

**Climate Change: Science, education and  
stewardship for tomorrow's estuaries**



**National Estuarine Research Reserve System  
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The National Estuarine Research Reserve System is administered by NOAA's National Ocean Service, Office of Ocean and Coastal Resource Management, Estuarine Reserves Division. For more information, visit us online at [www.nerrs.noaa.gov](http://www.nerrs.noaa.gov) or contact us at: 1305 East-West Highway N/ORM5, Silver Spring, Maryland 20910. Phone number: 301-713-3155

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## Introduction

Climate change is a fact for our times. Among scientists, only the degree and timing of impacts remains uncertain. There is no question that the Earth as a whole is warming more rapidly than has been recorded in geologic history and that this warming has and will continue to produce significant environmental effects in most parts of the planet. The Intergovernmental Panel on Climate Change (IPCC), representing over 1,500 scientists from 60 countries, is in agreement that some portion of this warming trend is due to human activities.<sup>1</sup> The IPCC was established by the World Meteorological Organization and the United Nations Environmental Program to assess scientific, technical and socio-economic information pertinent to understanding climate change, its potential impacts and options for adaptation and mitigation. One of the world's leading scientific journals, *Science*, reviewed all credible articles on climate change published between 1993 and 2003; none took issue with the consensus in the science community that humans are contributing to climate change. Due to this respected evidence, it is incumbent on scientists and coastal managers to use their skills to measure the impacts of climate change and inform coastal decision-makers in order to facilitate adaptation, develop mitigation plans and educate the public.

The National Estuarine Research Reserve System will be a key part of this effort.<sup>2</sup> As part of a coastal place-based network, reserves and the communities they serve will be significantly affected by climate change. Because the impacts are so dramatically evident in coastal regions, the reserve system serves an important function as an indicator of climate change and a venue for research, education, and training activities that can inform the public and decision-makers. The reserve system has identified several major probable climate change impacts to reserve ecosystems, including changes in sea-level, salt marsh extent and community structure, range extension of invasive species, storm frequency and severity, shoreline erosion and migration, hydrology, and water quantity and quality.

The reserve system is composed of 27 sites representing different biogeographic regions of the United States and implements effective programs in research, education, training, and stewardship that address the challenges posed by climate change. The reserve system has been monitoring weather and water quality for more than 10 years and provides the ideal platform for evaluating climate change. Scientists supported by the National Oceanic and Atmospheric Administration (NOAA) are working in the reserve system to observe first hand the effects of climate change on coastal habitats and communities. The Coastal Training Program engages coastal managers and policy makers through science-based training programs and technical support as they struggle to adapt to the impacts of changing sea levels and coastal hazards. Likewise, K-12 education and teacher training programs aim to produce a generation of young people with strong understanding of coastal processes and issues. Reserve programs are currently addressing many aspects of climate change and are poised to educate target audiences about climate change processes.

A key strength of the reserve system is partnerships. The reserve system is a partnership program between NOAA and the coastal states. Each reserve is managed on a daily basis by a lead state agency or university, with input from local and regional partners, ensuring the widespread exchange of information, knowledge and resources. The regional focus and local management of

the reserve system are strong assets in the development of specific adaptation, mitigation and education plans that address local and regional climate change effects. As the federal partner in this system, NOAA ensures the development and strength of multiple supporting partnerships throughout the agency, including the Climate Program Office, the National Centers for Coastal Ocean Science, the Coastal Services Center, the Center for Operational Oceanographic Products and Services, Sea Grant, National Marine Sanctuaries, as well as the Office of Ocean and Coastal Resource Management's Coastal Zone Management program, Marine Protected Areas program, and Coral Reef Conservation program. NOAA will also facilitate partnerships with other federal agencies such as EPA, USGS and USFWS. Furthermore, through the "seamless network," the reserves are coordinating with National Marine Sanctuaries, National Wildlife Refuges and the National Parks to conserve sensitive coastal and marine resources and ecosystems by identifying where existing synergies and avoiding duplication. In addition to federal partners, a host of state and local partners will be important for addressing climate change. These include universities, state task forces, and non-profits such as The Nature Conservancy, Union of Concerned Scientists, Coastal Conservation Association, and various energy coalitions.

An additional strength of the reserve system is the collaborative nature of programs, where research, monitoring, education, stewardship and training programs build on each other's efforts. Reserve education, stewardship and coastal training program staff facilitate information about monitoring and research priorities of coastal managers to the research staff to enhance the relevance of reserve system research. In turn, the reserves translate research information for coastal-decision makers via the Coastal Training Program, for students via the K-12 education program, and for visitors and adult public through adult outreach programs for a broad spectrum of individuals. Multiple sectors or programs working together collaboratively often meet the reserves' short and long-term goals and objectives. Many of the activities described in this paper are best accomplished via collaboration of multiple reserve programs. For example, habitat monitoring efforts will be more robust with assistance from: community education and Coastal Training Program activities such as training of volunteers to assist in surveys; stewardship program coordination of restoration projects, either active or as reference sites; and education program activities aimed to communicate the results of expanded monitoring efforts to the public and policy makers.

This paper outlines the capabilities and strengths of the reserve system, as well as potential short and long-term activities, to address climate change in critical coastal areas. Short-term activities are those that can occur with current funding and within the next five years. Long-term activities are those that are planned for implementation in five or more years with current and/or additional funds. While the issue is urgent and well-understood, the reserve system must also be flexible to address future needs and opportunities. The three goals of the National Estuarine Research Reserves System, which reflect the three IPCC themes, are:

- 1) Contribute to scientific understanding of climate change and monitor ecosystem changes.
- 2) Assess climate change impacts on human and estuarine ecosystem communities, vulnerability of these communities, and their capacity for adaptation and mitigation.
- 3) Provide educational opportunities and training related to effects of climate change on human and estuarine systems to increase public awareness and foster behavior change.

Goal I: National Estuarine Research Reserves will contribute to scientific understanding of climate change and monitor ecosystem changes.

## **Background**

The reserve system currently contributes and will have additional capabilities to enhance its contribution to our understanding of the physical basis for climate change and the effects of such change on coastal ecosystems and natural communities. This section discusses activities relevant to climate change within the context of the goals and objectives of the National Estuarine Research Reserve System (NERRS) Strategic Plan<sup>3</sup> and steps toward establishing a national research effort that complements the national monitoring effort embodied in the System-Wide Monitoring Program (SWMP) Plan.<sup>4</sup>

## **Objectives**

### ***I. Enhance Scientific Understanding of Climate Change***

Understanding the global carbon budget and identifying sources and sinks of carbon dioxide is integral to understanding and accurately predicting global climate change. As underscored in the latest IPCC report, predictions of short and long-term change depend on increasing our understanding of carbon cycle feedbacks associated with climate change and incorporating that information into climate models.<sup>1</sup> Reserves are located in some of the most productive ecosystems on Earth and thus can serve as excellent locales for studying the carbon balance in coastal environments.

### **Ongoing and short-term activities**

The System-Wide Monitoring Program demonstrates short-term variability and long-term change in key data parameters relating to climate change.

- Specific SWMP datasets can inform modeling efforts, and can be coupled with surface elevation table (SET) data and other local or regional data to increase understanding of changes in dynamic estuarine systems.

### **Long-term activities**

Specific research activities include assessing:

- Effects of atmospheric CO<sub>2</sub> enrichment on estuarine primary productivity;
- Impact of increasing temperature on community respiration;
- Role of sediment transport in carbon sequestration;
- Effects of changing hydrology on sediment transport;
- Effects of changing atmospheric deposition of nutrients on primary productivity;
- Effects of sea level change on the composition, extent, and productivity of submerged and emergent vegetation; and
- Effects of changing land cover/land use on radiative absorption.

The reserve system is also taking steps to incorporate the products and data resulting from these activities into new and existing forecasting and modeling efforts. All such research activities align directly with all the objectives listed under Goal 2 of the NERRS Strategic Plan which is to “increase the use of reserve science and sites to address priority coastal management issues.”<sup>3</sup>

## ***II. Monitor Ecosystem Changes***

The System-wide Monitoring Program’s current operational status is already sufficiently robust to contribute actively to the monitoring of changes in physical parameters such as salt wedge extent, precipitation, mean water temperature, and in some cases, sea level change. As the reserve system implements Phases II and III of SWMP, biological monitoring and habitat mapping and change analyses respectively, reserves enhance their capacity to serve as a network of sentinel sites for the purpose of monitoring current and future ecosystem shifts induced by climate change, as well as serve as reference sites for restoration projects occurring adjacent to reserves.<sup>4</sup> Intertidal and emergent habitat maps are being created for all reserves and can provide a baseline for monitoring future climate change induced habitat changes.

### **Ongoing/Short-term activities**

- Expand and geo-reference reserve system network of SETs thereby increasing the ability to monitor changes in sea level.
- Obtain and classify high resolution habitat imagery for all reserves.
- Establish timetable and commitments for repeated image collection and change analyses of medium and high resolution habitat imagery.
- Use reserves as restoration reference sites in partnership with NOAA’s National Marine Fisheries Service Office of Habitat Restoration. Currently five reserves are enhancing their monitoring activities to serve as reference sites for the Office of Habitat Restoration.
- Include reserve data in harmful algal bloom forecast models through partnerships with the NOAA’s National Centers for Coastal and Ocean Science (NCCOS).
- Expand the number of reserves with vertically-controlled tide gauges through partnership with NOAA’s Center for Operational Oceanographic Products and Services.

### **Long-term activities**

- Expand SWMP Phase II biological monitoring efforts to include tracking of invasive species.
- Expand SWMP Phase III monitoring to include estimates of changes in ecosystem productivity.
- Expand hydrological monitoring and mapping efforts within reserves, as well as Geographic Information Systems (GIS) mapping capability throughout the system. This could include the development of Digital Elevation Maps for each reserve which would be tied to the National Spatial Reference System.
- Develop more intensive harmful algal bloom monitoring efforts in partnership with NCCOS or other offices.

## **Needs**

In order to accomplish some of the activities above, the reserve system will need access to high resolution Light Detection and Ranging (LIDAR) data from remote sensing systems. Reserves will also need habitat classification maps at a finer spatial scale than current maps, which depict

30 meter resolution, to better detect habitat changes. Additionally, SWMP monitoring stations will need to be incorporated into the National Spatial Reference System and local tidal datums. Note: Needs identified here are preliminary and not comprehensive in nature. Additional human and fiscal resources will be needed to carry out many of the activities noted within this document.

Goal II: National Estuarine Research Reserves will assess climate change impacts on human and estuarine ecosystem communities, vulnerability of these communities, and their capacity for adaptation and mitigation.

## **Background**

As a result of climate change, coastal areas are expected to suffer from increased erosion, sea-level change, and storm frequency and intensity. Human development on the coasts will exacerbate these impacts. In its reports, IPCC Working Group II assessed the scientific, technical, environmental, economic and social aspects of vulnerability. They assessed sensitivity and adaptability to climate change, and the potential negative and positive consequences for ecological systems, socio-economic sectors and human health.<sup>1</sup> The reserve system has a potentially important role in assessment of impacts and vulnerabilities in coastal areas by providing a platform for socio-economic studies that use existing capabilities and partnerships. Reserves can function as a platform for temporal assessment of the impacts to and resilience of human and coastal communities in a changing climate. Past, present and future assessment data will be needed to understand community resilience.

Historical ecology studies conducted at reserves provide insight about adaptation of estuarine systems to past climatic conditions. Current SWMP data, ecological characterizations and socio-economic data provide a picture of current conditions in an estuary and potential effects of climate change impacts. Current and historical data would also provide support for future modeling efforts of inundation and storm intensity, as well as their potential impact on coastal communities.

## **Objectives**

### ***I. Identify vulnerabilities of estuarine ecosystems to climate change***

Full implementation of SWMP provides the foundation for meaningful synthesis of data reflecting current and projected abiotic and biological impacts. Current capabilities include 108 abiotic monitoring platforms and 27 weather stations, bio-monitoring at 18 reserves<sup>4</sup>, habitat monitoring and mapping, and baseline and historical data from reserve ecological characterizations. These capabilities help us better understand estuarine ecosystems and their vulnerability to climate change. By understanding vulnerabilities, reserves can determine how systems may adapt and become more resilient and identify where it is appropriate to acquire and/or restore land for protection of key ecosystems.

### **Ongoing/Short-term activities**

- Develop monitoring protocols and data management plans for key ecological components across the reserve system.
- Establish reserves as a network of standard reference and/or sentinel sites for identifying potential changes in estuaries and for monitoring and prioritization of restoration efforts across the country. The concept of sentinel sites will be based on the existing monitoring capabilities in cooperation with NOAA's National Geodetic Survey and Center for Operational Oceanographic Products and Services, as well as other NOAA partners. Each reserve will serve as an observational node within the network.

### **Long-term activities**

- Produce maps of projected sea level change and inundation scenarios for reserves using visualization and forecasting tools.
- Produce a data synthesis every five years focused on the ecological effects of sea-level change within the reserve system.
- Implement an historical ecology project to assess how reserve habitats have adapted to climate changes.
- Implement biological monitoring of reserve marshes and nearby marsh restoration projects to evaluate restoration success.
- Assess the success or failure of reserve restoration efforts impacted by climate change.

## ***II. Identify vulnerabilities of coastal communities to climate change***

Through the Coastal Training Program reserves collaborate with many stakeholder groups that will be affected by climate change. Baseline socio-economic data is now being used to help inform reserves on the dynamics of coastal communities. There are a few social science graduate research fellowship projects underway to assess coastal communities' ability to address climate change. Additionally, many reserves have been trying to assess the most important needs and concerns of coastal communities in relation to the impacts and mitigation of and adaptation to climate change.

Reserves operate and build facilities in the coastal zone and need to be cognizant of climate change when establishing facilities, as well as implementing sustainable operating practices to reduce vulnerability. Reserves manage the land within their boundary, either as a single agency or in cooperation with others. Land managers need to be aware of vulnerability of habitats and their shifting patterns and be strategic when acquiring new land to incorporate within their boundary.

### **Ongoing/Short-term activities**

- Elevate the importance of conducting social science at reserves and encourage use of reserves as living laboratories to better understand effects of climate change on coastal communities and ways to adapt to and mitigate changing conditions.
- Coordinate with universities and other institutions gathering social science data to apply their studies to reserves and integrate information with ongoing reserve studies to better educate the public and inform future management decisions related to climate change.



- Encourage and support reserve system Graduate Research Fellowship projects addressing socio-economic issues related to climate change.

#### **Long-term activities**

- Assess the vulnerability of reserve infrastructure and land conservation to climate change.
- Conduct a baseline socio-economic assessment of coastal communities and social barriers related to understanding community vulnerability to climate change.
- Identify socio-economic indicators that reflect climate change impacts.

### ***III. Support, influence, and disseminate policies or actions to mitigate the impacts of climate change***

The reserves can use their large collective voice to promote energy and other climate-related policies that will reduce greenhouse gas outputs into the atmosphere and to develop operational policies that address coastal climate change impacts. Reserves are working with local energy coalitions and other state and local groups that are trying to educate the public about policies and actions to help mitigate impacts of climate change. For example, some reserves are working with local advisory groups and task forces to understand and plan for impacts associated with sea-level change, including shoreline change and stormwater management.

#### **Ongoing/Short-term activities**

- Adopt energy efficiency policies like green building practices, recycling, teleconferencing, and carbon sequestration at reserves, as well as track and report on the economic and environmental savings of these policies. The reserves can also look to other countries' successes to reduce energy and resource waste in striving to meet their own climate change goals.
- Promote and deliver training to decision-makers in communities near reserves on tools and information that affect local and regional community climate change policies.

#### **Long-term activities**

- Produce and promote stories about reserve economic and environmental savings to send strong messages to national policy makers. The reserves will partner with other environmental agencies, and potentially other countries, to work towards improved national, regional and local policies around climate change.
- Assess decision-maker audiences in coastal communities to identify knowledge and resource gaps in their ability to mitigate climate change impacts. Planned periodic updates of these assessments will enable reserves to effectively support community response to changing climate scenarios and impacts.
- Assist coastal communities in building their capacity to assess vulnerability to climate impacts, as well as adopt and implement management strategies that reduce climate change impacts and improve coastal ecosystems.
- Invest strategically in land acquisition by incorporating climate change data and predictions on sea level change.

## Needs

Reserves need access to high quality visualization and forecasting tools to connect ecosystem and socio-economic data to coastal community planning and adaptation. Reserves need to increase their coordination with local institutions that are employing social science data, forecasting tools, and vulnerability assessments, to prepare coastal communities for climate change impacts and the ability to mitigate these impacts. Note: Needs identified here are preliminary and not comprehensive in nature. Additional human and fiscal resources will be needed to carry out many of the activities noted within this document.

Goal III: The National Estuarine Research Reserve System will provide educational opportunities and training related to effects of climate change on human and estuarine systems to increase public awareness and foster behavior change.

## Background

As place-based entities, the reserves are connected to coastal communities and existing education infrastructure and are poised to respond to climate change at the local level by educating and training community members to foster behavior change and mitigation. The education community agrees that habitat, land use and sea-level change, as well as biotic and abiotic indicators are important topics to focus climate change education efforts. Many reserves are already committed to providing education and training opportunities, including field based experiences, for coastal citizens such as visitors, community groups, teachers and students on various topics related to estuaries, the coastal environment and the potential effects of climate change.

The IPCC Working Group III is charged with assessing available information on the science of climate change resulting from human activities.<sup>1</sup> Similar to the IPCC Working Group III, the reserve system seeks opportunities to:

- 1) Educate stakeholders on the effects of climate change,
- 2) Foster behavior changes that slow climate change by reducing greenhouse gas emissions and applying carbon mitigation strategies, and
- 3) Mitigate the adverse ecological, social, and economic impacts of climate change by training decision-makers, resource managers, and the public to plan and prepare appropriate adaptation and response strategies.

## Objectives

### *I. Affect behavior change among decision-makers and the public in response to climate change*

Central to affecting behavior change is the need to define what key concepts a climate literate citizen should know to make informed decisions and act as stewards of the planet. The reserves contributed to the Climate Literacy Principles and Concepts<sup>5</sup> document which builds on research, science and technology benchmarks developed by the American Association for the Advancement of Science (AAAS) Project 2061. This document provides a prioritized list of “Big Ideas” that can be used to guide future product development and training opportunities by reserve education and coastal training programs.

In order to affect behavior change among decision-makers and the public, the reserve system can draw on existing education, outreach and coastal training programs to enhance awareness about climate change and encourage individual actions that address climate change issues.

#### **Ongoing/Short-term activities**

- Educate the public and students about climate change impacts on the coastal and ocean environments and actions they can take to limit emissions of greenhouse gases to reduce their carbon footprint in their home or neighborhood. This can be done, for example, through interpretive exhibits, Estuaries Day or Earth Day activities, and community education initiatives.
- Collaborate with local and state agencies to prioritize education needs, as well as focus and promote conservation strategies that decision-makers and the public can use.
- Develop a climate toolkit that serves as a repository of information on climate change for reserve educators, teachers and the general public. The toolkit could include maps of projected sea-level change, community and coastal manager needs assessments, a list of actions that can be taken to limit carbon emissions and increase community resiliency, relevant literature, regionally focused presentations on impacts and actions, as well as information on green building resources and networks.
- Identify specific strategies reserves can develop within their revised management plans regarding education activities that directly and indirectly relate to addressing climate change.
- Describe potential scenarios to help local decision-makers plan for projected community changes and increase community resiliency.

#### **Long-term activities**

- Collaborate with key NOAA partners, such as the Climate Program Office, to assess needs of various regional audiences and produce targeted education materials.
- Collaborate with other federal agency programs, such as the Environmental Protection Agency’s National Estuary Program, to foster and implement programs such as “climate ready estuaries,” based on the National Park Service Climate Friendly Parks program.
- Implement student, teacher, and community programs that expand climate literacy to foster behavior change. These programs can increase knowledge about the link between oceans, atmosphere, and human activity.
- Translate key information and data with user-friendly visualizations and engaging content for decision-makers and the public.

- Develop coordinated training activities to help coastal communities develop institutional capacities that reduce or mitigate vulnerabilities to climate impacts and enhance their ability to respond to acute hazards (i.e., severe storms, harmful algal blooms).
- Enhance the ability of coastal communities to integrate risk-wise decision-making into a broad range of community planning activities.

## ***II. Lead by example through effective land conservation and infrastructure practices and planning, as well as exhibits and outreach***

In an effort to mitigate the impacts of climate change at local and regional scales, the reserve system can refine its existing green practices and can continue to build green facilities that set an example for the community and can serve as demonstration or teaching tools. Additionally, the reserves can draw on their expansive local and regional knowledge to develop and communicate mitigation strategies for coastal communities. Many reserves already employ green building techniques and landscaping practices while improving and building their facilities. Some reserves are building Leadership in Energy and Environmental Design (LEED) certified research and education centers, including the ACE Basin Reserve in South Carolina, the Grand Bay Reserve in Mississippi, and the Apalachicola Bay Reserve in Florida. Reserves are also designing exhibits that focus on the potential impacts of climate change.

### **Ongoing/Short-term activities**

- Demonstrate a low-carbon economy through green building design examples at reserves and lead thinking about new facility location and construction methods that account for sea-level change and climate change.
- Inventory reserve actions that have been taken to mitigate climate change. This includes reserve staff members analyzing and reducing their carbon footprints.
- Incorporate climate change knowledge, impacts and actions into reserve strategic planning efforts and management plans.
- Use sustainable facility and landscaping attributes at reserves to educate the public, as well as commercial and municipal groups, about incentives and benefits of sustainable design techniques.

### **Long -term NERRS activities**

- Develop and adopt system-wide standards for green infrastructure and require sustainable elements in future construction and acquisition initiatives.
- Develop and disseminate, in partnership with others, management strategies for coastal communities, managers, and decision-makers to anticipate and respond to sea level change and other climate change impacts.
- Develop regionally focused presentations about effective conservation, infrastructure planning, and climate change related activities.

## **Needs**

Reserves need to have access to and rely on credible sources of information on climate change and network with appropriate councils and task forces to provide the most recent, reliable, and relevant information to coastal communities. Good science-based and locally relevant

visualizations, maps and other tools are also needed to deliver climate change messages to local communities. Note: Needs identified here are preliminary and not comprehensive in nature. Additional human and fiscal resources will be needed to carry out many of the activities noted within this document.

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<sup>1</sup> Intergovernmental Panel on Climate Change <http://www.ipcc.ch/>

<sup>2</sup> National Estuarine Research Reserve System <http://nerrs.noaa.gov>

<sup>3</sup> NERRS Strategic Plan 2005-2010 [http://nerrs.noaa.gov/Background\\_StrategicPlan.html](http://nerrs.noaa.gov/Background_StrategicPlan.html)

<sup>4</sup> NERRS System-Wide Monitoring Plan <http://www.nerrs.noaa.gov/Monitoring/welcome.html>

<sup>5</sup> Climate Literacy Principles and Concepts

[http://www.climate.noaa.gov/education/pdfs/climate\\_literacy\\_poster-final.pdf](http://www.climate.noaa.gov/education/pdfs/climate_literacy_poster-final.pdf)

**Goal 1: National Estuarine Research Reserves will contribute to a scientific understanding of climate change and monitor ecosystem changes.**

The St. Joseph Bay Buffer Preserve within the Apalachicola Bay Reserve in Florida is part of a study by Dr. Bill Platt from Louisiana State University and Dr. Loretta Bataglia, University of Illinois, who are examining habitat effects of climate change/rising sea levels and the interaction of hurricanes, fire and climate change on habitats and species along the Gulf Coast. This work is taking place at Apalachicola and Weeks Bay Reserves. The project is supported by an Earthwatch grant, and the researchers are hopeful for additional support hopeful from the National Science Foundation.

At Hudson River Reserve in New York, researchers are working to understand the function and migration of marsh as it relates to erosion caused by sea-level rise. The Hudson River Reserve is investigating options for managing the shoreline with respect to both the tradeoffs in ecosystem services and costs of different erosion control measures.

At North Inlet –Winyah Bay Reserve in South Carolina, scientists are monitoring emergent vegetation, investigating flooding and subsequent change in sediment and pore water properties, and installing Surface Elevation Tables (SETs) to monitor relative changes in sea level and the response of the emergent marsh communities. They also are engaged in long-term monitoring of zooplankton and nekton communities to assess changes relative to climate change.

At the Delaware Reserve, Dr. Jonathan Sharp and graduate student Alex Parker are examining the roles of bacteria, phytoplankton, and protozoans in the carbon cycle in nearshore waters. These studies provide insights into the relative importance of the “microbial loop” in estuaries compared to ocean environments.

At the Chesapeake Bay Reserve in Maryland, researchers are using SETs in a tidal fresh marsh and a salt marsh to determine whether sedimentation in the marsh is keeping up with sea level rise and erosion. Maryland is highly vulnerable to sea level rise because significant geologic land subsidence in Maryland compounds global sea level rise.

**Goal 2: National Estuarine Research Reserves will assess climate change impacts on human and estuarine ecosystem communities, vulnerability of these communities, and their capacity for adaptation and mitigation.**

Staff members at Waquoit Bay Reserve in Massachusetts have worked with partners from the Cape and Islands Renewable Energy Collaborative to develop a Regional Energy Action Plan for the Cape and Islands and have provided input for the Cape Cod Commission Regional Plan. They have a seat on the Falmouth Energy Committee and helped to develop the Climate Action Plan for the town of Falmouth and have been active in getting towns on the Cape to commit to the Cities for Climate Protection program.

The Hudson River Reserve in New York has been involved with several groups to address climate change, such as the Hudson Valley Regional Advisory Committee on Climate Change that is composed of 30 government and non-profit organizations targeting municipalities, non-governmental organizations and the public. Reserve staff have also participated in the Hudson River Watershed Floodplain Prediction Workgroup and Rising Waters Initiative to address sea-level rise impacts and planning.

The North Carolina Reserve has undertaken initiatives to educate decision-makers about shoreline stabilization and stormwater management, and provide more information to state policy-makers. In Mississippi and Alabama, reserves have provided community planners and elected officials training on mapping coastal inundation scenarios and development strategies that will help communities reduce adverse impacts from flood and storm events.

The Coastal Training Program of the Chesapeake Bay Reserve in Maryland has conducted presentations on climate change issues for county and state decision-makers. The presentation uses Maryland's GIS visualization tool based on LIDAR elevation data that show state and local sea level rise vulnerability.

There are a few social science graduate research fellowship projects underway to assess coastal communities' ability to address climate change: (1) outreach and research with religious institutions to enhance understanding of climate change impacts and environmental literacy to facilitate stewardship in the Waquoit Bay, MA area; (2) examination of the social landscape that defines the land-use decision making framework, system and communication networks that hold potential or may limit effective decision-making in a Great Bay, NH watershed and (3) investigation of stakeholder perception and knowledge of ecosystem-based management with a focus on recreational fishers and fishery managers in the Jacques Cousteau, NJ Reserve area.

**Goal 3: The National Estuarine Research Reserve System will provide education and training related to effects of climate change on human and estuarine systems to increase public awareness and foster behavior change.**

At the Waquoit Bay Reserve in Massachusetts, classes are provided for teachers and students about climate where participants learn to make observations of weather patterns, precipitation, storm events, erosion, animal and bird migrations, and plant phenology at their schools and in their own local area. They can then compare these observations with long term data collected through SWMP and other monitoring data. The reserve partners with the New England Science Center Collaborative, New England Aquarium, Gulf of Maine Ocean Observing System, and New England Ocean Science Education Collaborative to offer climate related education opportunities.

At the Narragansett Bay Reserve in Rhode Island, they are developing a habitat focused self-guided hike in the Reserve. By describing big-picture ecological concepts and how land-use changes over time along the trail, they hope to emphasize awareness and importance of strategic habitat restoration.

The Hudson River Reserve in New York offers canoe trips that highlight habitat function and the impact of invasive species, climate change, and sea level rise.

The Waquoit Bay Reserve in Massachusetts since 2000 has provided a community education course entitled Green Home: Focus on Energy, a series of talks by experts to give practical advice in an effort to reduce fossil fuel use. Initially offered to homeowners, the course has focused more recently on training particular audiences such as plumbers, architects, and home builders because lack of training by these professions was identified as a barrier for community members implementing energy efficient practices and installing renewable energy in their homes. They have held workshops by partnering with their respective professional organizations as well as other Cape and Islands Renewable Energy Collaborative members.

Educators at the Jacques Cousteau Reserve in New Jersey are encouraging a regional approach to understanding climate change and shoreline variability. They are educating and promoting a dialogue between decision-makers in three states via video-conferencing. The states include New Jersey, Maryland and Virginia. Coastal decision-makers who will participate include county and local staff on wetland boards, planning and zoning board members, floodplain managers, emergency management officials, state agency representatives and elected officials.

The Chesapeake Bay Reserve in Maryland is incorporating elements of climate change and sea level rise into all aspects of student and community education programs and teacher trainings. In addition, the Reserve is developing a workshop for educators on climate change.