumps and so there is a lot of food around. Also people are not shooting gulls anymore. People are not collecting gull eggs anymore. There is a lot of refuse out there, and then also in the winter months there are a lot of people out there fishing and a lot of gulls eat food from fishing boats that, instead of dumps, helps them survive through the winter months. So a number of factors have led to their increase.

AUDIENCE QUESTION: Those factors have changed in the last 50 years?

PETER PATON: Particularly the shooting is probably one of the main things.

AUDIENCE QUESTION: Peter, this is for you again. I was wondering if you could put Boston Harbor Islands and Boston Harbor in sort of a regional context in terms of bird populations, like shorebird migration, warbler migration and winter resident and waterfowl, and some of the other things.

PETER PATON: I have only been out there six days. I cannot honestly say anything about shorebird populations in terms of shorebird use of Boston Harbor, because I have not experienced them. Shorebirds migrate in spring, in May, and there is some shorebird migration in the summer and fall, July and August. And there is not a lot of beach habitat in the islands. There are probably relatively small numbers of shorebirds that move through the area. Most of the shorebirds are going to go and stop at places like Cape Cod and Monomoy and those areas in the springtime, so there would be small numbers moving through here. Waterfowl populations, the Take a Second Look Group has been monitoring waterfowl populations since 1983, and there are large numbers of waterfowl that use Boston Harbor in the winter months. In a regional context, because for Neotropical migrants there is probably some use of the islands. There are always birds that breed on the islands, but they are all relatively small, so species that require large tracks of forest will not be there. The habitat just does not exist out there. But during fall migration, I am sure that birds stop over on the islands, particularly young birds, and they keep on moving farther south.

AUDIENCE QUESTION: I have a question about invasive species. I am interested in marine bioinvaders, and we assume that once they get there, it is very difficult to eradicate them. But I wondered about the plant species. You were talking about a very high number of invasive species on the islands. What would you recommend for restoration, for removal, or can you talk about how they are impacting the islands?

GARY DAVIS: In the West coast we have got three pretty aggressive invaders, marine plants that could invade the islands right now: *Caulerpa taxifolia* that came from the Mediterranean, a brown alga *Undaria* that came from Japan, and another brown alga, *Sargassum* that came from Japan. The best results are to catch an invasive species early and to put a lot of resources into it as quickly as you can and try and contain the area. The *Sargassum* moved through the area before anybody was paying much attention, and I think we are going to live with it for a time. But the other two we have caught relatively early and I think we will contain them. So I think it is being vigilant, finding the resources, mobilizing the community to get there quickly and understand that it is a big problem.

MARY FOLEY: We have time for one more question and, as moderator, I am going to take advantage of asking it. Bill, this is a question for you. Can you comment on fire history of Boston Harbor Islands? Have you learned anything or picked up any indications in that direction?

BILL PATTERSON: We will look at that by looking at the charcoal and the sediments, and I usually do not do that until I get done with the pollen, so I have not gotten to that yet. I think it is reasonable to assume, based on what we know about the Cape and Islands and elsewhere along the coast, that fire did occur before Europeans arrived. And then the occurrence of fire increased dramatically after Europeans arrived. So I would expect that what we would find is that there was some level of fire that it was impacting the vegetation, that fire increased, and then in the last 50 to 75 years it has decreased dramatically as fire suppression has become effective.

SUMMARY REMARKS

KATHY ABBOTT
President
Island Alliance
408 Atlantic Avenue, Suite 228
Boston, MA 02110

Before the closing address by Massachusetts Secretary of Environment Affairs, I wanted to take a second to say how exciting it is to be able to sit in a room like this and hear real data, because for many of us who are in the business—not in the science business but in all the other realms, whether you are an island manager, or a policymaker, or a regulator—we are dealing with all those kind of "squishy" issues. So to sit here and hear real data has been incredibly refreshing. It is also incredibly humbling to be in the presence of so many of you who work in the sciences and who are creating new knowledge for those of us who have to go out and do the squishy things. So thank you.

Massachusetts Biodiversity Days 2002

Robert Durand
Secretary, Executive Office of Environmental Affairs and Chair, Boston Harbor Islands Partnership
Boston, MA 02114

Closing Address

Let me just thank everybody who is involved: the Boston Harbor Islands Partnership agencies, the universities in the Greater Boston area—not only Massachusetts Institute of Technology (MIT) but Harvard University and the University of Massachusetts—the Harbor Institute, and the great advisory council that we have, and the great Boston Harbor Islands friends group that we have. This is truly a great partnership and a great opportunity for us to really use the islands as an outdoor classroom; to use this as a model in trying to get a hold of some of the invasive species. I really see the Boston Harbor Islands as the last true urban marine wilderness left on the East Coast.

We have made tremendous progress through the Massachusetts Water Resources Authority (MWRA), the Board of which I also chair, in cleaning up Boston Harbor. And that was done well before I became chair. We have seen, as Andrea Rex pointed out, tremendous improvements in water clarity. Last week, I was doing a sporting column at the end of Deer Island with a salt water fishing magazine that was there to report on the great striped bass and bluefish opportunities that exist in Boston Harbor. I have duck hunted out at Graves Light with Kevin McHale formerly of the Boston Celtics. There are tremendous opportunities that present themselves now as a result of the harbor cleanup.

There are opportunities for us to follow the great work that people like Edward O. Wilson have done on biodiversity protection. If we can get some control of the invasive species that exist on these islands, perhaps do some controlled burns as Bill Patterson was talking about, and manage these properties well, I think it is going to be great not only for the number of different bird populations and other insect and mammal populations, the marine ecosystem in and around those islands, but also great for tourism, which adds another whole dimension to all this.

What is the carrying capacity of these great islands, and how are we going to manage the carrying capacity so that as we move forward in terms of biodiversity protection we are not adversely affecting future opportunities, because we are overusing the islands? That is a debate for another day.

Ed Wilson in his recent book, *The Future of Life*, talked about the loss of biodiversity. And he says, I think of the causes of declining hippo populations—it is loss of habitat, it is invasive species, it is pollution, it is over-population, and it is over—harvesting. I usually add the *g*, global warming, and I am glad today that Duncan and others brought that up. Because as we see a sea level rise of 22 inches over the next century here, we are going to see the loss of some of the lands that we are quickly going after to protect.

But Professor Wilson also points out that in order for us to sustain the standard of living that exists here in the United States globally, it would take the natural resources of four earths, which is an alarming statistic. It is obvious that we as people have to change our approach to these issues. And Wilson gives us great hope. He talks about the fact that in order for us to change that dynamic, as in all human endeavors when we have a sea change, we really need to change the ethics. Change the ethics of people not only in this state, in this country and around the world, but specifically here with the islands. We have a great opportunity I believe because of the pollution that existed here before. Because of that pollution, they did not get the use that they could have had. We sort of have an opportunity to really wipe the slate clean and start over again. To the extent that we can be pioneers in protecting these great resources in a way and managing them in a way that increases the biological conservation value of those islands, while at the same time promoting them as great recreational facilities and an outdoor classroom for our kids in the Greater Boston area and for tourism, people who come to Boston from around this globe.

We can be successful only if we take the type of approach that has been talked about today. And that is getting the data early on, being able to have the resources available through the collaboration, through the partnership, to manage these islands in a way that will bring us the greatest biodiversity value as they present. We may make some decisions about some of these islands having more value from a biodiversity standpoint, while some of the other islands may be more important from a cultural standpoint, and we need to highlight that as well as recreational opportunity that will present itself in other islands. I think we should be willing to make those distinctions. There should be that distinction between the islands that exist out there and, depending on what types of species that exist, what potential for species may exist, we may want to take a different approach in our management approach to dealing with those issues.

So this seminar is, for me, just the beginning of many events that are occurring this weekend. Ed Wilson and Peter Aldenbach in 1997, I think it was, had a Bio Blitz in the Town of Concord. We took that concept three years ago, after meeting with Wilson, and made it statewide. And he looked at me, he said, this is an awfully aggressive young guy who thinks he is going to take this statewide, I do not know if it is going to work or not. But I am happy to report that this weekend we have 325 communities statewide. That is 50,000 volunteers, over 200 schools in our Third Annual Biodiversity Days, where we have challenged schools and local folks to identify 200 animal, plant, and insect life in their community and by doing that, engaging them in the exercise of connecting them as people to the natural world in which they are all a part. I think it is doubly important today, given the fact that our kids spend a tremendous amount of time in sports, in theater, on the Internet, at home doing homework and just do not have that connection between them as people and the natural world in which we all live. If we do not make that connection for them early on, if we do not make them *biophiles*, as Ed Wilson would say, early on, then we are going to lose that environmental ethic that he talks about, that will sustain us for the future. We will lose the environmental stewards that are so critically important to shape our public policy. So the Biodiversity Days not only provides us with information in terms of informing through these citizen scientists with over 150 technical experts over that weekend. It helps inform our biomap, where we took 22 years of natural heritage data, developed core habitat areas around the state with that data supporting natural landscapes, and now in geographic information system (GIS) format, have been able to identify those lands in Massachusetts with the most significance from a biodiversity standpoint. It will not only help inform that the Biodiversity Days, in terms of looking for indicators out there that may present itself for further study by the technical experts, but more importantly I think, it allows us through environmental education exercise to really engage students in the public in this great endeavor so that we can instill in them that environmental ethic so that they can come out as they did just a short few weeks ago with 164 organizations statewide in support of the Governor's Environmental Bond Bill, a $945 million Environmental Bond Bill that passed the Senate and now it is over in the House. In order for us to make the kinds of contributions here in the islands, we need the resources in our capital infrastructure through our State Park (DEM) and Metropolitan District Commission (MDC) park infrastructure. But in order to do that, we need the Environmental Bond Bill to pass.

We are creating, I believe, through this Biodiversity Days exercise, not only great opportunities to inform science, but also to build the army that will support the public policy that will change us here, not only in Massachusetts, but throughout this country. So, I think that is exciting. I have to attend personally to over 14 events this weekend. I start tomorrow on the

Harbor Islands; we are kicking this off at the Harbor Islands. I end up at Harvard Forest in Petersham on Sunday. I am doing an event with The Nature Conservancy in Plymouth. I am up in Rowley at Maudsley State Park or out in the western part of the state, and all of the commissioners that work for me at Fish & Wildlife, MDC, DEM, Food & Agriculture, Department of Environmental Protection (DEP) at many events, and all of my senior staff, people like Peter Lewenberg who has just done a great job with the Boston Harbor Islands. My eyes and ears and my point person on the Boston Harbor Islands has just done a fantastic job of promoting this internally. We really have some great opportunities.

We are using every opportunity at my disposal to help provide these resources, more recently with Duke Energy and the gas pipeline. The have provided for $5.3 million infrastructure improvements at Peddocks and a continuing monitoring program on that pipeline so we can see if there is any adverse effect to the marine environment as well. So, these are great things. We have got tremendous opportunities with the Environmental Bond Bill. I think that the work that you did here today will help better inform our public policy decisions on the islands, and we look forward to working with you.

Abstracts of Poster Presentations

A Survey of Aquatic Invertebrates on the Boston Harbor Islands

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Aquatic invertebrates can be used as an indicator of water quality. A comprehensive survey of aquatic invertebrates was done on the Boston Harbor Islands national park. Most of the 34 islands are part of a glacial drumlin field stretching across the Boston Harbor. Smaller islands near the eastern edge of the harbor consist of rock outcrops.

Before going out into the field, aerial photographs, topographic maps, and previous records were consulted to determine where water might potentially be present. Islands with possible freshwater bodies were surveyed, and the salinity of any standing water found was measured with a refractometer. Water with a salinity of less than 5 ppt (parts per thousand) was sampled with a 0.5 mm net. Any invertebrates found were collected and fixed in the field, and taken back to the lab for identification.

Aquatic habitats could be assessed according to the diversity and types of organisms present. Ponds and marshes were healthier habitats overall, as indicated by higher diversity and more sensitive species of aquatic invertebrates. These habitats are found mainly on islands formed by drumlins. Tidal rock pools are found usually on islands consisting of rock outcrops. These are much less stable, more dynamic and are indicated by low diversity of organisms. The healthiest aquatic habitat, a small marsh in between two drumlins, was found on Grape Island. The island is relatively untouched and undisturbed in its history, factors which appear to have influences on habitat health. Most of the islands were highly disturbed, and all habitats were relatively poor. No state-listed species were found.

Avian Surveys in the Boston Harbor Islands: Preliminary Results

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During the 2001 field season, we conducted a series of pilot surveys to quantify avian community structure on 18 islands in Boston Harbor. Boat and transect surveys were used over 5 days from mid-May to mid-July. Fifty-nine species of birds were observed, with the greatest number of species detected on three islands within the inner harbor: Grape, Peddocks, and Spectacle. Peddocks Island, the largest in the harbor, supported more species than any other island. Observers in boats counted 1,344 Double-Crested Cormorant nests and 383 Herring Gull nests, with most located on rocky islands in the outer harbor. Other breeding waterbirds observed during the pilot study included Snowy Egrets, Black-Crowned Night Herons, Glossy Ibis, Great Black-Backed Gulls, and Canada Geese. In addition, 7 pairs of American Oystercatchers were detected on 6 different islands, and at least 30 pairs of Least Tern attempted to nest on Rainsford. The most startling finding was the large number of Common Eider chicks (>200 downy individuals <1 week old) seen off the outer islands, with most observed on the water near Calf Island. Previously there was only 1 record of 1 pair of eiders nesting on the outer islands in 1982. Thus, Boston Harbor now has the largest nesting congregation of Common Eiders in the southern-most portion of their range along the East Coast. During the 2002 field season, we will initiate a series of more intensive surveys designed to estimate densities of breeding birds on each of the islands.

Boston Harbor Botanical Surveys 2001

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In 2001, 26 islands in the Boston Harbor National Park Area were inventoried for vascular plant species. Approximately 490 species in 92 plant families were identified on these islands, including native and naturalized non-native plants. Of the species identified so far, 190 species (or 40%) are exotic plants. The islands with the largest number of species identified in 2001 are: Worlds End (274); Thompson (207); and Peddocks (204). Duration and type of human uses are the primary factors determining the composition of the flora on the islands. The outer islands are less diverse than those closer to the mainland. Species totals for the largest of the outer islands are: Calf (84), Great Brewster (76), Middle Brewster (31), and Outer Brewster (57). The lack of diversity on these islands is most likely attributable to exposure to wind and spray, resulting in slower recovery of habitats from past impacts.

Four plant species listed as endangered (E), threatened (T), special concern (SC), or watch list (WL) by the Massachusetts Natural Heritage and Endangered Species Program were documented on the islands in 2001. These species are: seaside angelica (Angelica lucida-WL, one population), Carolina crane's-bill (*Geranium carolinianum* var. *confertiflorum*-WL, one population), seabeach dock (*Rumex pallidus*-T, four populations), and showy goldenrod (*Solidago speciosa*-WL, one population).

In 2002, inventories and rare plant searches will continue on islands where last year's surveys are incomplete. Much of the 2002 field season will involve the classification of the islands' upland plant communities.

Developing Visitor Impact Indicators and Monitoring Procedures for Recreation Sites on the Boston Harbor Islands

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This poster presents first-year results from the visitor carrying capacity study - resource component. The study component aims at formulating visitor impact indicators, standards and monitoring procedures for the Boston Harbor Islands national park area in support of its Visitor Experience and Resource Protection (VERP) implementation. During the first year of this study visitor impact indicators were identified and monitoring procedures for selected indicators were developed and applied in the field. This poster illustrates monitoring results of different types of recreation sites, including camping sites, picnic sites and viewing/resting sites. The monitoring procedures involved documentation of location using global positioning system (GPS), application of a condition class rating system, and quantitative measurements of a series of visitor impact indicators. Twenty-two islands (and peninsulas) with known or potential recreation sites were investigated in the summer of 2001. A total of 139 official and unofficial recreation sites were identified and assessed. The results show that the majority of recreation sites were in good condition, though unofficial recreation sites tended to suffer more resource damage by visitors. The spatial patterns of recreation sites and their conditions are also illustrated in the poster.

Documenting the Recovery of Boston Harbor's Ecosystem

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Boston Harbor began to show signs of recovery from pollution years before the completion of new wastewater treatment facilities on Deer Island in 2001. In the decade since the Boston Harbor Project began, the harbor's water has become healthier for humans and the marine ecosystem. The most dramatic improvements were in bacteria levels throughout the harbor; most of the harbor now meets the most stringent bacterial water quality standards. In the sediments, the benthic community is recovering, with increases in both abundance and biodiversity. The rapidity of the some aspects of the harbor's recovery has been surprising: for example, average benthic biodiversity more than doubled by 1996, five years after sludge discharges ended. There is also encouraging news for contaminants in seafood species tested-flounder, lobster, and mussels. For the most part, contaminant levels in these species are well below U.S. Food and Drug Adminstration limits.

With the commissioning of the long ocean outfall on September 6, 2000, the Massachusetts Water Resources Authority ended discharges from the Deer Island treatment plant to Boston Harbor. In the year after discharges were ended, average nitrogen concentrations in the harbor water decreased 55%; phosphorus concentrations decreased 31%; chlorophyll, the green pigment in plants used to measure amounts of algae, decreased 49%; and water clarity measured as Secchi depth increased about 12%. More improvements-perhaps even seagrass beds will return-are anticipated for the future as the sediments continue to recover, and the harbor reverts to a natural seasonal cycle of nutrient levels.

Historical Aerial Photograph Analysis of Boston Harbor Island Shoreline Evolution

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The Boston Harbor Islands are the only coastal drumlin field found within the United States. Historical aerial photographs of selected islands were used to identify long-term sedimentation trends, providing a basic understanding of island geomorphology. All photographs were converted to digital format and georeferenced to the same coordinate system within a geographic information system (GIS), to facilitate data analysis and illustrate the extent of shoreline evolution on each island.

The natural processes responsible for reworking sediment comprising the islands include storms, wind-generated waves inside the harbor, tidal currents, and slope failure, all operating in a regime of accelerated sea-level rise. Erosional scarps and accretionary features such as beach dunes and tombolos found along the island shorelines are attributed to both natural and man-induced processes. Erosional trends related to wave energy, composition and geotechnical properties of slope sediment, overland flow, and the abundance or lack of vegetation in an exposed area. The driving processes behind sediment transport cells, which modify island morphology, are northeast storm waves, local wind-generated waves, and boat wakes.

Historical aerial photograph analysis along with fieldwork data documenting seasonal change serve as a foundation study of long-term evolution of island shorelines and are useful for defining future research on natural and human processes responsible for shoreline erosion. This information will be of value for planning of future park facilities as well as contributing to the preservation of important natural and cultural resources.

How many is too many? Social Carrying Capacity at Boston Harbor Islands, a National Park Area

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The enabling legislation for Boston Harbor Islands requires that park managers protect and maintain natural and scientific values of the islands, while at the same time, mandating that managers improve access to Boston Harbor Islands and enhance public outdoor recreation. It is projected that park visitation to the islands could double over the next few years and quadruple in the foreseeable future leading to impacts on park resources. Applied to parks, carrying capacity addresses the level and type of visitor use that can be accommodated without causing unacceptable impacts to natural/ cultural resources and the quality of the visitor experience. Contemporary carrying capacity frameworks, such as Visitor Experience and Resource Protection, emphasize the need to formulate indicators and standards of quality. Indicators of quality are measurable, manageable variables that define the quality of visitor experiences. Standards of quality define the minimum acceptable condition of indicator variables. This study reports findings from a multi-phased program of carrying capacity research at the islands. The study was conducted at seven publicly accessible islands over the summers of 2000 and 2001. In the first phase of research, surveys were administered to 695 visitors to identify indicators of the quality of visitor experience. In the second phase of research, surveys were administered to 724 visitors to help identify standards of quality for related indicator variables. Study findings will be used to help formulate a set of indicators and standards of quality for Boston Harbor Islands.

Inventory of Intertidal Resources of the Boston Harbor Islands, a National Park Area

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The Boston Harbor Islands, a new addition to the national park system, encompass about 60 km of shoreline more than 30 islands. In 2001, we carried out an intertidal natural resources inventory designed to develop an intertidal zone classification scheme for the islands, provide detailed intertidal habitat maps and summary statistics for 15 islands, compile species lists, and develop a list of potential management issues. The habitat maps were derived from field-based delineations using a global positioning system (GPS). Classifications were based on substrata and biotic communities. Mixed coarse sediment was the most common intertidal substratum in the islands. Mussel reefs were another frequently encountered substrate type, and *Mytilus edulis* was the most common biotic assemblage. Detrended Correspondence Analysis (DCA) showed a gradient in both substrata and biotic assemblages from the inner to outer islands with the outer islands more dominated by rocky intertidal assemblages. Ninety five species of animals, 70 marine algae, 15 vascular plants and three fungi were identified to the species level in the Boston Harbor Islands intertidal zone. Of the animals, 85 are native species, eight non-native, and two of unknown (cryptogenic) origin. Of the seaweeds, 66 are considered native and four non-native. The invasive species included the recent invasive crab, *Hemigrapsus sanguineus* but did not include *Codium fragile* ssp. *tomentosoides*. By comparing the lists from our survey to those of nearby locations, it is clear that more intertidal species will be found in the Boston Harbor Islands with continued observations.

Lichens of the Boston Harbor Islands

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A total of 60 species of bryophytes and 91 species of lichens have been recorded from the Boston Harbor Islands national park area. About 20% of the lichens represent a distinct maritime floristic element, and some of these (e.g., *Caloplaca verruculifera*) have not been documented in eastern Massachusetts before.

The numbers of species per island/area are less than areas of comparable size on the mainland.

For example, Peddocks Island (188 acres) has 52 lichen species, as compared with 99 recorded for Mt. Wachusett (130 acres). Also, islands farther from Boston have more species than those closer to Boston, probably as a result of lower air pollution levels. For example, Thompson Island, which is comparable in size (157 acres) to Peddocks but closer to Boston, has only about half the number of species (28). Also, smaller islands have lower species counts than larger ones; for example, Green Island (1.7 acres) has 5 species of lichens, while nearby Calf Island (17 acres) has 17 species.

The long history of human activity in the park has probably had an overall negative impact on the bryophyte and lichen diversity. However, some remarkable species persist, e.g. the lichen *Cetraria arenaria* and the moss *Fissidens exilis*. In addition, the human introduction of cement and imported stones may have actually helped to stabilize, or even increase, the diversity in certain areas. One such area on Spectacle Island may be useful for "seeding" other areas of the park, and because of this, it is one of four areas which we will recommend for protection.

Survey of Macrolepidoptera and other Insects within the Boston Harbor Islands National Park Area

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A total of 351 species of macrolepidoptera were identified on 11 islands within the Boston Harbor Islands National Park Area during 2001. Over half (214 species) were Noctuidae, followed in decreasing abundance by Geometridae (84), Notodontidae and Arctiidae (16 each), Sphingidae (8), Lasiocampidae (5), Lymantridae (3), Saturniidae and Thyatiridae (2 each), and Drepanidae (1). Lovell Island (34 species per trap night) was the most diverse, followed by Grape (25) and Worlds End (23).

Two listed species were encountered: *Abagrotis nefascia* (Noctuidae) on Lovell Island and *Spartiniphaga inops* (Noctuidae) at Worlds End. Both of these moths are listed as Special Concern in Massachusetts.

Eight non-native macrolepidoptera were documented within the Boston Harbor Islands during this study: *Idaea dimidiata* (Geometridae), *Chloroclystis rectangulata* (Geometridae), *Lymantria dispar* (Lymantridae), and the Noctuidae, *"Apamea" ophiogramma*, *Rhizedra lutosa*, *Calophasia lunula*, *Noctua pronuba*), and *Oligia strigilis*. The Boston Harbor records for *O. strigilis* are probably the first United States records.

Despite selective sampling, 112 species of microlepidoptera were documented at Boston Harbor Islands. A total of 37 species of butterflies were encountered during 2001 within Boston Harbor Islands. No state-listed species were encountered, and all but the Dusted Skipper (*Atrytonopsis hianna*) are common and widespread. Brian Cassie has observed butterflies at Worlds End from 1995-1999, recording 48 species, raising the total number of species recorded for Boston Harbor Islands to 50, which is also the total for Worlds End. The author encountered relatively few (11) species of Odonates, however another observer of a multi-species swarm at Worlds End on the evening of August 13 added an additional five species, including the state-listed *Anax longipes* (Special Concern).

On May 30, three Eastern Smooth Green Snakes (*Opheodrys vernalis*) and at least 10 Northern Brown Snakes (*Storeria dekayi*) were found under several wide boards (mostly plywood) on Peddocks Island.

Based upon results of long-term light trapping by the author at other sites, the 351 species recorded during this study probably represents a minimum of 50% of the total macrolepidopteran fauna present on the Boston Harbor Islands. Although this inventory provides significant information on the insect fauna, particularly

Lepidoptera, Odonata and tiger beetles, this study is merely the beginning of an understanding of the invertebrate ecology of the Boston Harbor Islands.

Reducing Muskrat (*Ondatra zibethicus*) Damage to Plants: An Integrated Pest Management Approach

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After clearing and grubbing, over 3.5 million cubic yards of Central Artery/Tunnel excavate was placed on Spectacle Island and its landfill capped. Permanent seeding began in 1995; planting was completed by early spring 2000. About 3,000 trees and more than 26,000 shrubs and vines were planted. Low turf & meadow grass mixtures were seeded as were mixes in shrub beds and around trees.

In autumn 1997 some muskrat damage to a small number of black cherry (*Prunus serotina*) was observed. Increasingly, woody plantings were damaged up to 18 inches (45 cm) above ground in the absence of snow, often in association with muskrat scat. Vole/rabbit signs, however, were not found. Shooting and an effort to live trap began in early 2000. Tree guard installation began in early 2001. This poster contrasts different types of trees as being more or less susceptible to muskrats: smooth vs. rough bark; deciduous vs. needle evergreen; few vs. many lower branches; single vs. multistem; larger vs. smaller caliper; and Rosaceae vs. other families, respectively. This approach can help managers identify present species needing tree guards and future species unlikely to be damaged. The integrated pest management (IPM) program is also illustrated. Muskrat is reported in the literature to exhibit food preferences, to have reduced marshes to mud in the North and South, and to alter succession. Muskrats can reduce biodiversity within the Boston Harbor islands.

Restoring Native Vegetation

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The native vegetation of the Boston Harbor Islands has been disturbed or destroyed by 350 years of intensive farming and public uses. We are attempting to restore small areas of the Boston Harbor Islands to its pre-European settlement vegetative state. These small woodland areas can act as showcases of native ecology for aesthetic, ecological and educational purposes. With proper management, it is possible that these areas could spread to cover larger portions of earmarked islands, thus becoming a more sustainable ecosystem. Planting sites currently exist on Bumpkin, Lovells, and Thompson islands.

Our source for native trees comes from seeds collected locally, thus insuring a hardy genotype that developed in symbiosis with our local ecosystem. The trees are raised in our volunteer-tended nursery located on Long Island.

In correlation with our tree growing and transplanting activities, we also conduct inventories of the tree cover existing currently on the islands. This allows us a greater understanding of the existing ecosystem and helps us determine best areas for the establishment of our native woodland sites. Data collection has been completed for Bumpkin, Gallops and Grape islands.

This project logged in 900 hours of volunteer time in 2001. We are always open to enthusiastic new volunteers.

Funding for our project for 2002 is provided by the Massachusetts Department of Environmental Management, the U.S. Department of Agriculture Forest Service, and the Volunteers and Friends of the Boston Harbor Islands, Inc.

Vegetation History of the Boston Harbor Islands

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The native vegetation of the Boston Harbor Islands has had a long history of manipulation and alteration. Review of historical documents and writings, as well as analysis of a sediment core from Calf Island help us understand the nature and extent of changes that have occurred. Although many of the islands had experienced American Indian encampments prior to the time of the arrival of European settlers in the 17th Century, at least some of the islands were forested when first seen by European explorers. The vegetation on the islands has changed with differing uses since that time. Fishermen, military units, recreational visitors, summer residents and farmers have altered the existing vegetation to suit their individual needs. When used by the military, the islands were often cleared for parade grounds and to prevent undetected invasion. Cottages used by summer residents may have been surrounded by non-native plantings and/or cleared of native brush. Agricultural activity included livestock grazing and clearing native vegetation for fields for planting and to produce better forage. As some of the islands were abandoned or used less intensively during the last century, some native species have reoccupied the land but invasive non-native species have also flourished. Comparisons of historical aerial photographs with current photographs indicate that some of the islands include more shrub and tree vegetation today than 60 years ago. The current vegetation (nearly 400 years after settlement of the islands by Europeans) includes a mixture of forests, shrub thickets, and grasslands as well as manicured landscapes.

Wetlands Inventory and Characterization for Boston Harbor Islands and Vicinity

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The U.S. Fish and Wildlife Service recently completed a wetlands inventory for the National Park Service's Boston Harbor Islands national recreation area. This work focused on mapping wetlands through aerial photointerpretation following National Wetlands Inventory (NWI) procedures and creating a digital database for geographic information system (GIS) applications. A series of 1:24,000 NWI maps have been prepared to show the type, shape, and distribution of wetlands in this area. The maps have been digitized to create a digital wetland inventory database. The wetland digital database was enhanced to include hydrogeomorphic-type descriptors for mapped wetlands. These attributes describe landscape position (the relationship between a wetland and a water body, if applicable), landform (shape of wetland - e.g., basin, floodplain, flat, fringe, island, or slope), and the water flow path (e.g., inflow, outflow, throughflow, or bidirectional flow). Combining the hydrogeomorphic-type descriptors with NWI features allowed the Service to produce a preliminary assessment of wetland functions for the study area. Among the functions evaluated were surface water detention, shoreline stabilization, nutrient transformation, fish and shellfish habitat, waterfowl and water bird habitat, and other wildlife habitat. A wetland characterization report will be prepared for the Boston Harbor Islands. The poster shows some of the preliminary findings of this inventory.

Managing for Biodiversity at Worlds End Reservation

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Community and species diversity at Worlds End Reservation contributes significantly to the overall biodiversity of the Boston Harbor Islands. Five priority natural community types and four rare species are found at Worlds End. Natural resource management will focus primarily on maintaining a mosaic of community types at Worlds End in order to protect its ecological integrity and regional significance. Several conservation targets were identified by The Trustees of the Reservations to achieve these management goals (Worlds End Management Plan, 2002), including restoring salt marsh in Damde Meadows, maintaining early successional habitats (e.g., grasslands and maritime juniper woodland/ shrubland), and preserving approximately 20 acres of mature oak-hickory forest that may represent the original community type at Worlds End.

Habitat and species diversity will be enhanced at Worlds End by restoring approximately 15 acres of salt marsh and other intertidal environments within Damde Meadows. Field surveys indicate limited species diversity within the existing brackish pond and *Phragmites*-dominated marsh. Tidal flows will be restored by installing two, 4 feet by 8 feet box culverts within existing stone dikes located near the Martin's Cove end of Damde Meadows.

Much of the biodiversity at Worlds End is supported by early successional landscapes that require regular disturbance to prevent encroachment by woody vegetation. Grasslands provide important habitat for grassland breeding birds, numerous moth and butterfly species, and the only extant population of showy goldenrod in the greater Boston area. Invasive plants, both woody and non-woody species, pose a significant threat to the ecological function of grasslands at Worlds End, as well as the Maritime Juniper Woodland/Shrubland community, a priority natural community that occurs along the margin of Rocky Neck. Active management of early successional habitats at Worlds End will be necessary to protect the function of these critical habitats. Alternatively, a "hands-off" approach to management may be appropriate within the mature oak-hickory forest due to the apparent absence of invasive plants.

A GIS Database of the Boston Harbor Islands Area

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The National Park Service has assembled a Geographic Information System (GIS) Database of the Boston Harbor Islands Area from numerous agencies and partners, including MassGIS. This database is to aid scientists, administrators, and decision makers in their efforts to better understand the island area. In addition, it ensures that cooperators working with the National Park Service have access to the same geographic datasets. Each of the cooperators is encouraged to contribute their data and documentation so that others may benefit from the data collection.

Example Geographic Datasets (GIS Data):

- Areas of Critical Environmental Concern
- GPS Data
- Channels
- Coastline
- Color Ortho Imagery
- Discharge Points
- Eel Grass Beds
- Elevation Data
- Environmental Sensitivity Index
- Ferry Routes
- Geology
- Intertidal Data
- Landuse / Landcover
- Moorings
- AutoCad Data
- NOAA Charts
- Panchromatic imagery
- Paths
- Roads
- Shellfish Areas
- Shellfish Stations
- Social Trails
- Soils
- Streams
- Structures
- USGS Bathymetry
- Vernal Pools
- Wetland Areas

In addition, Global Positioning System (GPS) technology was used as a tool to collect data and convert it so that it could be used with the GIS database. Examples of these data include:

- Built Water Features
- Flora Fauna Farm
- Memorials
- Piers
- Recreation Areas
- Paths, Social Trails
- Selected Built Features
- Unauthorized Recreation Use
- Waste Management

This poster depicts the status of the NPS GeographicInformation System (GIS) Database of the Boston Harbor Islands Area. Highlighted are some of the datasets included in the database.

Technical Details:
Coordinate system Information:
Projection: Universal Transverse Mercator
Zone: 19
Datum: North American Datum of 1983 (NAD83)
Units: Meters
Spheroid: Geodetic Reference System 1980 (GRS80)

Data Documentation:
Metadata: Federal Geographic Data Committee Compliant (FGDC)

Sea Grant
National Sea Grant College Program

BOSTON
HARBOR
ISLANDS

A national park area