

SUSTAINABLE SOLUTIONS FOR BIODIVERSITY LOSS ON CAPE COD

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Landscape Mosaics
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ABSTRACT

Cape Cod is part of a terminal moraine archipelago of the northeast United States. Cape Cod is a popular tourist and retirement destination; noted for its quaint shingled houses, villages, beaches and bays. Cape Cod's popularity brings the burdens of increasing human population, sprawl, and loss of open space, air and water pollution, and a decline in the quality of life. Sustainable green design, planning initiatives, environmental education, and stewardship offer solutions to the impacts of overdevelopment on Cape Cod.

Keywords: sustainability, biodiversity, Cape Cod, land use,



Figure 1: Cape Cod Satellite, NASA

Aerial photographs capture the pattern and coloration of the Cape Cod salt marsh, including images of inundation, barrier beach dissolution through storm damage and flooding of the salt marshes in an additive and subtractive process of water, wind and tide.

Landscape Mosaic:

Despite centuries of human intervention, Cape Cod continues to support a rich diversity of natural habitats within the mosaic of landscapes, including:

Coastal/Marine Ecosystems

Estuarine Shellfish Habitats, Salt Marshes, Coastal Salt Ponds, Anadromous Fish Runs

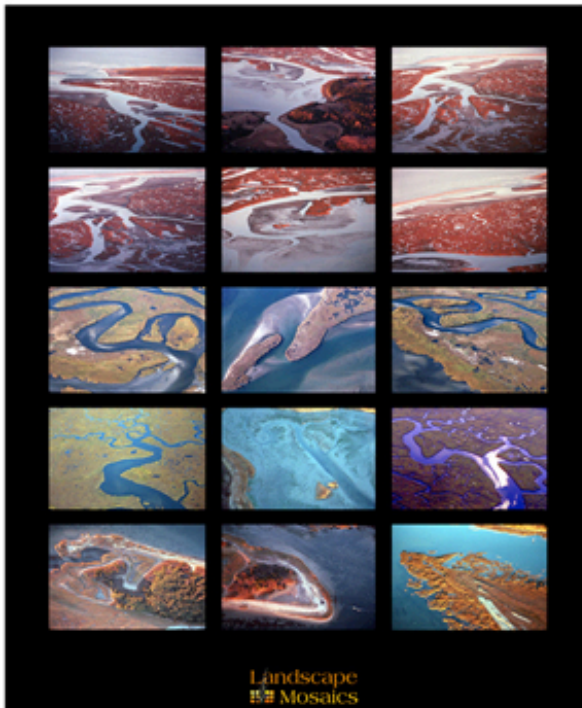


Figure 2: Cape Cod Salt Marsh Aerial, Joseph Ingoldsby



Figure 3: Cape Cod Salt Marsh, Joseph Ingoldsby

The Salt Marsh of an estuary is one of the most productive zones on earth. The mixing of the tidal and fresh waters and the input of nutrients feeds a host of species, which depend on it for food and cover. The salt marsh is tough yet fragile. It withstands extremes of temperature, freezing and thawing, saturation and drought. The plants of the salt marsh are uniquely adapted to life on the edge of the sea. Salt marshes (Fig 3) can be differentiated into distinct zones, which correspond to increasing elevation and decreasing durations of submergence.

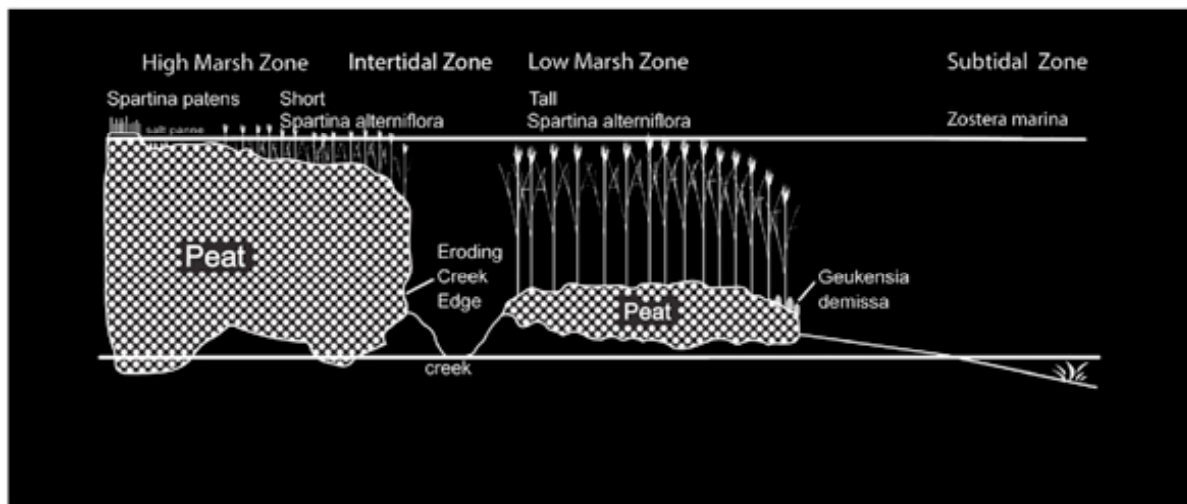


Figure 4: Schematic cross-sectional view of a salt marsh with creeks. (© Joseph E. Ingoldsby)

The lowest zone is vegetated by a variety of drifting or attached algae and eelgrass, **Zostera marina** of the **Sub-tidal Zone**. As Fig. 4 shows, a tall form of *Spartina alterniflora* may be found growing along the edges of channels, creek banks and ditches, marking a change of elevation. The next highest zone is the intertidal area from mean low tide to mean high tide. This is the **Low Marsh - *Spartina alterniflora* Zone**. *Spartina alterniflora* dominates the low marsh, where it forms dense, continuous stands. The Low Zone is generally submerged with each flood tide, depending on the degree of tidal exchange between the marsh and

coastal waters. *Spartina alterniflora* is uniquely adapted to this **Intertidal Zone**. These plants can pump oxygen from air passages on their leaves to air chambers in their hollow roots through diffusion. This allows the plants to respire and to extract nutrients by converting the iron sulfide in the anaerobic soils to iron oxide. The soil around the *Spartina* roots is often surrounded by rust red soils. *Spartina* exude excess salt from special glands on their leaves to preserve their osmotic pressure; *Spartina* stomata open at low tide and close during high tide [5].

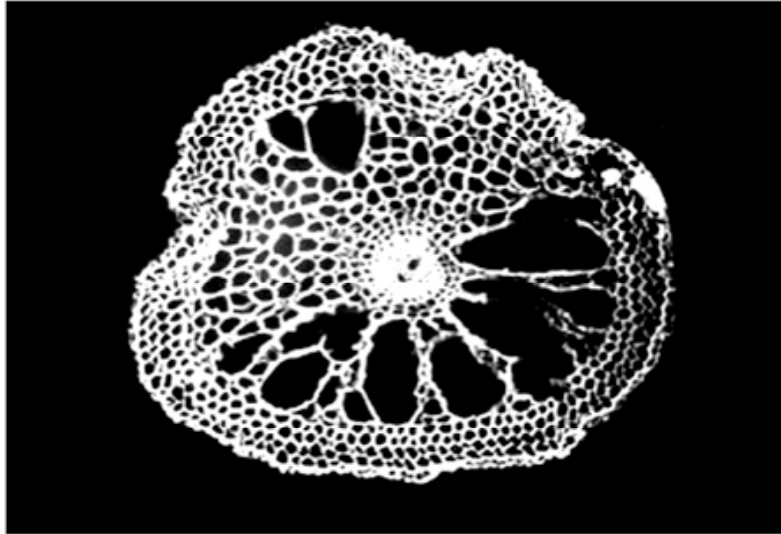


Figure 5: Cross-section of Aerenchymal tissue. (Photo © Irv Mendlessohn)

The Aerenchymal tissue (Fig5.) allows *Spartina* to exchange gases, even when surrounded by an anoxic soil. The tissue, illustrated in the Fig.5 photograph, is visible as a series of circular passageways around the periphery. Plants cannot use nutrients efficiently without oxygen, so this tissue allows a connection between the aerobic leaves and the stems, which are usually surrounded by anoxic water [6]. *Spartina alterniflora* can withstand submergence longer than most other plants of the salt marsh. However, extended continuous inundation will suffocate the *Spartina* plants, since they are unable to breathe under water. This phenomenon has been documented at Jamaica Bay, New York, where the tall form of *Spartina alterniflora* is drowning in a combination of sea level rise and lack of marsh accretion, reducing the low marsh to barren mudflats [7]. The **High Marsh Zone** is the uppermost zone of the salt marsh and is usually only centimeters higher than the Low Marsh. However, this elevation difference is enough to restrict the tidal intrusion to spring flood tides and storm tides. The lower edge of this zone may include the short form of *Spartina alterniflora* mixed with *Spartina patens*. *Spartina patens* (salt hay) dominates the High Marsh, where it mixes with other grasses, including *Distichlis spicata* (spike grass). *Juncus geraldii* (black rush), often indicating freshwater intrusion into the salt marsh, marks the next increase in elevation, with High Marsh forbs to the ***Iva frutescens* Zone**. In New England, the salt marsh is often framed by a forested terrestrial edge that demarcates the saltwater zones from the freshwater zone. Each zone's plant palette represents an adaptation to degrees of salinity, submersion and elevation [8].

Upland Ecosystems include: Barrier Beaches, Dune Systems, Critical Woodland, Pitch Pine/Scrub Oak Barrens, Sandplain Grasslands, Heathlands, and Grassy Heaths. Beyond the narrow ribbon of salt marsh, between land and sea, lies the sand plain and dunes of Cape Cod.



Figure 6: Barrier Beaches and Dune Systems

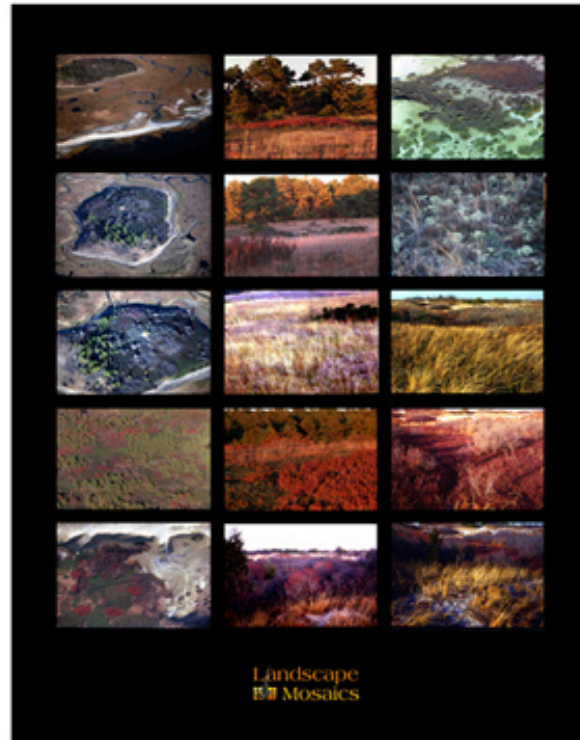


Figure 7: Pitch Pine / Scrub Oak Barrens and Sand Plain Grasslands

Coastal dunes are a landscape of unconsolidated sand, blown from barrier beaches and the seaward shore. If the salt marsh is a landscape of water and the sand plain is a landscape of fire then the coastal dunes are a landscape of wind. The sand is held in place by an extensive carpet of American beachgrass (*Ammophila breviligulata*). *Ammophila* is uniquely adapted to colonize and stabilize the shifting sands of the dunes by being able to send chutes upwards of six feet through blowing sands. Beach heather (*Hudsonia* species) and bearberry (*Arctostaphylos uva ursi*) are sub-shrubs that grow in the stable and sheltered dunes of the North Atlantic coast. As stabilization of the dune proceeds; shrubs, vines and trees grow in succession. Plants include: bayberry, rose and juniper, poison ivy, grape and green brier. Life is tenuous in the coastal dunes with wind and waves able to blow out and wash away plants from the shifting sands with every storm. Over the years I have documented the additive and subtractive process of the coastline and the coastal dunes particularly evident in the parabolic dune formations at the tip of Cape Cod and the restorative dune work within the Cape Cod National Seashore.

The Sand Plain is a landscape of fire. The soils are dry and porous; the plants are those, which can survive fire and drought. Some, as the pitch pine, are dependant on fire to open their cones to germinate; others survive the droughts and fires as black oak, bearberry, sweet fern, cladonia and andropogon grasses, which can resprout and are deep rooted. The plant palette like the salt marsh has adapted over time to survive the harsh conditions of the sand plain.

Freshwater Ecosystems

Quaking Bogs, Sphagnum Bogs, Cedar Swamps, Coastal Plain Ponds

Development Impacts:

This archipelago of sand is continuously reshaped by the forces of nature in an additive and subtractive process of wind and waves and is particularly vulnerable to overdevelopment of its open space and finite aquifers. Each natural habitat is threatened by development, pollution and overuse. Cape Cod has reached the tipping point. The five main pressures driving biodiversity loss are: habitat change, over-exploitation, pollution, invasive alien species and climate change.

Habitat change: There has been a tripling of the Cape's population since the late 1960s on ¼ of Cape Cod's open space land area. Population increases, development pressures, landscape fragmentation and overuse of coastal landscapes impact Cape Cod's habitats and biodiversity.

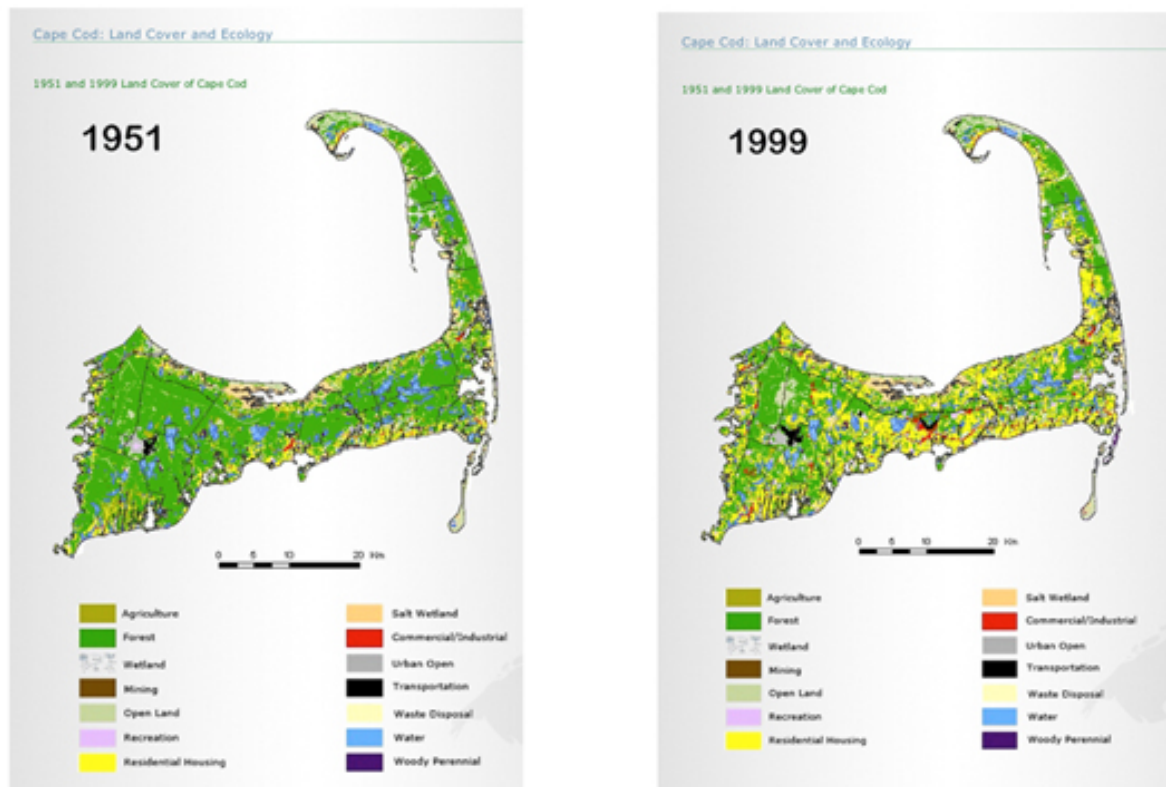


Figure 8-9: Losing Cape Cod- 1951, 1999, Stone, T.A. 1999, Losing Cape Cod, Woods Hole Research Center, Falmouth, MA

Overexploitation: 85% of Cape Cod's oyster reefs are gone from over-harvesting and degradation. Fishery closures are seasonally regulated to allow the populations to rebuild. Development and tourism affects migratory and native species. Over-harvest of natural resources, including clear cutting of forest, and unregulated fishing, historic grazing pressures, overpopulation reduce the biodiversity of Cape Cod.

Pollution: Drinking water quality degradation, estuarine water degradation, military base runoff, septic system wastewater threaten the health of Cape Cod's waters. As increasing numbers of people occupy coastal watersheds, the associated coastal waters receive increasing pollutant loads. Coastal embayments throughout the Commonwealth of Massachusetts and along the U.S. eastern seaboard are becoming nutrient enriched. The elevated nutrients levels are primarily related to the land use impacts associated with the increasing population within the coastal zone over the past half-century. The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities. The primary nutrient causing the increasing impairment of our coastal embayments is nitrogen, with its primary sources being wastewater disposal, and non-point source runoff that carries nitrogen (e.g. fertilizers) from a range of other sources. Nitrogen related water quality decline represents one of the most serious threats to the ecological health of the near-shore coastal waters. Coastal embayments, because of their shallow nature and large shoreline area, are generally the first coastal systems to show the effect of nutrient pollution from terrestrial sources.

Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine Critical

Invasive alien species: Foreign ship bilge algae multiply within the nitrogen rich bays. The southern Sesarma crab denudes the salt marsh grasses along the shore.

Climate change: Sea level rise- *Spartina patens* high marsh tidal inundation causes salt marsh dieback. Warming ocean temperatures shift coldwater species north as lobsters, menhaden and smelt, altering the Atlantic fishery and the cultural history. Conversely, southerly species expand their range northward creating a broken trophic cascade.



Fig. 10: Salt Marsh Dieback-Broken Tropic Cascade © Joseph E. Ingoldsby

Biodiversity Loss:

That narrow ribbon of marsh between land and sea is dying. What is killing the salt marsh is still not fully known. The stress of climate change, sea level rise, warming trends, drought and salinity change, together with coastal development, pollution and a constricted growing area often lead to the development of stress-related pathogens and opportunistic predation, which infect, attack and kill the salt marsh grass [9]. The *Spartina* marsh is stripped bare, leaving the hollowed out memory of the marsh grass roots, which erode with each high tide as the rising tides move steadily inland, inundating the High Marsh. *Spartina patens* and *Distichilis spicata* of the High Marsh cannot adapt or migrate quickly enough to counter the effects of sea level rise, and so the High Marsh of Cape Cod is slowly drowning [10]. Climate change also affects species composition. There is scientific documentation that the southern *Sesarma* crab has established a beachhead at Wellfleet Bay, Massachusetts, where the crab is eating the low marsh *Spartina alterniflora* to bare mud, slowly stunting and killing the marsh grasses [11]. The trophic cascade of predator and prey

is out of balance. Salt marsh dieback is not a local problem. Scientists report salt marsh dieback from Maine to Louisiana. The end result is a loss of coastal protection, habitat, estuarine landscape and sustainable fishery.

Sustainable Solutions:

We need a new vision of biological diversity for a healthy planet and a sustainable future for humankind to Restore the Lands, Protect the Seas, and Inform the Earth's Stewards.

Science Based Planning Case Studies:

Association for the Preservation of Cape Cod

APCC is one of the region's leading nonprofit environmental organization working for the adoption of laws, policies and programs that protect and enhance Cape Cod's natural resources and quality of life. These include protecting water quality, restoring salt marshes, supporting local agriculture, revitalizing town centers, documenting and conserving critical habitat, and preserving Cape Cod's cultural heritage.

In 2008, APCC spearheaded an advocacy effort that in 2009 helped to secure Congressional authorization of the Cape Cod Water Resources Project, which was proposed as a 10-year, \$30 million program with \$24 million coming from the federal government and \$6 million from non-federal funds.

The Cape Cod Water Resources Restoration Project is a landmark initiative that is the largest water restoration project ever proposed for Cape Cod. The 76 individual projects within the larger watershed project will result in the restoration of 7,300 acres of shellfish beds through storm water remediation, 4,200 acres of migratory fish runs that include runs for river herring and American eel, and 1,500 acres of degraded salt marshes - all of which are critical to the economic vitality and ecological health of the region. In 2010, the project received start-up money from the American Recovery and Reinvestment Act, which enabled work on the first round of projects to commence.

Woods Hole Research Center, (WHRC)

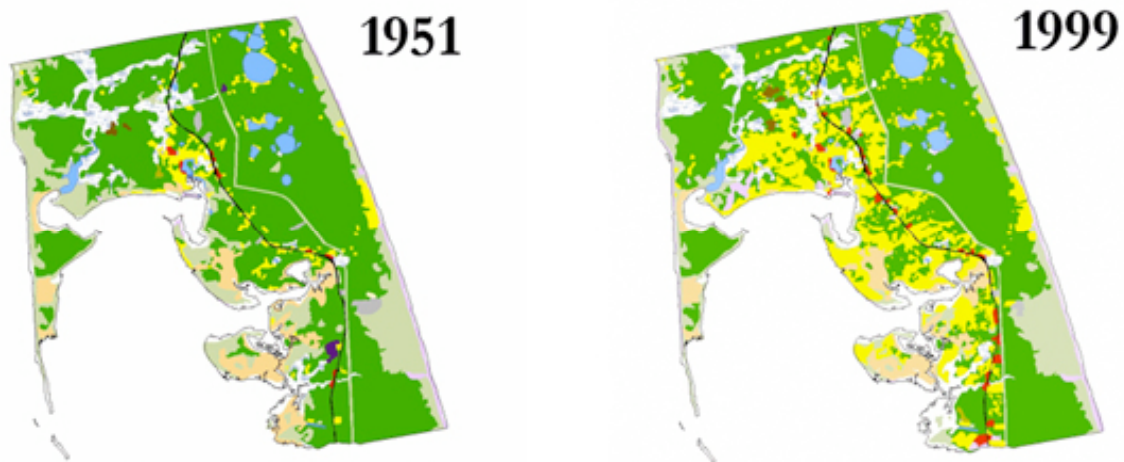


Figure 11, 12: Losing Cape Cod- Wellfleet 1951, 1999, Stone, T.A., Woods Hole Research Center, Falmouth, MA

Losing Cape Cod:

Woods Hole Research Center scientists study the environment of Cape Cod not only because it is a combination of ecosystems unique in the New England region but also because it is changing rapidly - more rapidly than any other region in New England. The Cape is changing from a farming and fishing economy with seasonal visitors to a tourist center with larger, year-round population that builds bigger and more homes on what remains of open space. Sprawl is here, fueled by demographic forces, weaknesses in zoning, and lack of vision. The project tracks land use and land cover change from 1950 using aerial photography and GIS

mapping. The graphics contrasting Cape Cod in 1950 with Cape Cod in 1990 depict a built out landscape with overpopulation, inadequate infrastructure, declining water quality and estuarine decline [12]. Today, Cape Cod is attempting to come to grips with the economic building boom of the 1990's.

Cape Cod Planning Commission

The Planning department of the Cape Cod Commission prepares and implements the **Cape Cod Regional Policy Plan (RPP)**, which establishes broad goals and specific standards for the future development of Cape Cod. The department also helps communities pursue their Local Comprehensive Plans (LCPs) and supports local and county decision makers as they pursue the establishment of specially protected areas known as Districts of Critical Planning Concern (DCPCs). The Planning department also provides a variety of specialized planning services and technical assistance to Cape Cod towns and citizens. The Cape Cod Planning Commission has created design guidelines for Cape Cod, comprehensive economic development strategy, and has coordinated with stakeholders on watershed planning for wastewater treatment, infrastructure and green energy development.

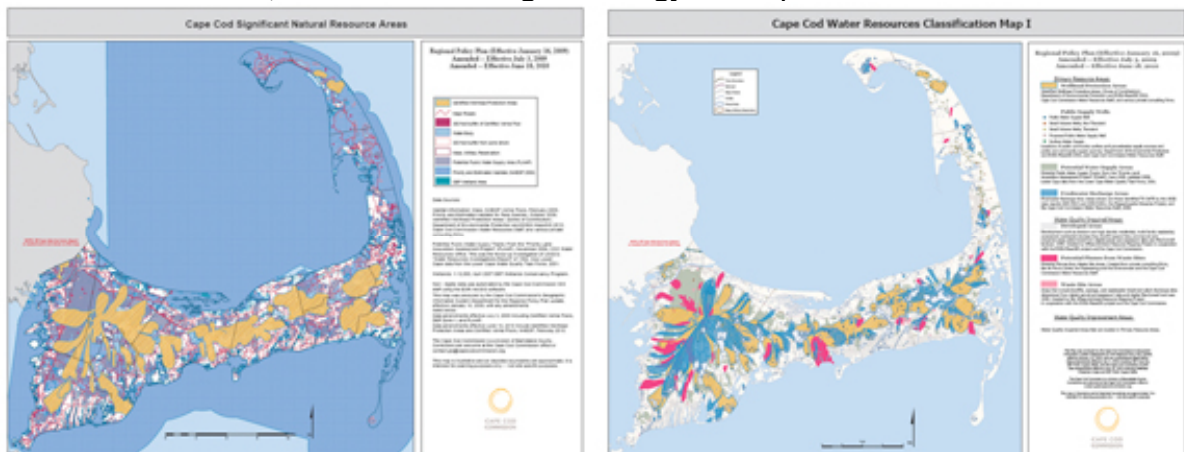


Figure 13: Cape Cod Significant Resource Areas, Cape Cod Commission

Figure 14: Cape Cod Water Resources Classification Map I, Cape Cod Commission

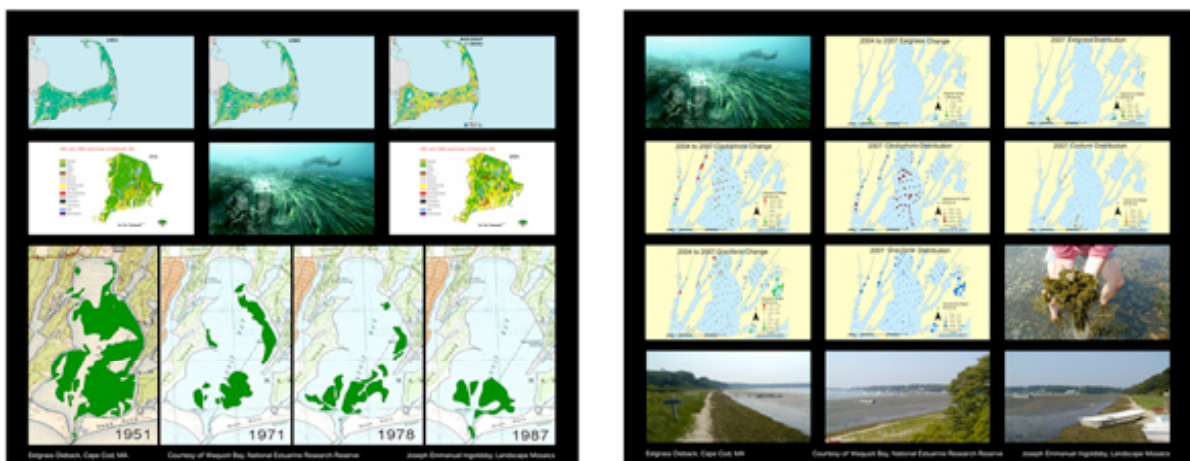


Figure 15: Losing Cape Cod, Stone, T.A., WHRC; Costa, Joseph- Eelgrass Mapping,

Figure 16: Waquoit Bay, Costa, Joseph; Potter, Morgan, DCR, Waquoit Bay Reserve Mass DEP Wetlands Conservancy- Cape Cod Eelgrass Mapping; Joseph E. Ingoldsby

ABOUT THE MASSACHUSETTS ESTUARIES PROJECT

GENERAL INFORMATION

[VIEW ESTUARY PRIORITIZATION LIST](#) | [VIEW ADDITIONAL PROJECT DOCUMENTS](#)

WHAT ARE ESTUARIES?



Estuaries are special bodies of water occurring when the sea extends inland and meets the mouth of a river or streams. The estuaries of Southeastern Massachusetts - the harbors and bays of Cape Cod, Buzzards Bay and the Islands - are ecosystems that provide home and habitat for shellfish and sea grasses and breeding grounds for important commercial offshore marine fisheries. Rapid population growth over several decades has created an abundance of nutrients that have leached into the estuaries through ground and surface waters. Nutrients, such as phosphorus and nitrogen, act as a fertilizer to aquatic plants. The result: changes in water quality and the buildup of invasive weed and algal growth causing fish kills, closed beaches, destroyed productive shellfish areas and creating aesthetically displeasing waters that adversely affect the valuable tourist industry and coastal property values.

WHAT IS THE MASSACHUSETTS ESTUARIES PROGRAM?

The Massachusetts Estuaries Project effort will begin to fix this problem by determining all of the factors specific to each estuary that are causing the problem. Project partners will determine the geographic area contributing nutrients to a specific estuary, determine what the nutrient sources are, what the nutrient load is, and how great a nutrient load the estuaries can tolerate without dramatically changing their character and usages. In most cases, returning the estuaries to the water quality condition that support sensitive shellfish habitats and lush eel grass beds, it will be necessary to remove a significant percentage of the nutrient loadings coming from an estuary's watershed. Nutrient removal may come primarily in the form wastewater treatment and secondarily through storm water management programs including of limited use of lawn fertilizers. In some scenarios, changing the water flow within an estuary to increase flushing may compliment nutrient reduction and removal efforts.



This project will provide water quality, nutrient loading, and hydrodynamic information for 89 estuaries in Southeastern Massachusetts. This information will be combined through the use of a linked watershed/estuary model that will predict the water quality changes that will result from land use management decisions. Over the next six years a report for each of the 89 estuaries will evaluate several water quality conditions and how that relates to the health of the estuary and the land use changes necessary to bring about that improvement. This project is a collaborative effort by two state agencies, the Executive Office of Environmental Affairs (through the Department of Environmental Protection) and the University of Massachusetts's School of Marine Science and Technology and is subsidized by funding that allows communities to undertake this evaluation at approximately 40 percent of the actual cost.

Figure 17: About the Massachusetts Estuaries Project

Friends of Herring River- Herring River Restoration

Historical Overview of Alterations to the Herring River System

The reconnection and gradual incremental increase in tidal exchange between the Herring River estuary and Wellfleet Harbor is the primary proposed process for tidal restoration envisioned for the Herring River floodplain and its adjoining tributary stream basins. Increased tidal exchange will result in several important beneficial changes to the Herring River's estuarine characteristics and floodplain features, which include improvements to water and sediment quality, coastal wetland habitats, and fisheries and shellfish habitat.

The restoration project comprises the following objectives:



Herring River Restoration Narrative

- Restoration of the natural tidal range and salinity throughout the floodplain including all tributary stream basins.
- Reestablishment of the physical connection with the marine environment for exchange of sediment, nutrients, organic matter, and biota.
- Restoration of a natural sediment budget to counter wetland subsidence and sea level rise.
- Improvement of water quality realized by increased salinity, alkalinity, and pH, and decreased metals and coliform bacteria.
- Elimination of salt-intolerant plants including non-native species, especially common reed (*Phragmites australis*).
- Reestablishment of native salt marsh plants and animals.
- Improvement of estuarine finfish and shellfish habitats and physical access to those habitats.
- Improvement in the natural control of mosquitoes and other nuisance insects.
- Improvement of recreational access: boating, finfishing, shellfishing, bird-watching, etc.

Environmental Education Programs:

Upper Cape Cod Regional Technical School - Green technologies, aquaculture

Cape Cod County Commission-Sustainable aquaculture and agriculture, CSA, CSF

Mass Audubon Wellfleet Bay Wildlife Sanctuary - Mass Audubon's vision connects people and nature through a holistic approach of policy, green LEED Platinum sanctuary development, stewardship, and public environmental education

Marine Biological Laboratory, (MBL)

The Marine Biological Laboratory (MBL) is an international nonprofit center for research, education, and training in biology. The oldest private marine laboratory in the country, the MBL currently supports a year-round staff of more than 275 scientists and support staff working in such fields as cell and developmental biology, ecology, microbiology, molecular evolution, global infectious disease, neurobiology, and sensory physiology. Each summer, an additional 1400 scientists and advanced students from around the world come to the MBL to study the diverse and abundant marine organisms found in local waters. The laboratory's educational program, which consists of six major summer courses and approximately one dozen special topics courses throughout the year, plays a significant role in training the world's experimental biologists.



Figure 19: Woods Hole Consortium, Aerial © Woods Hole Oceanographic Institution, 2009

Woods Hole Oceanographic Institution, (WHOI)

The Woods Hole Oceanographic Institution is a private, independent, not-for-profit corporation dedicated to research and higher education at the frontiers of ocean science for the benefit of society. Research staff at WHOI, belong to one of five research departments: Applied Ocean Physics and Engineering, Biology, Geology and Geophysics, Marine Chemistry and Geo-chemistry, and Physical Oceanography. In 2000, WHOI established four Ocean Institutes encompassing areas of significant concern to the public and policymakers: Coastal Ocean Institute, Deep Ocean Exploration Institute, Ocean and Climate Change Institute and the Ocean Life Institute.

Woods Hole Research Center, (WHRC)

The Woods Hole Research Center addresses global environmental problems related to climate change, land-use changes in tropical and boreal forests, and the health of the planet with research, fieldwork within the cultural communities.

Woods Hole Consortium:

In 2009, the Woods Hole Consortium was created including the Marine Biological Laboratory, Woods Hole Oceanographic Institution and the Woods Hole Research Center. This new alliance will bring their combined scientific power to bear on some of the major issues facing society today and spawn scientific growth and job opportunity on Cape Cod.

Sustainable Technologies:



Figure 20: Cape Wind

Cape Wind Project:

U.S. Secretary of the Interior Ken Salazar and developers of the nation's first offshore wind farm signed a 28-year lease last month launching the \$1 billion, 130-turbine Cape Wind project off the Massachusetts coast, following an nine-year federal review. The 25-square mile Cape Wind project faced intense opposition from two Indian tribes and some environmentalists and residents, who argue the project could raise electricity prices for local residents because of the cost of electrical grid and transmission line improvements, threatens marine life as well as maritime traffic and industry. Salazar called the Cape Wind lease "historic," but he said a more efficient permitting process is needed to fully harness potentially vast economic and energy benefits of wind power off the Atlantic Coast. The Cape Cod Wind project will create an average of 182 megawatts of clean energy representing 75% of Cape Cod's current energy needs. Salazar said, "These are areas with high wind potential and with fewer potential conflicts with competing uses," He said. "If we are wise with our planning, we can help build a robust and environmentally responsible offshore renewable energy program that creates jobs here at home."

Todd Ecological Design –Ocean Arks International Case Studies:

Ecological Design adapts knowledge from Nature and applies it to human problem, to the treatment of waste, to the growing of foods, to the production of fuel, and to the restoration of landscapes. Inventions include fresh water Living Machines and saline water Ocean Ark Restorers, which purify polluted water through increasingly complex ecosystems using biological engineering and green technologies. Installations are located around the globe.



Figure 21: John Todd Ecological Design

Conclusion:

After decades of biodiversity loss, Cape Cod has instituted a number of programs to repair and restore the landscapes and waters of Cape Cod. Science is now an integral part of the planning for the future of Cape Cod. An environmental education transformation has initiated watershed planning, estuary projects where eelgrass and benthic species are used as indicators of the systems health. Alternatives are being sought for septic systems, which have nitrified the estuaries and turned them into dead zones. Most municipalities in southeastern Massachusetts and Cape Cod are exploring approaches to better managing sanitary wastewater. Municipalities are seeking guidance about how to assess the quality of an embayment and how to institute the land based changes necessary to control sources of nitrogen and restore impaired water quality conditions. Drinking water is finite on Cape Cod. An aggressive land acquisition program has targeted critical aquifer lands for protection against further contamination. Smart Growth is being promoted through the Cape Cod Planning Commission and the Woods Hole Consortium. This would direct growth to developed areas and protect critical habitat lands. Sustainable farming and fishing are being practiced and CSAs and CSFs are supplying organic and sustainable produce directly to the townspeople. New green technology is being developed and installed on Cape Cod, including

the Cape Wind Project. Biomedical and marine engineering advances are being developed within the Science Village of Woods Hole that speaks to a sustainable future for Cape Cod.

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