

Tools for Coastal Climate Adaptation Planning

A Guide for Selecting Tools to Assist with Ecosystem-Based Climate Planning



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Climate change will influence the decisions we make about coastal ecosystems and human communities in the future.



Potential climate change effects include (but are not limited to) changes to sea and water levels, storm severity and frequency, erosion and sediment transport, freshwater inflows, and water chemistry and quality. Many coastal natural resource managers and communities in the United States have begun to plan for the impacts of climate change on their local ecosystems and infrastructure.

Although the field of climate adaptation planning is still relatively new, a variety of processes and approaches are emerging for assessing and reducing the vulnerability of coastal ecosystems and infrastructure to climate change. These processes and approaches require or benefit from the use of geospatial analyses and tools. Many factors can make it difficult for practitioners to select tools most suited to their needs and capacities, however. Some of these difficulties include the wide range of tools, the difficulty of finding information about tool functions, and the lack of ways to compare the tools' functionality, data requirements, training requirements, and strengths and limitations.

About This Guide

The purpose of *Tools for Coastal Climate Adaptation Planning* is to provide the information necessary for coastal natural resource managers and community planners to select appropriate tools for their projects. This guide focuses on spatially explicit solutions for climate-related planning. It provides detailed information on a set of key tools that either alone or used in conjunction with other tools can facilitate multi-sector climate adaptation planning (i.e. climate adaptation planning that incorporates elements of ecosystem health and social wellbeing) and describes the utility and role of tools in relevant planning processes. In this guide we focus on software and web-based tools that help incorporate data (geophysical, environmental or socioeconomic) and specialized analyses into the planning process.

This guide is targeted at practitioners and decision makers involved in coastal zone management, natural resource management, protected area and habitat management, watershed management, conservation, and local planning in the coastal United States including the Great Lakes. The information and tools in this guide are also highly applicable to many inland and international regions.

There are many ways to effectively use this tool guide.

- **If you are new to climate adaptation planning**, we suggest that you read the guide from the beginning to better understand how tools fit into the planning process.
- **If you are already engaged in a climate adaptation planning process but are new to tool use**, you can go directly to **Characteristics of Tools** to learn about the various types of tools and then look at **Selecting a Tool** to ensure that you understand the issues you need to consider before choosing a tool.
- **If you are interested in finding a tool for a specific issue**, you can read about the profiled tools in **Tool Snapshots** and learn how they have been applied in on-the-ground projects in **Tools in Action**.



Planning For Climate Change

Addressing climate change impacts is a relatively new application of the planning process (see *Box 1*). Climate change planning can refer to either reducing greenhouse gas emissions due to human activity (often called "mitigation") or adapting human and natural environments to the potential impacts of climate change. Although these two approaches are not necessarily mutually exclusive, most planning efforts focus on either emissions reduction or adaptation. This guide will focus on the tools available for adapting natural and human environments to the potential impacts of climate change. For a review of tools for mitigation planning see *Urban Planning Tools for Climate Change Mitigation* (Condon, et al., 2009).¹

¹ Condon, Patrick M, Duncan Cavens and Nicole Miller. 2009. *Urban Planning Tools for Climate Change Mitigation*. Lincoln Institute of Land Policy, Cambridge, MA.

What is a Tool?

The term "tool" has been used to describe a wide variety of planning processes, policies, and analytical approaches. In this guide we focus on software and web-based tools that help incorporate data (geophysical, environmental or socioeconomic) and specialized analyses into the planning process.

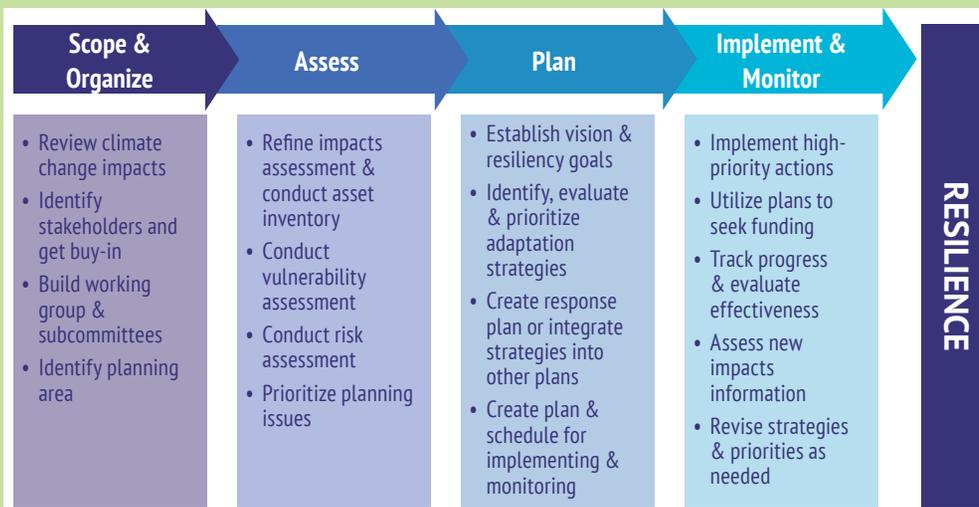
What is adaptation planning?

Adaptation planning seeks to reduce the negative impacts of potential climate effects by reducing exposure, promoting resilience, and accommodating adaptation of ecosystems, species, communities, and infrastructure to changing conditions. There are many approaches to adaptation planning (see *Figure 1* and *Appendix* for examples) that operate at different times and scales and have different implications for land use and conservation planning (e.g., adaptation actions could work to restore systems at the current time or limit development in the future). Adaptation plans can be spatially explicit plans specifying where actions should happen, non-spatially explicit plans describing strategies that should be undertaken within the planning region generally as emerging conditions warrant, or combinations of the two.

Where do vulnerability and risk assessments fit in?

Conducting vulnerability and risk assessments is a key analytical step in adaptation planning (see *Figure 1*). Climate change vulnerability assessments identify assets (in multi-sector planning, this includes both ecological and community infrastructure assets) which may be impacted by climate change. In addition to assessing assets' potential sources of vulnerability, risk assessments also consider the likelihood and consequences of potential climate change impacts. Due to the predictive nature of vulnerability and risk assessments, there is a degree of uncertainty in the results. Understanding and accounting for this uncertainty when considering management actions is an important aspect of adaptation planning.

Figure 1 Adaptation planning process



Adapted from **Adapting to Rising Tides**, a San Francisco Bay Conservation and Development Commission project studying the impact of rising sea levels on the Bay's resources (www.adaptingtorisingtides.org). This process was derived from ICLEI's Five Milestones for Climate Adaptation.

Box 1 The Planning Process

Planning processes, whether for towns, natural resources, or businesses, generally follow a similar path involving:

1. **Scoping** the problems, issues, or stressors that are driving the planning process
2. **Inventorying** and collecting relevant information
3. **Analyzing** this information to elucidate patterns, relationships, and potential future outcomes
4. Developing a **plan** based on the priorities and objectives resulting from the analyses and stakeholder input
5. Developing strategies, through policies or other actions, to **implement** the plan
6. **Monitoring and evaluating** the effectiveness of the plan and adjusting to unexpected or novel issues or stressors that are having an effect on the system

The unique element of public planning is the need to engage the public throughout the process. Public planning processes generally involve a number of interests, among them coastal residents, tourism, natural resources, and transportation. Since plans can affect the economic well-being of the community, the health of its ecosystems, and the services that the ecosystems provide to people, stakeholder input throughout the process is critical for the development of an equitable and implementable plan.



Box 2 Dealing with Uncertainty in Climate Planning

Since climate change planning is “forward looking” and depends on climate models for estimates of future climate impacts, there is inevitably a degree of uncertainty involved in the planning process. This science-based approach and its accompanying uncertainties provide both challenges and opportunities for engaging the public in the identification and interpretation of potential impacts at the local scale.

There are many approaches for addressing and accounting for uncertainties. One popular approach in urban planning and other fields is **scenario-based planning**. Scenario-based planning is valuable when the probability of a future event is unknown and the cumulative effects of an event, be it climate change or human development, will have a significant impact on future ecosystems and/or communities.

These planning approaches typically begin with the creation of a baseline scenario of current land use, management (e.g. resource use, restoration activities, fire management), and other stressors (e.g. storms, invasive species). Predicted changes (e.g. expected/proposed development, sea level rise, and increased storm surge) and possible responses of elements of interest (e.g. ecological and community infrastructure features) to these stressors are then modeled to create future scenarios. From these scenarios, planners can begin to identify thresholds of change—that is, points at which significant impacts will be realized. Planners can also “test” out various management options to see which may be the most effective.

Several tools included in this guide can help with scenario-based planning, such as CommunityViz, NatureServe Vista, and SLAMM (see **Tool Snapshots** section for more information on these tools). For a review of dealing with uncertainty in climate change planning, see **Scanning the Conservation Horizon**.¹

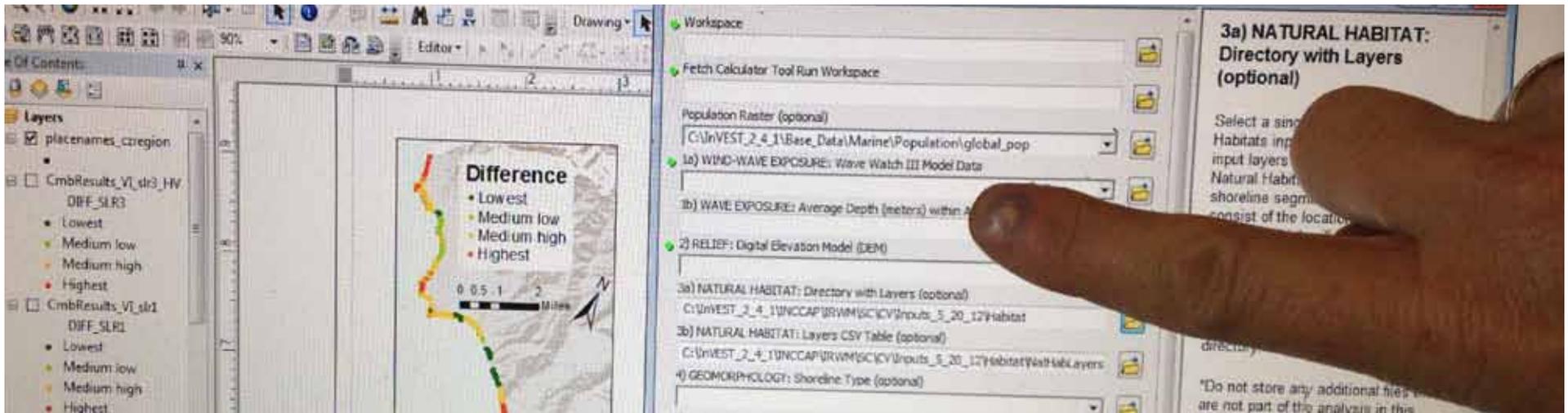
¹ Glick, P., B.A. Stein, and N.A. Edelson, eds. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. National Wildlife Federation, Washington, D.C.



Sea Level Rise and Coastal Flooding Impacts Viewer (NOAA Coastal Services Center).

Why take a spatial analysis approach?

Many of the questions raised by climate change planning are landscape-based and therefore best addressed by a geospatial approach. In the past several decades, geographic information systems (GIS) have been incorporated into many decision-making processes including climate adaptation processes. Although GIS software is very powerful, it can be difficult for users to determine how to apply it to specific problems. A number of specialized tools have been developed that integrate with existing GIS software and provide user-friendly interfaces and pre-assembled model functions. These tools range from models of geophysical and socioeconomic processes to tools that analyze a range of scenarios to help optimize planning decisions.



InVEST (Natural Capital Project, Stanford University)

Characteristics of Tools

The term “tool” has been used to describe a wide variety of processes, policies, and analytical approaches that assist decision makers develop and assess potential solutions to problems. In this guide, we focus on tools that are software and web-based applications. These tools help incorporate data (geophysical, environmental or socioeconomic) and specialized analyses into the planning process. To begin our exploration of these tools, we describe three ways to categorize tools. These different ways of thinking about tools can help you choose the tool best suited to your needs.

Figure 2 **Functionality of tool types**

Type/Function	Data Management	Analysis	Mapping/ Graphics	Scenario Development	Stakeholder Engagement
Visualization			√		√
Modeling		√	√	√	
Decision Support	√	√	√	√	√

Tool Types

Visualization Tools create simulations and graphics of current and potential future conditions and processes to help stakeholders understand and envision potential consequences of different management decisions. These tools often perform analyses but generally require less user input and customization than other analytical tools. Commonly, they do not have the ability to run customized analyses with local data. These tools are generally easy to use and do not require specialized software or hardware. Increasingly, they are available via the Internet.

Modeling Tools model current and potential future conditions of geophysical, biological, and/or socioeconomic processes. These are generally the most technically challenging tools to use and often require GIS software and appropriate hardware, topical expertise, and training. Models also generally require local data on the process being investigated. It is important to consider data requirements when assessing the appropriateness of these tools.

Decision Support Tools help develop scenarios of future conditions resulting from potential climate change effects and management decisions. These tools can integrate various tool outputs (e.g., from models) to help develop “what if” scenarios that allow practitioners to investigate a wide variety of management outcomes. Decision support tools generally require at least a moderate degree of technical capacity such as GIS expertise.

Tools and the Planning Process

Another key characteristic of tools is how they assist in the planning process. Different tools perform different functions and are useful at different steps in the planning process (see *Figure 3*). A key element for selecting the proper tool for a task is to have a well identified planning process with key planning questions in mind. Tools work best when they are focused on the questions and processes for making decisions. In other words, tools should assist the process; they should not drive it. However, it is not uncommon to have to make alterations to a planning process to fit the data and tool functionality available after carefully considering options and consequences.

This guide will use the following generalized adaptation planning process:

- **Stakeholder Engagement**
- **Scoping/Inventory**
- **Assessment/Analysis**, includes the vulnerability assessment
- **Planning**, includes strategies and scenario development and testing
- **Implementation/Monitoring**

Sectors Addressed

The sector or sectors that a tool is appropriate for is another key characteristic. This guide has a focus on multi-sector planning therefore we highlight the ability of profiled tools to address issues in different sectors in the **Tools in Action** section. The five sector designations that we use (based on those used by the U.S. Global Change Research Program) are:

-  **Natural Resources** including ecosystems, coastal zones, and water resources
-  **Agriculture** and other working land classifications
-  **Built Environment** including urban, public health, and telecommunications infrastructure
-  **Transportation** including all human transport systems and pipelines
-  **Energy** including energy production and conveyance infrastructure

Figure 3 Tools and the planning process

Tools perform different functions and are therefore useful at different points in the planning process. The more specialized the tool, the more focused it is on a specific part of the process. Most of the tools featured in this guide focus on the analytical step of the planning process, and none of the featured tools focus on implementation and monitoring.

Tool Type		Stakeholder Engagement	Scoping/Inventory	Assessment/Analysis	Planning	Implementation/Monitoring	
Visualization	CanVis	←→					
	SLR Viewer	←→					
	SoVI		←→				
Models	HAZUS			←→			
	OpenNSPECT			←→			
	SLAMM			←→			
	InVEST			←→			
	CCVI			←→			
DST	CommunityViz	←→					
	NatureServe Vista	←→					

Introduction to the Tools

How these tools were selected

Tools in this guide were selected by reviewing existing surveys of the climate change planning needs and capacities of coastal managers and local governments, compiling information about available tools that address these needs, and selecting a set of tools most likely to be useful to these groups. The criteria used to determine utility to target audiences were that the tools:

- Provide functionality needed for vulnerability assessments and adaptation planning
- Be applicable to coastal regions
- Incorporate both ecosystem health and social well-being concerns or be easily integrated with other tools so that a multi-sector approach can be taken
- Be applicable to a broad range of geographies, species, ecosystems, and projects
- Be usable by target audiences (potentially in collaboration with other scientists or consultants) in terms of data, training, and equipment required (e.g., not require a particular group or organization or supercomputers to operate them)

- Be actively maintained and have technical support available
- Have examples of their successful use and/or validation of their results.

The ten tools described below met these criteria and will allow for a broad range of analyses needed for adaptation planning projects. However, there are many more tools available than can be covered in this guide, including regional tools; and tool availability and functionality and computing environments change constantly.

To learn about the availability and suitability of other tools, users are encouraged to research:

- NOAA's Digital Coast
» www.csc.noaa.gov/digitalcoast
- EcoAdapt's Climate Adaptation Knowledge Exchange
» www.cakex.org
- The Coastal-Marine Ecosystem-Based Management (EBM) Tools Network Database
» www.ebmtoolsdatabase.org

Figure 4 **Tools by Sector**

A few tools specialize in identifying and planning for climate change impacts for specific sectors. Integration tools, like decision support tools, can often incorporate analyses from multiple models, thus allowing them to address climate effects across a variety of several sectors.

	Natural Resources	Agriculture	Built Environment	Transportation	Energy
CanVis	√		√		
SLR Viewer	√		√	√	
SoVI			√		
HAZUS			√	√	√
OpenNSPECT	√	√	√		
SLAMM	√				
InVEST	√	√			√
CCVI	√				
CommunityViz	√	√	√	√	√
NatureServe Vista	√	√	√	√	√

CanVis

Developer **NOAA Coastal Services Center/USDA National Agroforestry Center**

Tool Type **Visualization Tool**

Sector  

Step in Planning Process **Stakeholder Engagement**

Website www.csc.noaa.gov/canvis

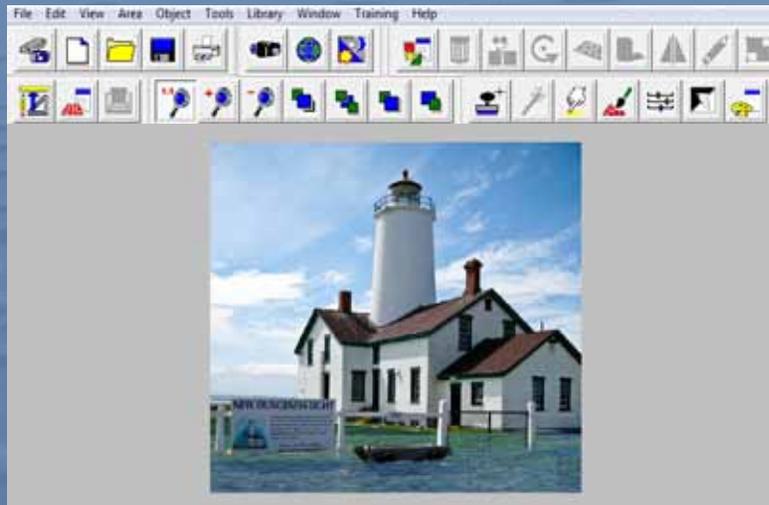
Description

CanVis image editing software allows users without specialized computer knowledge to create photo-realistic simulations for visualizing potential impacts from coastal development and sea level rise. Users create visual simulations by duplicating elements already in a digital photograph, adding elements from other images to a digital photograph, and/or taking advantage of CanVis's extensive element library to add elements (such as docks, rising waters, hotels, houses, marinas) to a digital photographs. The software allows elements to be resized, color-adjusted, and have shadows added to create realistic looking simulations. It also allows text to be added to photographs.

Examples of Use

- Illustrating the visual impact of offshore wind turbines on Lake Erie vistas
» www.csc.noaa.gov/digitalcoast/tools/canvis/action
- Illustrating the look and function of living shorelines to Maryland residents
» www.csc.noaa.gov/digitalcoast/tools/canvis/action
- Visualizing the potential impacts of sea level rise on coastal communities in Texas, Mississippi, Alabama, Florida, Georgia, California, Oregon, and Washington
» www.csc.noaa.gov/digitalcoast/tools/slviewer

CanVis is a photo simulation tool that allows users to visualize how a particular change or impact (such as new development, a proposed restoration project, or rising sea levels) might impact coastal resources and infrastructure. CanVis simulations have been incorporated into NOAA's Sea Level Rise and Coastal Flooding Impacts Viewer to help visualize how inundation might affect coastal resources.



Sea Level Rise and Coastal Flooding Impacts Viewer

Developer **NOAA Coastal Services Center**

Tool Type **Visualization Tool**

Sector   

Steps in Planning Process **Stakeholder Engagement, Scoping/Inventory, Assessment**

Website www.csc.noaa.gov/digitalcoast/tools/slrviewer

Description

The Sea Level Rise and Coastal Flooding Impacts Viewer allows users to visualize potential impacts from sea level rise. Users move a slider bar to show the effects of various levels of sea level rise on coastal communities. Visuals and accompanying data and information illustrate sea level rise inundation, flood frequency, marsh impacts, and socio-economic impacts.

The tool depicts the level of confidence in the inundation estimate based on the uncertainty of the LIDAR-derived land elevation and the tidal datum estimate. The process used to map the sea level rise inundation can be described as a linear superposition approach that attempts to account for local and regional tidal variability and hydrological connectivity. It uses the best available and publicly accessible elevation data to map literature-supported levels of sea level rise. The sea level rise is mapped on top of Mean Higher High Water, incorporating the local and regional tidal variation for each area. Hydrologically unconnected areas greater than one acre in size are preserved but are displayed separately from hydrologically connected inundation areas.

Examples of Use

- Methods for the Viewer were used to develop a vulnerability assessment for the Southeast Florida counties
» www.csc.noaa.gov/digitalcoast/action/slr-seflorida
- Demonstrating potential flooding impacts for sea level rise in coastal Mississippi
» www.csc.noaa.gov/digitalcoast/action/biloxi
- Developing an adaptation plan for sea level rise in Tybee Island, Georgia
» www.csc.noaa.gov/digitalcoast/action/tybee

The Sea Level Rise and Coastal Flooding Impacts Viewer allows users to visualize the potential impacts from sea level rise scenarios up to 6-feet above mean higher high water. The Viewer incorporates natural resource and socioeconomic information so that users can assess whether particularly sensitive or vulnerable assets may be exposed to increased risk from sea level rise.



SoVI® | Social Vulnerability Index

Developer **University of South Carolina**

Tool Type **Visualization Tool**

Sector 

Steps in Planning Process **Scoping/Inventory, Assessment/Analysis**

Website www.sovius.org

Description

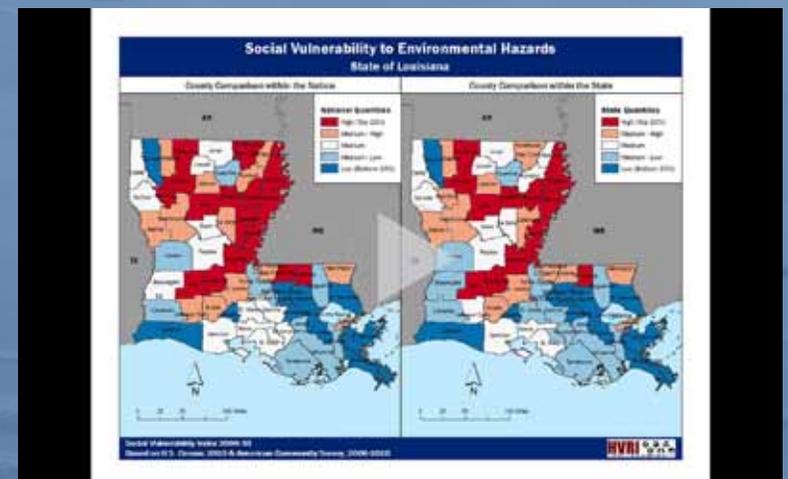
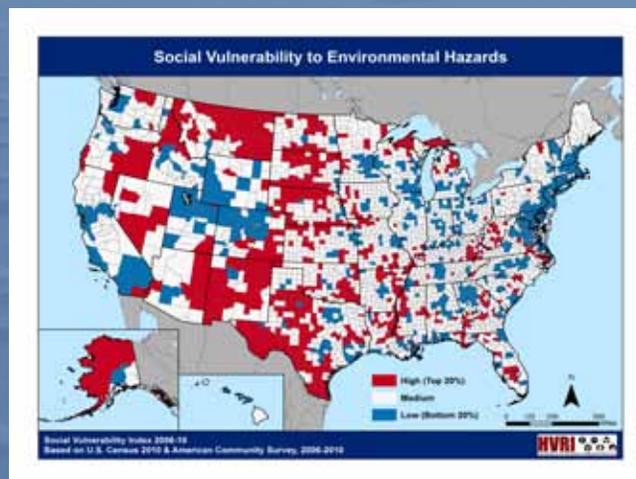
The Social Vulnerability Index (SoVI®) 2006-10 measures the social vulnerability of U.S. counties to environmental hazards and provides a metric that facilitates the examination of the differences in social vulnerability among counties. It shows where there is uneven capacity for preparedness and response and where resources might be used most effectively to reduce the pre-existing vulnerability. SoVI also is useful as an indicator in determining the differential recovery from disasters.

The index synthesizes 30 socioeconomic variables that the research literature suggests contribute to reduction in a community's ability to prepare for, respond to, and recover from hazards. SoVI data sources are primarily from the United States Census Bureau.

Examples of Use

- Used in Sea Level Rise Coastal Impacts Viewer
» www.csc.noaa.gov/digitalcoast/tools/slrviewer/index.html
- Used by South Carolina Emergency Management Division's Mitigation Program's Integrated Hazards Assessment Tool
» <http://webra.cas.sc.edu/ihat>
- Used with Oxfam American to identify counties in the Southeastern United States that are most socially vulnerable to drought, floods, hurricane-force winds, and sea level rise
» <http://adapt.oxfamamerica.org>

The Social Vulnerability Index measures the social vulnerability of U.S. counties to hazards by synthesizing 30 socioeconomic variables that affect a community's ability to prepare for, respond to and recover from natural disasters.



HAZUS-MH | Hazards-United States-Multi-Hazard

Developer **FEMA**

Tool Type **Model**

Sector 

Step in Planning Process **Assessment/Analysis**

Website www.fema.gov/hazus

Description

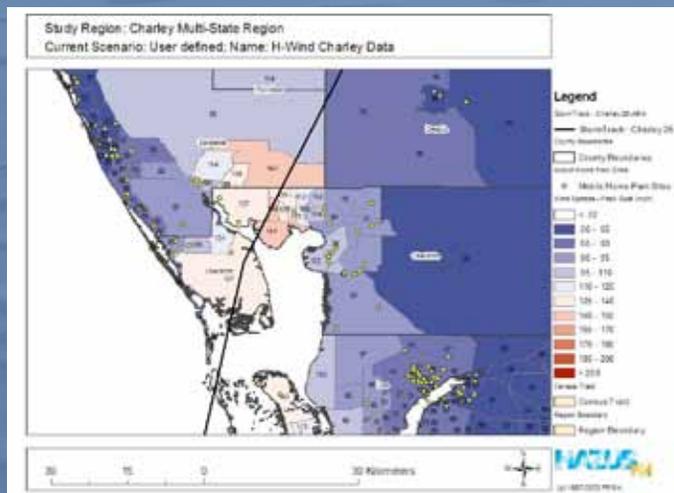
HAZUS-MH is a risk-assessment methodology for analyzing potential losses from floods, hurricane winds, coastal surge, and earthquakes. Potential loss estimates analyzed include physical damage, economic loss, and social impacts. Loss estimates can be performed anywhere in the United States for earthquakes and floods and in twenty-three coastal states for hurricanes and storm surge.

HAZUS-MH estimates losses on a first-principles basis that characterizes the extent and intensity of a hazard and combines the outputs of this analysis with damage functions, fragility curves, and valuation to generate economic and social losses. Users can edit the damage functions and fragility curves as well as parameters used in the analysis.

Examples of Use

- Supporting mitigation and planning within FEMA's Risk Map program
» www.fema.gov/rm-main
- Used in Economic Assessment of Green Infrastructure Study in Wisconsin
» [www.rff.org/RFF/Documents/RFF-Rpt-Kousky%20etal%20GreatLakes%20\(2\).pdf](http://www.rff.org/RFF/Documents/RFF-Rpt-Kousky%20etal%20GreatLakes%20(2).pdf)
- Used for disaster management by states and localities
» www.fema.gov/hazus/hazus-case-studies-and-success-stories

HAZUS-MH is a risk assessment tool for analyzing potential losses from floods, hurricane winds, coastal surge, and earthquakes. Although HAZUS-MH is not specifically designed for climate planning applications, many communities have used its analytical functions to assess potential losses due to sea level rise.



OpenNSPECT | Open-Source Nonpoint Source Pollution and Erosion Comparison Tool

Developer **NOAA Coastal Services Center**

Tool Type **Model**

Sector 

Step in Planning Process **Assessment/Analysis**

Website www.csc.noaa.gov/nspect

Description

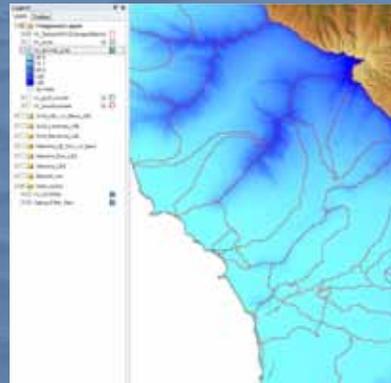
OpenNSPECT helps investigate potential water-quality impacts to rivers and streams from nonpoint source pollution and erosion resulting from development, other land uses, and climate change. Users first enter information about their area (land cover, elevation, precipitation, and soil characteristics) to create the base data layer. They then add different land cover change scenarios (such as a development or climate-change produced vegetation changes) or precipitation scenarios to get information about potential changes in surface water runoff, nonpoint pollution, and erosion.

The tool uses standard established models for runoff, nonpoint-source pollution, and erosion. Potential uses of OpenNSPECT for climate work (in development) include comparing differences in runoff volume and pollutant and sediment load under different (in amount, frequency and/or intensity) climate-change produced precipitation scenarios and examining changes in runoff caused by changes in land cover due to climate change.

Examples of Use

- Evaluating changes in nutrient and sediment loads from potential future loss of wetlands and population growth in South Carolina
» www.csc.noaa.gov/digitalcoast/_pdf/Integrating_N-SPECT_with_the_development_of_a_management_plan_for_the_Kingston_Lake_Watershed.pdf
- Identifying sediment source areas under different rainfall regimes in Hawaii
» www.csc.noaa.gov/digitalcoast/stories/pelekanebay
» www.csc.noaa.gov/digitalcoast/stories/koolaupoko
» www.csc.noaa.gov/digitalcoast/stories/laolaobay

OpenNSPECT allows users to investigate potential water quality impacts to streams and rivers from erosion and nonpoint source pollution. The model can be applied to climate planning work to assess how changing precipitation or land use might impact water quality.



SLAMM | Sea Level Affecting Marshes Model

Developer **Warren Pinnacle Consulting, Inc.**

Tool Type **Model**

Sector 

Step in Planning Process **Assessment/Analysis**

Website <http://warrenpinnacle.com/prof/SLAMM>

Description

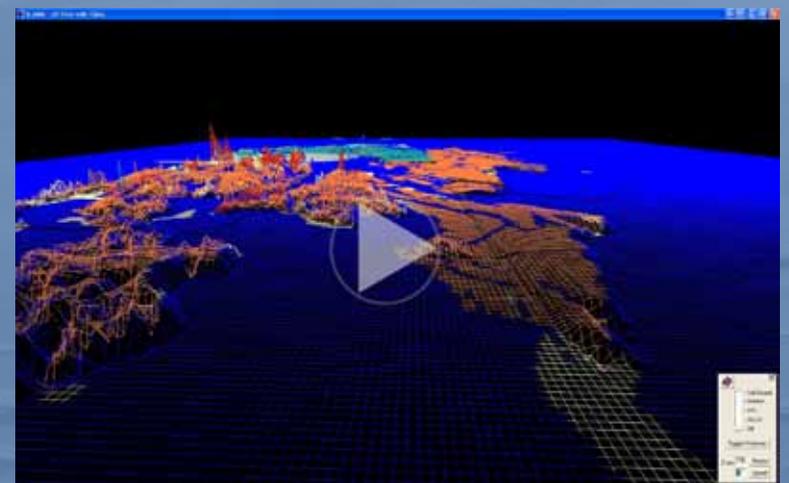
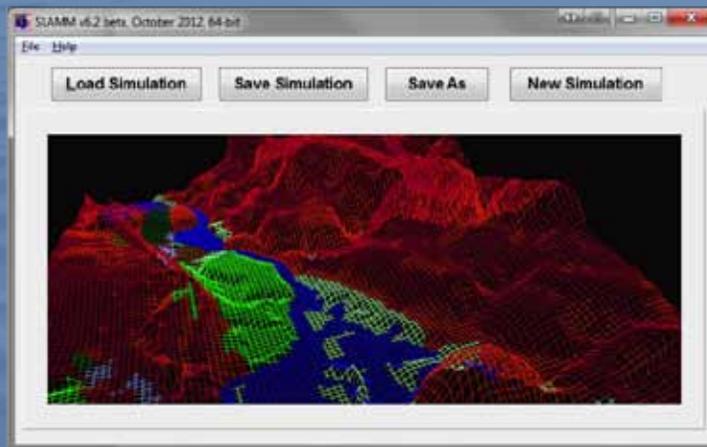
SLAMM simulates wetland conversion and shoreline modification resulting from long-term sea level rise. It identifies potential changes in both extent and composition of wetland types and accounts for inundation, subsidence, soil saturation, erosion, accretion, and barrier island overwash. The model uses a complex decision tree incorporating geometric and qualitative relationships to represent wetland changes and provides numerical and map-based output.

SLAMM also integrates a stochastic uncertainty analysis module to provide best/worst case scenarios and provides likelihood and confidence statistics accounting for uncertainty in future sea level rise, future erosion rates, and feedbacks between marsh vertical-accretion rates and sea level rise.

Examples of Use

- Supporting land acquisition and planning for more than 100 U.S. National Wildlife Refuges
» http://warrenpinnacle.com/prof/SLAMM/SLAMM_Projects.html
- Analyzing several sites in the Gulf of Mexico, including hindcasting for model calibration, parameter sensitivity analyses, and elevation uncertainty analysis
» http://warrenpinnacle.com/prof/SLAMM/SLAMM_Projects.html

The Sea Level Affecting Marshes Model simulates the conversion of wetlands due to long-term sea level rise. SLAMM assesses the impacts of inundation, erosion, overwash, saturation, and accretion on both the extent and composition of wetland types.



InVEST | Integrated Valuation of Environmental Services and Tradeoffs

Developer **Natural Capital Project**

Tool Type **Model**

Sector   

Steps in Planning Process **Assessment/Analysis, Planning**

Website www.naturalcapitalproject.org/InVEST.html

Description

InVEST is a family of tools that map and model ecosystem services and their variation under different management and climate scenarios. It enables decision-makers to assess tradeoffs among management choices and identify areas where investment in natural capital can enhance human well-being and biodiversity conservation. It can be applied in terrestrial, freshwater, and marine ecosystems worldwide at various spatial scales.

InVEST models are based on production functions that define how an ecosystem's structure and function affect the flows and values of environmental services. Outputs include a variety of metrics, including biophysical (e.g., area of property protected by coastal habitats from erosion and flooding), economic (e.g., value of property protected by coastal habitats), and social (e.g., number and demographic of people protected). These metrics resonate with diverse stakeholders and can be tailored to inform climate adaptation planning.

Examples of Use

- Designing a coastal zone management plan including coastal protection from storms and sea level rise in Belize
» www.naturalcapitalproject.org/belize.html
- Identifying strategies to maintain ecosystem services in Columbia including accounting for the impacts of climate change on water provision
» www.naturalcapitalproject.org/nasca.html

Ecosystems provide many key services to humans such as food production, air and water purification, and recreational opportunities. InVEST is a set of models that help map and value ecosystem services so they can be included in decision making processes. It also allows planners to assess tradeoffs associated with alternative management options.



CommunityViz

Developers **Placeways LLC and the Orton Family Foundation**

Tool Type **Decision Support Tool**

Sector 

Steps in Planning Process **Stakeholder Engagement, Scoping/Inventory, Assessment/Analysis, Planning**

Website <http://placeways.com/communityviz>

Description

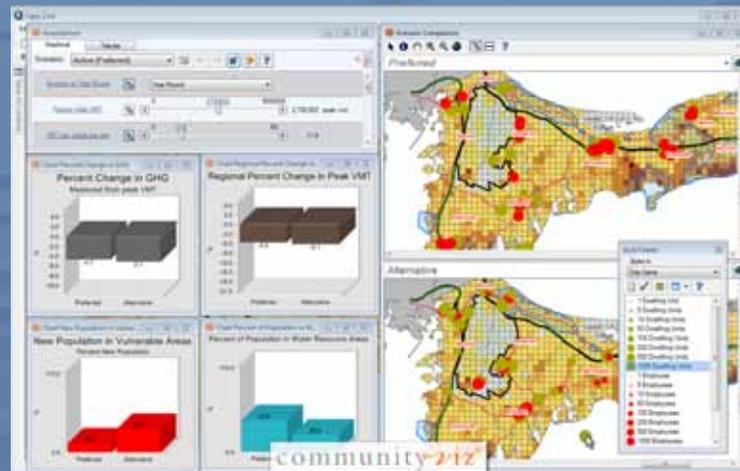
CommunityViz software helps planners and citizens visualize, analyze, and understand planning and design alternatives and their impacts. It supports scenario planning, sketch planning and geodesign, 3-D visualization, suitability analysis, impact assessment, growth modeling, and other planning techniques. The high-level, versatile real-time modeling environment can address climate change causes like greenhouse gases, vehicle travel, and energy use; planning and mitigation to create sustainable development patterns and avoid new building in areas vulnerable to sea level rise; and risk and impact assessment such as counting buildings affected by potential floods or storm surge.

CommunityViz also works well as an integration framework connecting to other climate change tools such as Hazus-MH and NatureServe Vista.

Examples of Use

- Used in an interagency climate change scenario-based planning pilot on Cape Cod
» <http://placeways.com/communityviz/gallery/casestudies/pdf/CapeCod.pdf>
- Creating a sustainable energy strategy for “Future Cities” in Arnhem, The Netherlands
» <http://placeways.com/communityviz/gallery/casestudies/pdf/Arnhem.pdf>

CommunityViz is a decision support tool that integrates a variety of analytical models as well as visualization and mapping capabilities to support a wide variety of planning activities. The mapping interface allows users to view the effects of a number of modeled features ranging from traffic counts to greenhouse gas production to flooding impacts.



NatureServe Vista®

Developer **NatureServe**

Tool Type **Decision Support Tool**

Sector 

Steps in Planning Process **Stakeholder Engagement, Scoping/Inventory, Assessment/Analysis, Planning**

Website www.natureserve.org/vista

Description

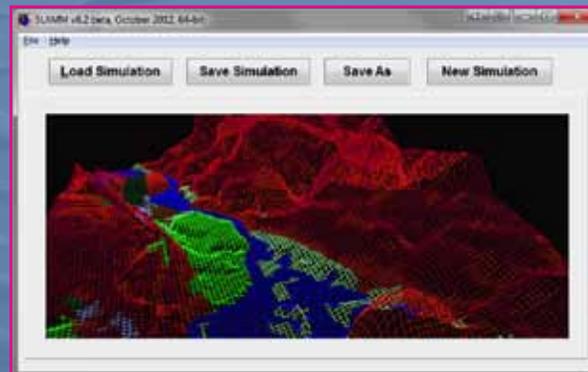
NatureServe Vista is a spatial decision support system for conducting cumulative effects assessment, mitigation planning, and conservation planning. It can help integrate conservation with land use, transportation, energy, and natural resources assessment and planning. It enables users to create, analyze, implement, and monitor land use and resource management scenarios that achieve conservation goals.

Vista can integrate considerations of climate change in a number of ways: 1) climate change effects can be integrated into scenarios to understand how they affect conservation elements; 2) the influence of development activities on future potential distributions of conservation elements can be assessed; and 3) climate adaptation scenarios can be created and used to evaluate management actions. Readily interoperable with a variety of other tools, Vista combines with Marxan to support development of optimized conservation solutions and with N-SPECT (or other hydrologic models) to support integrated land-water assessment and planning.

Examples of Use

- Evaluating the effects of sea level rise and urban growth on the southern tip of the DelMarVa peninsula in Virginia
» www.fws.gov/refuges/whm/pdfs/EasternShoreVirginiaNWR_RVA_Report.pdf
- Evaluating (as part of a toolkit) the effects of climate change and invasive species southern Oregon and northern Nevada
» www.fws.gov/refuges/whm/pdfs/SheldonHartNWR_RVA_Report.pdf
» <https://connect.natureserve.org/publications/rvaa>
- Assessing impacts of and potential adaptation and mitigation actions for climate change effects and potential renewable energy development on ecosystems and species in the Central and Mojave Basin
» <http://databasin.org/yale/pilots/natureserve>

NatureServe Vista helps integrate conservation with land use, transportation, energy, and natural resources assessment. Vista uses a spatially-explicit cumulative impacts approach to help users identify the potential effects of climate change on ecosystems and develop and assess alternative potential management scenarios.



Tool Matrix

Tool Name	CanVis	Sea Level Rise and Coastal Flooding Impacts Viewer	SoVI Social Vulnerability Index	HAZUS-MH Hazards–United States– Multi-Hazard	OpenNSPECT Open-Source Nonpoint Source Pollution & Erosion Comparison Tool
Developer	NOAA Coastal Services Center	NOAA Coastal Services Center	University of South Carolina	FEMA	NOAA Coastal Services Center
Tool Type	Visualization Tool	Visualization Tool	Visualization Tool	Model	Model
Purpose	Simulate potential impacts from sea level rise and coastal development	Assess the potential impacts of sea level rise and coastal flooding on coastal resources	Synthesize socioeconomic variables that affect community preparation, response, and recovery from hazards	Estimate economic and social losses from hazards	Assess potential water quality impacts to rivers and streams from nonpoint source pollution and erosion
Data Requirements & Key Inputs	Imagery such as photographs, satellite imagery, or pictometry	None. Users view pre-analyzed data for the nation via web browser	County (tract) level socio-economic and demographic input data. Data at the county level contained within the tool	Contains all data necessary to run and complete an analysis. Users supply additional data such as specific building data, soils maps, and stream gauges	Land cover, elevation, precipitation, and soils data
Key Outputs	Images in a variety of formats (e.g. .jpg, .tiff, and .png)	Inundation level (from 0-6 feet above Mean Higher High Water), inundation confidence level, marsh migration, socio-economic impact, and coastal flooding data visualization	Standardized input variables (z-scored), Factor Analysis Components, total SoVI Score, SoVI classification (Low, Medium, High) based on standard deviation, & state & national percentile rank	Maps delineating hazard characteristics, dollar value of the study region exposure, direct economic losses, essential facility functionality, shelter requirements, and debris	Sedimentation, nonpoint source pollution, and runoff volume
OS Requirements	Windows	Macintosh or Windows	Macintosh or Windows	Windows XP or Windows 7	Windows
Additional Software Requirements	None	Web browser with Adobe Flash installed	Web browser with Adobe Flash installed; data manipulation software (e.g. MS Excel)	ArcGIS 10.1 with Spatial Analysis	MapWindow Free open-source GIS program www.mapwindow.org
Training Requirements	None	None	None	Can be learned with user manuals. Training advised for understanding science & interpreting & applying model output.	Some training helpful
Price	Free	Free	Free	Free	Free

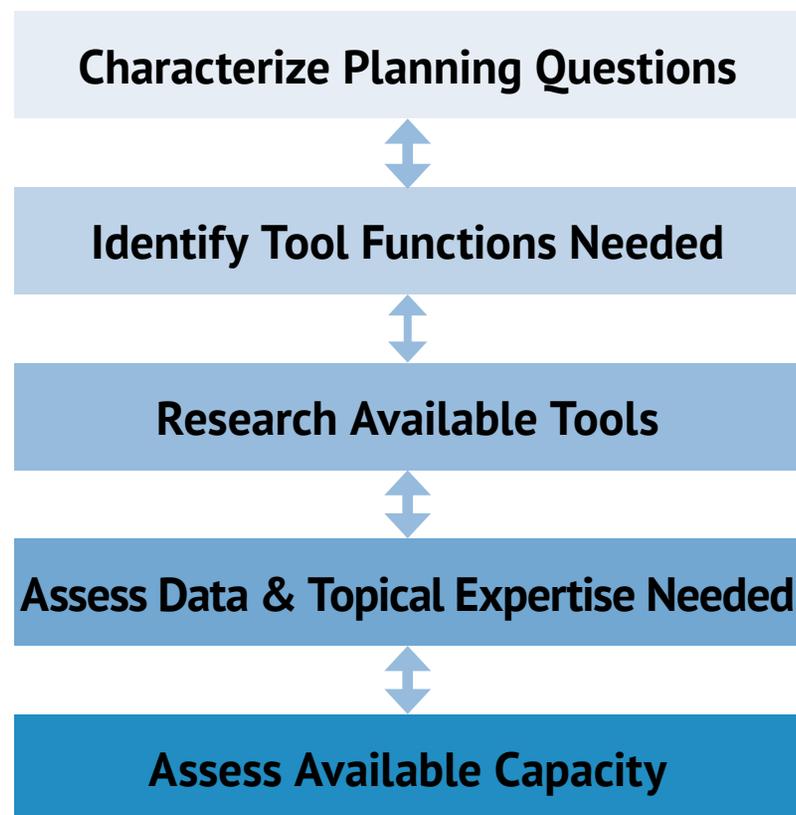
SLAMM Sea Level Affecting Marshes Model	InVEST Integrated Valuation of Environmental Services and Tradeoffs	CCVI NatureServe Climate Change Vulnerability Index	CommunityViz	NatureServe Vista	Tool Name
Warren Pinnacle Consulting, Inc.	Natural Capital Project	NatureServe	Placeways LLC and the Orton Family Foundation	NatureServe	Developer
Model	Model	Model	Decision Support Tool	Decision Support Tool	Tool Type
Project the potential effects of sea level rise on wetland systems	Evaluate how human activities and climate change affect terrestrial, freshwater, and marine ecosystem services	Assess species' vulnerability to climate change	Visualize, analyze, and communicate about planning decisions	Evaluate the impacts of management scenarios on land use and conservation goals	Purpose
Ascii raster files of wetland coverage, elevation, and slope for study area and historic sea level rise rates, tide ranges, 30-day inundation heights, datum correction values, accretion, erosion & sedimentation rates required. Ascii raster files of impervious surface & dike coverage optional. Uncertainty module can account for effect of missing data.	Variable according to model and data availability. Most models run with globally available datasets and information from peer- reviewed literature. Much of these data are included with InVEST. Users can input data more specific to their region	Past climate data & future climate projections for assessment area and ecological and distribution information for species to be assessed. Bioclimatic models of future climate-induced range shifts (optional). Some climate data sets available on tool website.	Variable according to analysis. Typical inputs are GIS vector layers such as parcels, zoning, roads & environmentally sensitive areas; demographics; future population growth projections; & future land- use plans or proposals. Wizard- based import of HAZUS-MH data.	Useful with basic data about distribution of conservation elements of interest & land use/ land cover data. Expert input on conservation element viability requirements & response to stressors is highly recommended. Data for basic coarse scale planning exists globally.	Data Requirements & Key Inputs
Graphical and numerical projections of potential changes in extent and composition of wetland types along with statistics of uncertainty results	Biophysical and socio-economic metrics	Scores of relative vulnerability to climate change of species assessed as well as indication of the factors causing vulnerability	Variable—includes scenarios (illustrated by maps, charts, reports) & measured by numerous impact indicators (environmental, economic, social, sustainability). Real-time analysis supports group discussions and geodesign.	Rich set of maps (ArcGIS grids), reports, and tabular outputs that can be exported to HTML and MS Excel formats	Key Outputs
Windows XP or Windows 7	Any ArcGIS-compatible OS	Macintosh, Windows, or online at https://adapt.nd.edu	Windows XP, Windows Vista, or Windows 7	Windows XP or Windows 7	OS Requirements
MS Word and MS Excel optional	Variable: ArcGIS 9.3 or ArcGIS 10 with Spatial Analyst	MS Excel (not required for online version); GIS helpful	ArcGIS Desktop (Basic, Standard, or Advanced) 10 or 10.1; Microsoft .Net Framework 3.5+	GIS: ESRI ArcGIS 10.x with Spatial Analyst; Other: Microsoft .Net 4 (free)	Additional Software Requirements
GIS expertise required to produce raster inputs. Basic understanding of model parameters and conceptual model function also needed.	Basic GIS skills required to format data and understand outputs	Training useful to ensure repeatability of assessments	No training required. Set-up requires intermediate ArcGIS skills & several hours of self-training.	Minimal training required for analyses. Basic GIS required to format data for input. Discipline expertise encouraged. Recommend 6-12 mos.	Training Requirements
Free	Free	Free	\$1400—government, non-profit & academic discounts available	Free	Price

Tool Name	CanVis	Sea Level Rise and Coastal Flooding Impacts Viewer	SOVI Social Vulnerability Index	HAZUS-MH Hazards-United States- Multi-Hazard	OpenNSPECT Open-Source Nonpoint Source Pollution & Erosion Comparison Tool
Top Three Strengths	<ul style="list-style-type: none"> • Free • Easy to use, can get results quickly • Free training available 	<ul style="list-style-type: none"> • Easy to use via Web browser, with GIS analysis results files available upon request (soon to be available as web map services) • Uses consistent data sets and analysis for coastal areas nationwide (complete in 2014) • Includes photos and allows users to visualize impacts of sea level at known locations 	<ul style="list-style-type: none"> • Grounded in science • Freely available for the entire nation • Provides evidentiary information on capacities/capabilities for planning, decision making, and emergency response activities 	<ul style="list-style-type: none"> • Provides credible results for large-scale events that can be used to plan for mitigation, emergency preparedness, and response • Provides results in easy-to-understand graphic and tabular formats • Has large user base (in the thousands) and organizations of users exist in every state 	<ul style="list-style-type: none"> • Easy to use within a GIS system, making results readily available for additional GIS analysis. • Provides simple method of looking at impacts from different land use scenarios. • Can define unique land use scenarios that simulate types of land use not found in the classified land cover, e.g., a golf course rather than just developed grass.
Top Three Limitations	<ul style="list-style-type: none"> • Requires source imagery • Cannot create 3D visualizations • Lacks certain functionality found in other software packages (e.g. content-aware tools, masking and gradient tools, etc) 	<ul style="list-style-type: none"> • Inundation scenarios do not include coastal storm surge, erosion, or other coastal processes • Cannot customize outputs or load additional local inputs into the tool for analysis • Appropriate for use as a screening-level tool allowing zoom-in to a scale of approximately 1:80,000 	<ul style="list-style-type: none"> • Understanding the statistics behind the algorithm can be challenging • Not available for use outside of US • Algorithm is sensitive to changes in geography and number of inputs 	<ul style="list-style-type: none"> • Inventory data and subsequently Level 1 analysis functionality unavailable for U.S. territories except Puerto Rico • Components of default inventory data may not line up on maps, e.g. placement of bridges and roads. This can be addressed by updating the default data with user-supplied data. • Can run out of memory and fail during coastal floodplain delineation for complex regions & events, e.g. St. Bernard Parish, La., & Miami-Dade County, Fla. Recommended work-around divides region into smaller geographies like a tract. 	<ul style="list-style-type: none"> • No time component to the model. Results are worst-case scenario because model lacks nutrient uptake, sediment redeposition outside cell of origin, etc. Estimates of pollutant concentrations are averages & do not account for higher concentrations at the beginning of runoff events • Runoff direction is determined by topography. Anthropogenic effects (e.g. ditching, diversions) must be simulated by altering the elevation model to force runoff into the desired pattern. • Only surface runoff simulated. No tracking of subsurface flow, springs, etc.
Documentation, Training & Technical Resources	Guidance document with step-by-step instructions, free monthly three-hour webinar workshops, training videos, with additional limited technical support	FAQs, methodologies, and related reference documents; brief "First Time Tips" video; 56-minute recorded webinar; in person tool instruction sometimes included in climate adaptation workshops	Web documents, training, technical support	Web documents, training, seminars, technical support	Tutorial downloaded with tool, on-line technical assistance, online live training webinars
Geographic Scale	Any scale	All U.S. coasts (2013) except Alaska and Louisiana	County level results freely available. For tract level, contact cogeogHVRI@mailbox.sc.edu	Multistate, state, regional & county levels	Almost any, depends on scale of land cover and elevation data
URL	www.csc.noaa.gov/canvis	csc.noaa.gov/digitalcoast/tools/slrviewer	www.sovius.org	www.fema.gov/hazus	www.csc.noaa.gov/nspect

SLAMM Sea Level Affecting Marshes Model	InVEST Integrated Valuation of Environmental Services and Tradeoffs	CCVI NatureServe Climate Change Vulnerability Index	CommunityViz	NatureServe Vista	Tool Name
<ul style="list-style-type: none"> Provides information needed by policymakers & contains the major processes pertinent to wetland fate Is relatively simple to employ, open source, has minimal data requirements, and has low financial and computational costs of application Integrated uncertainty analysis 	<ul style="list-style-type: none"> Open source Can use globally available data applicable anywhere, including data limited regions Online support and training 	<ul style="list-style-type: none"> Provides a common framework for assessing a variety of terrestrial and aquatic plants and animals Allows screening of relatively long lists of species Extensive documentation and case studies available 	<ul style="list-style-type: none"> Interactive and highly visual decision-support tool Versatile—layers of functionality make it useful for a wide range of skill levels and applications Widely used and well established (thousands of licensees worldwide), well supported, and frequently updated 	<ul style="list-style-type: none"> Framework tool works with & integrates information from many other tools Covers many information integration, modeling, assessment, planning & adaptive management functions at multiple scales Key strength for projects that must integrate a number of conservation elements, objectives, & multiple land-use & climate change scenarios 	Top Three Strengths
<ul style="list-style-type: none"> No mass balance of solids; instead accretion rates are based on empirical relationships Overwash model subject to additional uncertainty; frequency of storms & magnitude of effects uncertain; may be turned off or parameters refined No concept of “marsh health”; marsh-types migrate inland on the basis of elevation or salinity; produced “tidal flats” may have dead standing trees or other decomposing vegetation; “transitional marsh” produced when dry lands are regularly inundated 	<ul style="list-style-type: none"> Need some GIS training Although models are developed to be used widely and transferable, data for some models can be difficult to obtain For climate change analysis, many models use annual average data; depending on the model used, scale can be limiting 	<ul style="list-style-type: none"> Does not apply to marine species Current versions restricted to conterminous 48 states, Canada, and the tropical Andes Not a substitute for an in-depth vulnerability assessment of high profile species 	<ul style="list-style-type: none"> Not for engineering-level design--best for plans and directional decisions No built-in data and relatively little built-in modeling, so knowledgeable user is needed for set up Not free (see prices below) 	<ul style="list-style-type: none"> Raster-based platform is a disadvantage for applications where maintaining precision of small features (e.g. point and linear features)is important but this may be changed in the future Scale can also be limiting although recent projects have approached 40,000 square miles The breadth of functions provided may lead to a slow learning curve to fully employ the tool 	Top Three Limitations
Users manual, technical documentation, and user forum	Users manual, technical documentation, and user forum	Comprehensive guidelines document, recorded training webinars, custom training, technical support	Extensive built-in & online help, free tutorials, full-service technical support, 1-3 day instructor-led web-based/classroom training, Planners Guide	Complete users manual, web-based or onsite training, technical support	Documentation, Training & Technical Resources
Currently limited to ~13,000 km ² at lower resolution, 15 km ² at very fine resolution. Next release version will have no limitations.	Models ranging in scale from <1-100,000 km ² at high resolution. 50m to 1km segments depend on the resolution of data inputs.	Most effectively applied at the state or province scale	Any scale from building or site to entire regions	Operates at any scale with tradeoffs at very large extents in raster cell size (resolution)	Geographic Scale
www.warrenpinnacle.com/prof/SLAMM	www.naturalcapitalproject.org	j.mp/nscuvi	www.placeways.com/communityviz	www.natureserve.org/vista	URL

Selecting a Tool

Selecting the right tool out of the many available can seem like a daunting challenge to even the most experienced practitioner. Taking a systematic approach to selecting a tool can make the decision process easier and more straightforward. We suggest that project teams work through the process described below when selecting a tool. There are no right or wrong answers to the questions posed below, but the discussions that your team has and the conclusions you reach will help you determine the suitability of available tools.



1

Characterize Planning Questions

When selecting a tool, start by considering the goals of the planning process in which you are engaged. During the scoping process, you should have determined the information you need for planning and the specific planning questions that need to be answered. Tools should help provide this information and answer these questions.

Considerations

1. What sectors (e.g., natural resources, built environment) do you need to address?
2. What issues (e.g., at risk human populations, critical habitats, critical species) do you need to address?
3. Are your questions broad in scope (e.g., general questions about potential vulnerability) or fairly specific (e.g., predicted range shift for an individual species)?
4. What geographic scale(s) are you concerned with (e.g., regional, for an individual protected area, for an individual municipality)?
5. What temporal scale(s) are you concerned with (e.g., do you need to assess immediate or long-term impacts)?
6. Are your questions primarily at a “planning scale” (e.g., need to identify general areas that may be impacted, are suitable for activities, etc.) or do you need results that help determine optimal actions at specific sites?
7. Do you need to understand the interactions of multiple stressors (e.g., climate change and development)?

Helpful Hints

Planning questions can be general in nature. However, the more specific and measurable they are, the easier it is to identify and select tools with the necessary functionality, outputs, and supporting data. It is important to note that many questions can be answered without tools, and many steps in the planning process are iterative and may involve changing or refining your questions. And while tools should not drive the planning process, if your planning questions are very general in nature, learning about available tool functionality may be useful in helping you focus attention on areas that are more readily addressed.

2

Identify Tool Functions Needed

Figure out the general functions you want the tool to perform and where in the planning process you will use the tool.

Considerations

Tool functions can be broadly categorized as:

1. Visualization (e.g., create photo simulations, maps, graphs, charts)
2. Modeling (e.g., model socio-economic, geophysical, and ecological processes)
3. Decision support (e.g., integrate models and create visualizations to develop scenarios)

Steps in the planning process where tools might be useful:

1. Engaging stakeholders
2. Scoping the project
3. Assessing vulnerability and risk
4. Developing and assessing potential management and conservation actions
5. Assisting in implementation projects or permitting

Helpful Hints

The same tool may be useful at different stages in a planning process, e.g., some tools do visualization and modeling). Some processes may benefit from using multiple tools, e.g., starting with a simple visualization to help scope the planning issues more effectively and then moving on to more quantitative/analytical tools to evaluate more explicit management/planning options.

3

Research Available Tools

Read about available tools (starting with the **Tool Snapshots** and **Tool Matrix** in this guide!) and use online databases (referenced at the end of this section) to see if any tools seem to provide the functionality your process requires and outputs that would help address your planning questions.

Considerations

1. How well do your desired functionality and outputs align with the tool's functionality and outputs?
2. Does the tool work in/for your issues and sectors of interest?
3. Does the tool already work for your location?
4. Does the tool work at the needed geographic and temporal scales?
5. Can the tool be customized to fit your project needs if it does not do so currently? How difficult/expensive would that be, if so?

Helpful Hints

Be aware that there is not always an exact match between “off the shelf” tools and project needs. Projects will often need to weigh the costs and benefits of using existing tools that are not an exact match (and potentially supplementing these tools with custom GIS processes) with the costs and benefits of not using any tools or developing their own custom tools.

Also, if you are unsure if a tool is a good fit for your particular process, we suggest speaking with the tool developer to determine if the tool can answer your questions and be used at your capacity level. If their tool is not appropriate, they may have ideas of other suitable tools.

4

Assess Data & Topical Expertise Needed

Once you have identified a tool that may suit your needs, figure out the data inputs, information, and topical expertise needed to use it.

Considerations

1. What datasets, information, and topical expertise are needed?
2. Are the datasets and information accessible and in a usable format (e.g., spreadsheets, GIS files, hard copy reports)?
3. Are the data sets and information at the appropriate spatial and temporal scales?
4. How reliable are the available datasets and information (e.g., from a trusted source, collected recently enough)? Are they precise and accurate enough?
5. How feasible is it to obtain datasets and information that are not currently available? If collecting new data and information is being considered, what are the costs and how much time is needed?
6. Are topical and local experts available to provide information for and advise on tool use?

Helpful Hints

Many a planning project has been delayed or discontinued waiting for the “ultimate” dataset or model result. Don’t let the perfect be the enemy of the good (or good enough). It may well be that additional information will make for a better planning effort, but make sure you explore the benefits of initiating your planning with existing data. Planning processes are iterative by nature, and plans can (and should) be revised as new information arises.

5

Assess Available Capacity

In addition to considering the availability of data, consider the availability of human and technical resources for using tools.

Considerations

1. Are there training resources available?
2. Can you provide sufficient time for project personnel to get trained in the use of the tool and actually use it?
3. Do you have the financial resources for any needed personnel training, hardware, and software?

Helpful Hints

If a tool looks ideal for your particular process but you do not have the capacity to use it in-house, we suggest contacting the tool developer to see if they have suggestions for collaborations or technical assistance for using the tool. In some cases, there may be accomplished tool users in government agencies, non-governmental organizations, and/or academia that may be able to operate the tool for you and provide you with results.

Toolkits

The previous sections of the guide refer to use of a single tool, but in many instances, a single tool cannot address all of a project's needs. In these cases, many projects have used multiple tools. Use of multiple tools can range from using a visualization tool in conjunction with another tool to visualize its results to complex cross-sectoral assessments utilizing a variety of modeling, decision support, and visualization tools.

While the use of multiple tools often occurs in an ad hoc fashion, multiple tools can also be assembled into carefully-planned integrated toolkits. In an integrated toolkit, the output of one tool can be used as input into another, potentially iteratively, to increase overall functionality and/or streamline processes (e.g., integration of tools focused on ecosystem health and social well-being, automated data exchange between tools). An example of a planned toolkit is the Integrated Land-Sea Planning Toolkit (www.utmsi.utexas.edu/images/stories/Land%20sea%20tech%20guide%20reduced%20size.pdf). When planning a toolkit, it is suggested that a workflow diagram showing data inputs, analyses to be conducted, and outputs needed for decision making be created to ensure smooth interoperability of the tools and validity of the final results.

Integrated toolkits can provide extremely powerful analytical approaches specifically customized to user needs. A toolkit approach can be challenging, however, because projects need the skills and resources to learn and apply multiple tools. Skilled GIS analysts are often capable of learning several tools and constructing these toolkits (potentially in collaboration with the tool developers), and organizations without skilled technical staff on hand may be able to use a toolkit approach through collaboration with other organizations.

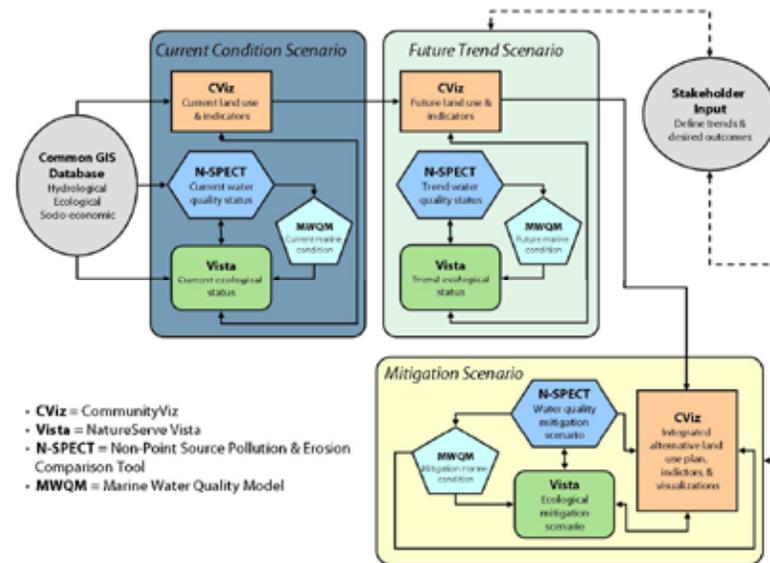


Figure 5. **Toolkits**
Multiple tools can be used in conjunction with each other to provide specialized analyses. This diagram shows how information flows between four different tools in the Integrated Land-Sea Planning Toolkit.

Other Sources of Tool Information

Prior to initiating tool use or if you do not find an appropriate tool (using this guide or in other searching), we highly recommend speaking with others engaged in similar work about their approaches and experience. In addition to the case studies and examples of use provided in this book, **NOAA's Digital Coast** (www.csc.noaa.gov/digitalcoast), **EcoAdapt's Climate Adaptation Knowledge Exchange** (www.cakex.org), and the **EBM Tools Network Database** (www.ebmtoolsdatabase.org) provide additional examples of case studies to help you learn from and connect with practitioners involved in similar work.

The Tool User's Responsibilities

Tool developers work hard to ensure that their tools work as advertised and perform analyses appropriate to the questions they are designed to address. Tool users also bear responsibility for making sure that the tools are properly applied. Prior to initiating tool use, tool users should make sure they understand a tool's underlying assumptions and its data requirements. During tool use, technical staff using tools and topical experts should maintain a close working relationship to ensure that the best available data are used and assumptions made during tool use are appropriate and clearly articulated to the end users.

Adapting to Rising Sea Levels in California

Tool Used Sea Level Rise and Coastal Flooding Impacts Viewer

Project Partners

- **Port of Long Beach**
- **AECOM**
- **San Francisco Bay Conservation and Development Commission**
- **Association of Bay Area Governments**
- **Metropolitan Transportation Commission**
- **Bay Area Air Quality Management District**

Data Used

- **Sea level inundation (1 foot increments up to 6 feet)**
- **Mean Higher High Water tidal datum**
- **Confidence intervals**
- **LIDAR-derived topography**

Products generated by tool use

- **Maps of coastal inundation in 1-foot increments**
- **Levels of confidence for each inundation map**
- **Impacts on coastal infrastructure and communities**

Project Contact

Rebecca Lunde

West Coast Regional Coordinator
NOAA Coastal Services Center



One of the busiest seaports in the world, the Port of Long Beach is just one of California's many coastal assets that faces significant potential impacts—economic and environmental—from rising sea levels.

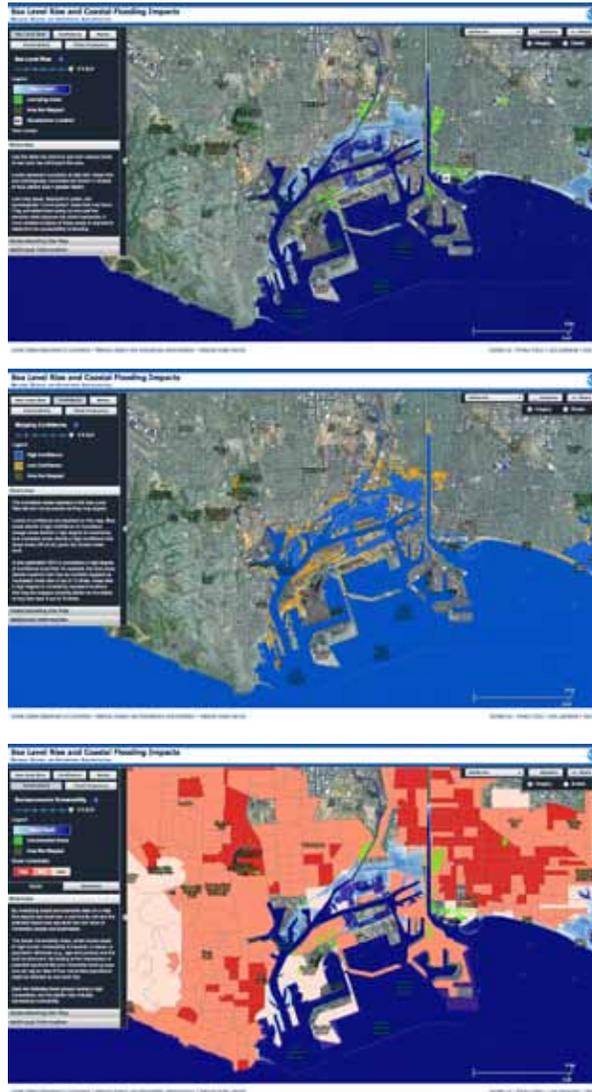
Project Background

Climate change and its potential impacts on the economy are a growing concern for California decision makers and citizens. A 2012 study by the National Academy of Sciences estimates that sea level could rise nearly 2 meters along parts of the California coast by 2100. The California Climate Adaptation Strategy recommends that communities in the state begin to develop adaptation plans to address the potential impacts of climate change.

Using the Tool

Several California agencies are using the Sea Level Rise and Coastal Flooding Impacts Viewer (Viewer) for their adaptation planning efforts. The Port of Long Beach, one of the world's busiest seaports, is working with AECOM, an environmental engineering and technical services firm, to conduct an initial exposure analysis of Port assets using the Viewer's inundation layers. The Viewer was also used at the project kick-off meeting to provide a visual and interactive way to help local stakeholders and Port staff understand potential impacts.

Plan Bay Area, a long-range transportation and land-use planning effort conducted by a number of regional planning and transportation agencies in the San Francisco Bay region, is also working with AECOM. They are using the Viewer's inundation data to determine if future development projects would be impacted by sea level rise, and if so, to what extent.



Outcomes

The Viewer uses a consistent, unified dataset based on high resolution elevation data and currently provides the best available estimates of inundation due to sea level change for the U.S. West Coast. State agencies are increasingly recommending that local organizations use the Viewer to address climate impacts when updating their local coastal plans. In addition, the San Francisco Bay Conservation and Development Commission, the Bay's coastal zone management agency, is considering using the Viewer to implement new policies requiring that sea level rise be considered when permitting coastal projects.

The Viewer allows users to visualize potential impacts from rising seas—inundation, flood frequency, marsh impacts, and socioeconomic impacts—and assess the levels of uncertainty in the model.

Assessing the Impact of Sea Level Rise on Coastal Wetlands in SE Louisiana

Tool Used SLAMM | Sea Level Affecting Marshes Model

Project Partners

- **National Wildlife Federation**
- **Warren Pinnacle Consulting, Inc.**

Data Used

- **Elevation data**
- **Wetlands**
- **Land cover**
- **Accretion**

Products Generated by Tool Use

- **Maps of land cover by year**

Project Website

» www.warrenpinnacle.com/prof/SLAMM/SLAMM_Projects.html

Project Contact

Marco Propato, Ph.D.

Research Associate, Warren Pinnacle Consulting, Inc.

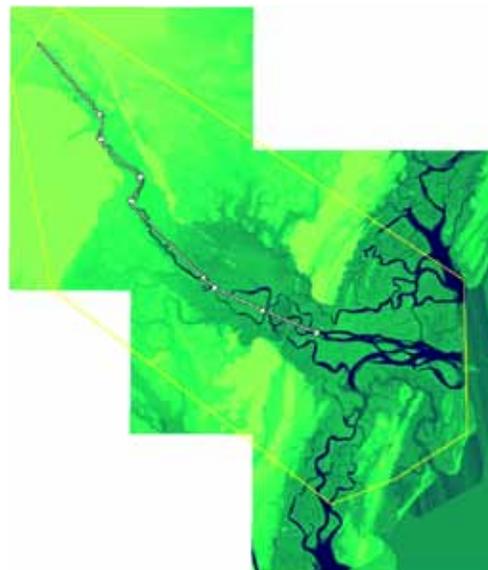
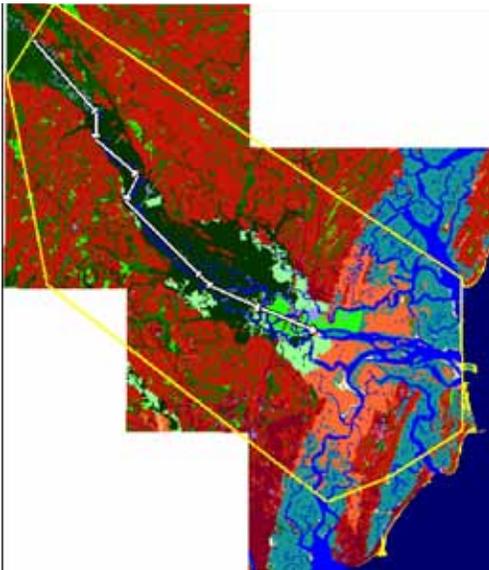


Project Background

Coastal Louisiana wetlands contain about 37% of the estuarine herbaceous marshes in the conterminous U.S. and sustain more coastal wetland loss than all other states in the conterminous U.S. combined. The long-term stability of these wetlands is often a function of a wetland's ability to maintain elevation equilibrium with mean sea level through processes such as primary production and sediment accretion. This study investigated the potential impact of current and accelerating sea level rise rates on key coastal wetland habitats in southeastern Louisiana using SLAMM.

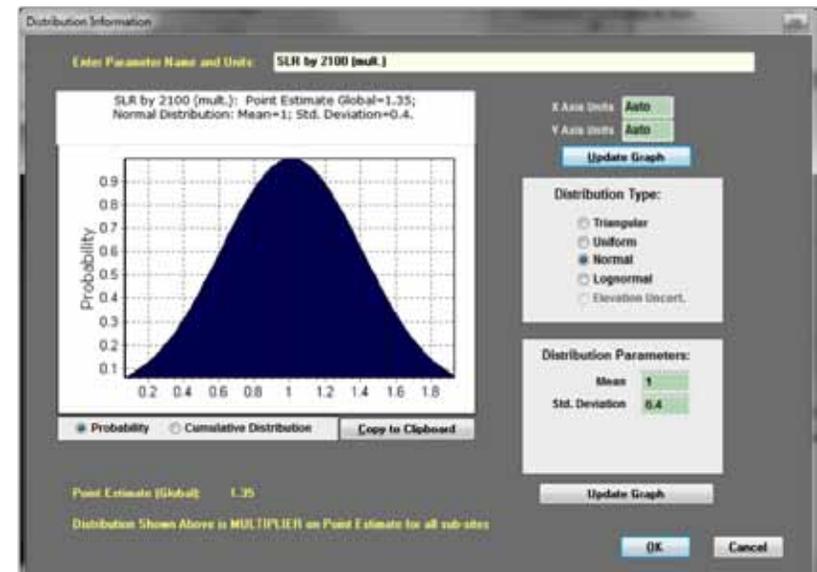
Using the Tool

Model calibration was conducted using a 1956-2007 observation period, and hind-casting results predicted 35% total marsh loss compared to the 39% total marsh loss observed. Multiple sea-level rise scenarios were then simulated for the period of 2007-2100. Results for potential wetlands losses by 2100 ranged from 9% of the 2007 wetland area under the lowest sea level rise scenario to 24% of the 2007 wetland area in the highest sea level rise scenario. Model results also suggested much of the region's bald cypress-water tupelo swamp habitat will become permanently flooded (affecting regeneration) even under the lower scenarios for sea level rise.



Outcomes

These findings will aid in the development of ecosystem management plans that support processes and conditions that result in sustainable coastal ecosystems. Findings will inform a wide range of management decisions and issues for the region ranging allowable harvest in cypress swamps to prioritization of habitat restoration projects to development of strategies that allow for habitat migration.



SLAMM uses a complex decision tree that incorporates geometric and qualitative relationships between variables like elevation (left) and land cover (center) to represent wetland changes. In addition to its numerical and map-based outputs, the model integrates an uncertainty analysis module (right) to provide best/worst case scenarios and provides likelihood and confidence statistics accounting for future uncertainties.

Incorporating Natural Capital into Climate Change Adaptation in California

Tool Used InVEST | Integrated Valuation of Environmental Services and Tradeoffs

Project Partners

- **Natural Capital Project**
- **Center for Ocean Solutions**
- **Integrated Regional Water Management planners in Santa Cruz and Greater Monterey Counties**

Data Used

- **Geomorphology**
- **Relief**
- **Dunes**
- **Wetlands**
- **Kelp**
- **Sea level change**
- **Wind and wave exposure**

Products generated by tool use

- **Vulnerability assessment of the Santa Cruz and Greater Monterey County IRWM regions**
- **Appendix to the Greater Monterey County IRWM Plan consisting of the InVEST analysis**

Project Website

» www.greatermontereyirwmp.org/wp-content/uploads/2012/08/AppendixK_Habitat_Vulnerability_Adaptation.pdf

Project Contact

Suzanne Langridge, Ph.D.
Ecologist, Natural Capital Project
Stanford University



Project Background

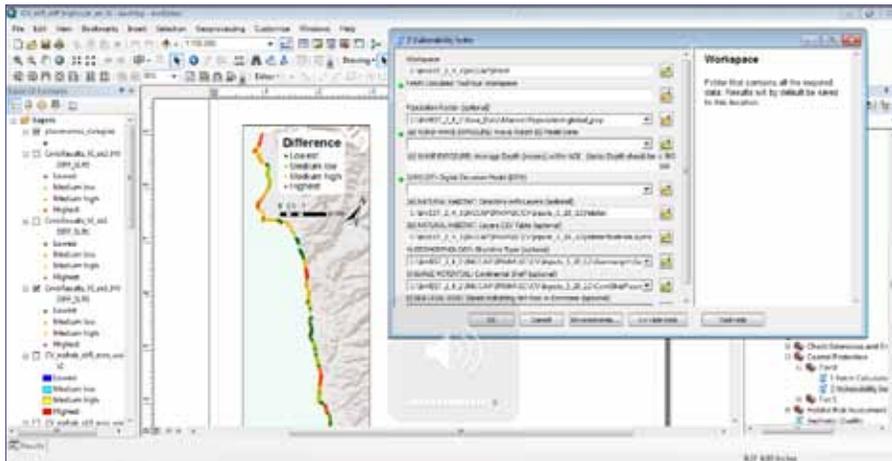
Global sea level rise will have far-reaching consequences for the population, development, and infrastructure of the Monterey Bay region. Sea level rise will affect the region through increased frequency of flooding; gradual inundation; increased rates of cliff, bluff and dune erosion; and exacerbated effects of storm surge, large waves and high tides. These impacts could have significant consequences for the economy and culture of the region and lead to loss of habitats—e.g., beaches, dunes, wetlands, lagoons, kelp forests—and the protective, recreational, and cultural services they provide.

Integrated Regional Water Management (IRWM) planners are required to consider climate change impacts as part of their plans. This project engaged IRWM planners in using the InVEST Coastal Vulnerability model to visualize and raise awareness of the vulnerability of the region to erosion and inundation from sea level rise. The project focused on the role of natural habitats in reducing this vulnerability.

Using the Tool

The Coastal Vulnerability model in the InVEST toolbox was used with the IRWM teams to highlight areas where natural habitats on the coast of the Monterey Bay region could reduce the vulnerability of water infrastructure and coastal communities. One of the key challenges for the process was that the locations of water infrastructure such as water treatment plants and pumps for Monterey Bay were not available to help address key questions about their vulnerability. Locations of people and agricultural land were used as proxies for areas with the greatest concentration of water infrastructure.

Model results suggest that sea level rise predicted through 2100 will lead to a more than 25% increase in coastal segments in the highest vulnerability category. They also suggest that coastal habitats can play a key role in reducing the vulnerability of people and prime agricultural land to coastal erosion and flooding.



InVEST is a set of models that help map and value ecosystem services so they can be included in decision making processes.



Outcomes

As a result of this engagement, the IRWM teams became more aware of the benefits of natural habitats for coastal protection of water infrastructure as well as other benefits they provide such as fisheries habitat and recreational. Nature-based approaches to adaptation that preserve and restore coastal habitats such as wetlands, dunes and kelp can be less costly and less damaging to coastal ecosystems as well as more resilient and flexible than other options.

Integrating Climate Change into Florida's State Wildlife Action Plan

Tool Used NatureServe CCVI | Climate Change Vulnerability Index

Project Partners

- Florida Fish and Wildlife Conservation Commission
- Defenders of Wildlife
- Massachusetts Institute of Technology Department of Urban Studies and Planning

Data Used

- Climate projections from Climate Wizard
- Sea level rise
- Species distribution and range data
- Species-specific information including ecology and natural history
- Information on other (non-climatic) threats to habitat
- Spatially explicit models of vulnerability showing potential impacts on species habitat under alternative scenarios (developed by MIT for six focal species)

Products Generated by Tool Use

- Vulnerability ranks
- Species accounts identifying model parameters and primary factors contributing to vulnerability
- Results from the vulnerability assessment were integrated into a threat assessment and used to develop adaptation strategies for six focal species (Florida panther, least tern, Atlantic salt marsh snake, short-tailed hawk, American crocodile and Key deer)

Project Websites

- » www.defenders.org/climatechange/flwildlife
- » <http://cakex.org/case-studies/2603>
- » <http://myfwc.com/conservation/special-initiatives/fwli/action-plan/download>

Project Contact

Natalie Dubois, Ph.D.

Climate Change & Wildlife Scientist, Defenders of Wildlife



*The results of this project's species vulnerability assessments led to the development of adaptation strategies for six focal species, including the least tern (*Sternula antillarum*).*

Project Background

The Florida Fish and Wildlife Conservation Commission (FWC) recognizes that climate change may impact species and habitat distributions in the state. While updating Florida's State Wildlife Action Plan (SWAP), the FWC wanted to assess how potential climate change impacts such as habitat loss and/or degradation (due to sea level rise, habitat shifts, altered hydrology, and altered disturbance regimes) may affect species' habitats. They also wanted to assess how impacts on population demographics and biotic interactions may affect management.

Using the Tool

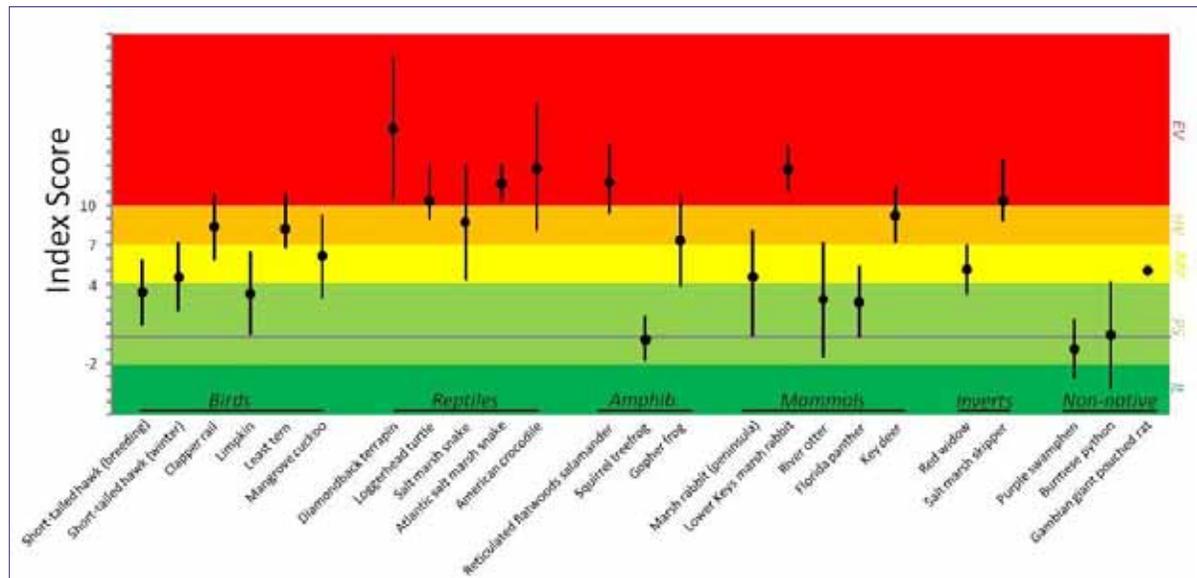
Species experts identified by the FWC provided the information needed to use the CCVI through worksheets and a conference call. Defenders of Wildlife staff parameterized the CCVI analysis using this information as well as guidance provided by the tool developer NatureServe. The CCVI was then used in a pilot effort to assess climate change vulnerability for 21 species occurring in Florida. The CCVI provided relative ranks of vulnerability and potential impacts for each species as well as a framework for identifying critical climate change drivers. Species experts reviewed the results of the assessment and provided feedback on the model parameters and outputs.

After the vulnerability assessment was completed, species experts, managers, and other conservation practitioners participated in a workshop that used the results to develop adaptation strategies for key species. The results of the CCVI were considered in conjunction with other threat assessments, including a spatially explicit scenario-based vulnerability assessment developed by MIT that incorporated additional features of the land-management context to identify where strategies might be implemented on the landscape.

Outcomes

The results of this project are informing the Florida SWAP and helping the FWC identify opportunities and management strategies to address the impacts of climate change for key species. The pilot study provided a foundation for the FWC to explore ways to apply vulnerability assessments more broadly and use results to inform agency decisions regarding species management, land acquisition, policy and regulation, and research and monitoring efforts including further integrating climate change into the SWAP.

In addition, this project provided insight on how CCVI can be adapted and/or modified to better capture factors influencing vulnerability of species and habitats in Florida.



The NatureServe CCVI uses a scoring system that integrates a species' predicted exposure to climate change within an assessment area and three sets of factors associated with climate change sensitivity.

Planning for Coastal Resiliency in the Houston-Galveston Region, Texas

Tools Used CommunityViz and WeTable

Project Partners

- Texas Coastal Watershed Program
- Placeways
- Texas A&M-AgriLife Extension

Data Used

- Standard base layers (e.g., boundaries, roads, municipalities, open water)
- Current land use
- Population projections
- Sensitive lands (e.g., environmentally sensitive, farmland, wetlands, floodplains)
- Soils
- Hurricane risk and SLOSH storm surge model results
- Miscellaneous additional information

Products generated by tool use

- Engaging and interactive CommunityViz geodesign framework used by untrained participants
- Potential regional growth scenarios (1 per table)
- Broad-spectrum impact assessments for each scenario with approximately 70 indicators

Project Website

» <http://tcwp.tamu.edu/current-projects/community-health-and-resource-management-charm>

Project Contact

Amy Anderson

Director of Planning, Placeways, LLC



Project Background

The Houston-Galveston region of Texas is growing rapidly, with anticipated population growth over the next 25 years estimated as high as 2.9 million people. Much of that growth is planned for coastal or near-coastal communities that face a number of potential hazards including hurricanes, sea level rise, water pollution, drought, flooding, and fire. In addition, local natural resources such as wetland areas, agricultural soils, and species habitat are facing pressure from development.

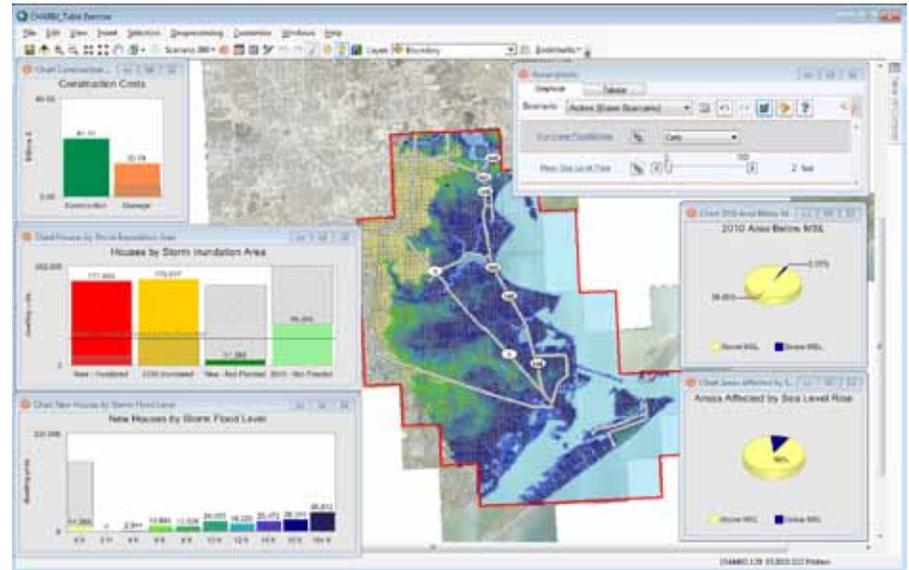
The goal of this project was to create a reusable public outreach and education workshop that would help coastal communities in Texas improve their quality of life while preserving and enhancing the natural coastal environment. The workshop, dubbed Coastal CHARM (Community Health and Resources Model), was designed to engage local stakeholders more deeply in the regional planning process. It had two purposes: teaching participants about pertinent topics like jobs and housing, climate change, hurricane risk, and water quality and gathering insight, opinions, and local knowledge from participants.

Using the Tool

The centerpiece of the workshop was a hands-on tabletop sketching exercise using CommunityViz software. The interface was projected on a low-cost “WeTable.” Participants broke into small groups and gathered around tables displaying a live map of the region. Using marker-like infrared pens as cursors, they pointed, clicked, and drew on the map to sketch alternative growth scenarios. As they sketched, charts and graphs tracked the likely implications of their plans on indicators for housing, economics, climate change, environment, hurricane risk, and water quality. Some challenges that became apparent through this process were that location-specific data needed to be pre-processing and artful trade-offs made between modeling rigor and ease of use.



The CommunityViz/WeTable setup allows participants to draw on a projected map and see the results of map changes.



Sophisticated models provide immediate feedback on parameters to users.

Outcomes

The workshops demonstrated that complex spatial modeling and decision support software can be used by the public through an intuitive user interface. As a result of these workshops, stakeholder awareness increased. Articles about the workshops in local media such as the Houston Chronicle were particularly influential. Similar workshops in other areas are planned. Future workshops will feature even more intuitive user presentation and improvements to the CommunityViz CHARM model including making it robust to variances in input data from different locations. In addition, CommunityViz has now added a wizard to integrate outputs from FEMA’s Hazus-MH model.

Assessing Conservation in Coastal Georgia

Tools Used NatureServe Vista, Marxan, Maxent, and Circuitscape

Project Partners

- Georgia Department of Natural Resources
- Georgia Conservancy
- Association County Commissioners of Georgia
- NatureServe

Data Used

- Habitat maps
- Species occurrences
- Predicted species distribution maps
- Current land use and infrastructure
- Proposed development (Developments of Regional Impact)
- County zoning
- Sea level rise maps from SLAMM

Products generated by tool use

- Biodiversity element reports
- Conservation value summaries
- Scenarios
- Scenario evaluations

Project Website

» www.natureserve.org/visitLocal/conference/BWB2010/04-28_PCrist-GA.pdf

Project Contact

Patrick Crist, Ph.D.

Director of Conservation Planning, NatureServe



Project Background

Coastal Georgia is a hotspot of biological diversity with 74 high priority animal species, 88 high priority plant species, and 25 high priority habitats. The Coastal Georgia Land Conservation Initiative, a program under the Georgia Department of Natural Resources, set a goal to conserve critical coastal lands and ecosystems while promoting appropriate economic growth and development. Key priorities for the Initiative were to assess the potential cumulative effects of sea level rise and large coastal developments on biodiversity and determine areas important for conservation and connectivity between conservation areas. To meet these needs, the partners initiated a coastal assessment to identify, document, and map high priority natural communities and rare species sites for consideration in land conservation programs.

Using the Tool

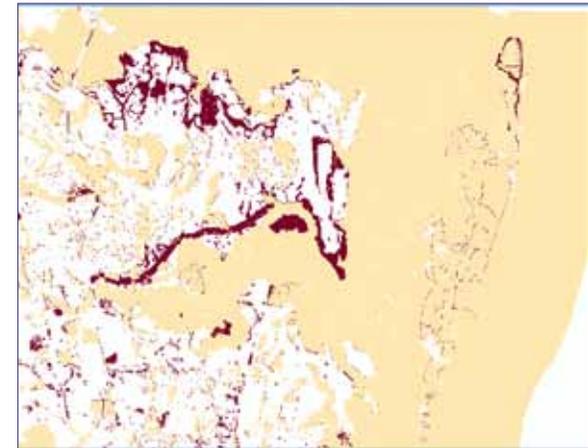
NatureServe Vista was used to integrate data and output from the other tools and conduct cumulative effects assessment of current, near term, and longer term (climate change) scenarios on biodiversity elements. Scenario evaluation identified areas and specific biodiversity elements (species and habitats) that could be impacted by future proposed development and sea level rise. Maxent and Circuitscape provided species distribution maps and connectivity areas respectively as input to NatureServe Vista. Marxan was used interactively with the NatureServe Vista database to create a set of optimized conservation scenarios that were then imported back into NatureServe Vista. SLAMM was not run as part of the project, but SLAMM sea level rise outputs were used in the project.

Outcomes

The NatureServe Vista project database, training, and a project use and maintenance manual were provided to the partnership. A follow up green infrastructure plan for part of the area was produced using the data and tool.



Current scenario



Current scenario with proposed future development



Current scenario with proposed future development and sea level rise



Final Thoughts

As this guide demonstrates, tools can provide extremely powerful functionality for climate adaptation processes including visualization of current and future conditions, improved understanding of biological, geophysical, and socioeconomic processes, and the ability to create “what if” scenarios. Some steps in the planning process are not well represented by tool functionality, however, particularly monitoring and evaluation (see *Figure 3*). We recommend this as a particularly important area for further research and development by the tool development community.

Geospatial technology and tools are currently undergoing considerable evolution with mapping services, viewers, and applications increasingly being offered over the Internet (i.e. cloud computing). The rapid move to online/cloud computing raises more options and challenges for tool users including choosing when to use these services versus obtaining and using software on a desktop and how to share data between cloud-based tools and existing desktop tools. Cloud-based tools are often focused on specific regions or localities and are thus not covered in this guide. We recommend finding out who the leaders in geospatial technology and analysis in your area are (e.g., universities, nonprofit organizations, state agencies) and connecting with them to find out what cloud-based tools are available or will be available shortly for your project region or site.

Finally and most importantly, we want to emphasize that tools should support your planning processes. The most important elements of a planning process are answering questions that need answering and making informed decisions. Tool use should neither drive nor discourage the process. While selecting a tool may seem daunting, using a structured approach to selecting a tool (described in this guide) will help you hone in on what you need from a tool and whether or not a tool is a good fit for your process. There are many resources and sources of expertise available to help you find solutions as well as a growing community of climate adaptation planners that are anxious to help and share approaches.

Good luck!

Appendix

Published climate change adaptation planning processes

Organization	Document Title	Scope	Sectors	Planning Steps
ICLEI ¹	Changing Climate, Changing Communities	Adaptation Planning	Built Environment	<ol style="list-style-type: none"> 1. Initiate 2. Research 3. Plan 4. Implement 5. Monitor/Review
U.S. Fish and Wildlife Service ²	Scanning the Conservation Horizon	Vulnerability Assessments	Natural Resources	<ol style="list-style-type: none"> 1. Identify Conservation Target 2. Assess Vulnerability 3. Identify Management Options 4. Implement Management Options
State of California ³	Climate Adaptation Planning Guide	Adaptation Planning	Natural Resources, Built Environment	<ol style="list-style-type: none"> 1. Exposure 2. Sensitivity 3. Potential Impacts 4. Adaptive Capacity 5. Risk and Onset 6. Prioritize Adaptive Needs 7. Identify Strategies 8. Evaluate and Prioritize 9. Phase and Implement
U.S. Fish & Wildlife/NatureServe ⁴	Conducting Refuge Vulnerability Assessment and Adaptation Planning	Vulnerability Assessment and Adaptation Planning	Natural Resources, Built Environment	<ol style="list-style-type: none"> 1. Characterization 2. Issues Prioritization & Workplan 3. Characterize Current and Future Scenarios 4. Evaluate Effects 5. Identify Strategies 6. Synthesize Strategies into Alternatives
NOAA ⁵	Adapting to Climate Change: A Planning Guide for State Coastal Managers	Adaptation Planning	Natural Resources	<ol style="list-style-type: none"> 1. Establish Planning Process 2. Assess Vulnerability 3. Create Adaptation Strategy 4. Design Implementation and Maintenance Process

1 Jackson, E., L. Barry, and N. Marzok. 2011. *Changing Climate, Changing Communities: Municipal Climate Adaptation Guide and Workbook*. ICLEI Canada, Toronto, Ont., Canada

2 Glick, P., B.A. Stein, and N.A. Edelson, eds. 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. National Wildlife Federation, Washington, D.C.

3 California Emergency Management Agency and California Natural Resource Agency. 2012. *California Adaptation Planning Guide*. Sacramento, Calif.

4 Crist, P.J., M. Harkness, and P. Comer. 2012. *Manager's Guide to Refuge Vulnerability Assessment and Alternatives: Overview and Practical Considerations*. U.S. Fish and Wildlife Service. Arlington, Va.

5 National Oceanic and Atmospheric Administration. 2010. *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA Office of Ocean and Coastal Resource Management.

About Us

This guide was created by the Coastal-Marine Ecosystem-Based Management Tools Network (EBM Tools Network, www.ebmtools.org), coordinated by NatureServe (www.natureserve.org). The EBM Tools Network is a respected global network of ecosystem-based management practitioners and tool experts to promote methods and tools for improving conservation and management in coastal and marine environments and their watersheds.

The Network is over 5,000 members strong and includes members from federal, state, and local governments and international bodies; universities and research institutes; conservation groups; philanthropic foundations; and independent consultancies and for-profit tool providers. It is a trusted source of information about tools for coastal and marine conservation and management and provides tools-related information through trainings, webinars, live chats, workshops, focused meetings, conference presentations and symposia, listserves, newsletters, databases, and toolkits.

The EBM Tools Network's Training Program, led by NatureServe and NOAA Coastal Services Center, bridges the gap between practitioner needs and the knowledge of tool developers and application experts. The Training Program connects practitioners and experts in a number of ways including online education and resources, tailored trainings, and providing advice and technical services to communities and organizations.

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- Patrick Crist, NatureServe (NatureServe Vista)
- Christopher Emrich, University of South Carolina (SoVI)
- Dave Eslinger, NOAA Coastal Services Center (OpenNSPECT)
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- Chester Arnold, University of Connecticut

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4 (*clockwise from left*)

- * Beach erosion at the Outer Banks. CC-BY 2005 David Lindbo, Soil Science (<http://www.flickr.com/photos/soilscience/5086370189/>)
- * Upper Sugarloaf Key, Florida. Creative Commons BY-NC-SA 2009 KeysGLEE (<http://www.flickr.com/photos/keysglee/3960630614/>)
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5 Erosion effects on pilings in Rehoboth Beach, Delaware, after a November 2009 storm. Creative Commons BY-NC-ND 2010 Victoria Pickering (<http://www.flickr.com/photos/vpickering/4284581911/>)

6 High tide in Sausalito, California. Creative Commons BY-NC-SA 2010 Yanna.B (<http://www.flickr.com/photos/58537801@N07/5386391709/>)

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- 34** Dogs and owners frolicking along the shore of Monterey Bay near the Santa Cruz lighthouse. Creative Commons BY-NC-SA 2009 jacdupree (<http://www.flickr.com/photos/jacdupree/4107511270/>)
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- 42** Road in E.B. Forsythe National Wildlife Refuge, Oceanville, New Jersey. Creative Commons BY 2010 Bill Butcher / USFWS (<http://www.flickr.com/photos/usfwsnortheast/4730504447/>)

Tools for Coastal Climate Adaptation Planning

A Guide for Selecting Tools to Assist with Ecosystem-Based Climate Planning



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