Survey *of* State Initiatives *for* Conservation *of* Coastal Habitats *from* Sea-Level Rise

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September 2009

This survey seeks to summarize the actions that states have taken to protect essential habitats, such as wetlands and estuaries, from the anticipated rise in sea levels caused by anthropomorphic climate change. This is an overlap of two areas: policies addressing sea level rise as a result of climate change, and conservation policies. The intersection of these two policy areas can be neglected. Policies on sea level rise often focus only on protecting human development, and conservation policies often do not incorporate a dynamic coastline.

The fundamental issue for the survival of coastal habitats is habitat migration. Eustatic (global) sea level has been rising naturally for thousands of years, but coastal habitats have been able to adapt by migrating inland. The problem now facing policymakers is that two obstacles threaten the ability of

coastal habitats to migrate: first, human development inland often deprives coastal habitats of space to migrate to—coastal habitats are squeezed out between human development and rising sea levels. Second, the accelerated rate of eustatic sea level rise because of anthropogenic global warming may outpace the ability of coastal habitats to migrate. Furthermore, even if we were to immediately limit or eliminate greenhouse gas emissions, the accelerated pace of sea level rise will continue for at least 50 years.

However, states around the US are increasingly taking notice of this specific threat to natural habitats from sea level rise. Now, policies protecting human development often integrate environmental considerations; most states now strongly discourage or totally disallow 'shoreline armoring' such as seawalls and bulkheads out of recognition that they completely halt habitat migration. And coastal conservation policies often focus not just on current wetlands, but where the wetlands are projected to be after a rise in sea level. Many states have adopted future wetland locations into land-use planning, and target upland areas that may not currently be wetlands for land acquisition.

This is an attempt to comprehensively summarize how each coastal state is addressing this issue. The focus is not on a theoretical summary of adaptation options, but summarizing what has actually been done (both in creating policy and implementing it). The primary purpose is to serve as a reference for the Rhode Island Coastal Resources Management Council (CRMC) as it plans its own sea level rise policy, but it can hopefully be similarly relevant for other states.

Works of particular interest are marked with a *. Since the vast majority of the summary is formal in its attempt to be comprehensive, and thus likely not of interest to the general policymakers, the asterisks denotes a study or example that may be especially relevant beyond the state in which they originate.

The author apologizes for any omissions of significant policies or actions taken by states to address this issue. Also, the author regrets being unable to expand the survey to foreign initiatives, where there may well be exemplary and innovative actions not known in the U.S. Rhode Island is excluded from this survey as it currently lacks but will shortly have a policy explicitly addressing habitat loss from sea level rise.

General Information

* S. Julius, J. West et al. "Final Report, Synthesis and Assessment Product 4.4: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources." U.S. Climate Change Science Program and the Subcommittee on Global Change Research. June 2008.[1]

This is the most comprehensive summary of the threats of climate change to all ecosystems (including the threat of sea level rise to coastal habitats), as well as adaptation options. This should be consulted as the central resource for policymakers engaged with this issue. However, except for some case studies, there are not detailed and specific examples.

* U.S. EPA (2009). "Synthesis of Adaptation Options for Coastal Areas." Washington, DC, U.S. Environmental Protection Agency, Climate Ready Estuaries Program. EPA 430-F-08-024, January 2009.[2]

[1] http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-all.pdf
[2] http://www.epa.gov/cre/downloads/CRE_Synthesis_1.09.pdf

An overview of adaptation options, including examples of each method from different state programs. Unlike our "Survey of State Initiatives for Conservation of Coastal Habitats from Sea Level Rise," the synthesis lists the various adaptation options and then lists which states and which programs have pursued each. Our survey gives details for various citations given in the synthesis relating to habitat conservation.

* EPA. "U.S. Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region." January 2009.[3]

As explained in the Executive Summary: "Part I first provides context and addresses the effects of sea-level rise on the physical environment… Chapter 4 considers the ability of wetlands to accumulate sediments and survive in response to rising sea level. Chapter 5 examines the habitats and species that will be vulnerable to sea-level rise related impacts. Part II describes the societal impacts and implications of sea-level rise. Chapter 6 provides a framework for assessing shoreline protection options in response to sea-level rise."

This is a very comprehensive report; however, Chapter 6, which considers the options for management, focuses on protecting human infrastructure and secondarily on how such efforts should minimize harm on natural habitats. There is no discussion about what to do when prioritizing the protection of natural habitats.

Committee on Mitigating Shore Erosion along Sheltered Coasts, National Research Council Ocean Studies Board. "Mitigating Shoreline Erosion Along Sheltered Coasts." National Academies Press. 2007. [4]

This is a discussion shoreline management techniques, technologies and measures with—very usefully—specific examples from the United States and abroad given. A summary of sea level rise is on pages 34-36. But, similar to SAP 4.1, this focuses on preventing erosion, and protection of human infrastructure. In Chapter 3, page 66 discusses "Nontraditional and Innovative Methods," but again for the purpose of erosion control. Also in Chapter 3, managed land use is presented, but without examples. While Chapter 4 is about unintended environmental consequences of various measures, nowhere are there management options presented whose priority is the habitat.

P. Rubinoff et al. "Summary of Coastal Program Initiatives that address Sea Level Rise as a result of Global Climate Change." Rhode Island Sea Grant/Coastal Resources Center, University of Rhode Island. February 2008.[5]

Our survey is based off Rubinoff's paper. We shift the focus specifically to sea level rise on natural habitats instead of general climate change initiatives relating to coastal resources, provide more details, and include changes that have taken place since the February 2008 publication.

Environmental Law Institute. "Study of State Wetland Programs." March 2008.[6]

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[3] This exists in two versions: an expanded technical version, and a summarized and accessible version. Respectively:
http://www.climatescience.gov/Library/sap/sap4-1/final-report/sap4-1-final-report-all.pdf
http://www.epa.gov/climatechange/effects/coastal/SAP%204.1%20Final%20Report%2001.15.09.pdf

[4] Links to the book online, and a downloadable pdf of the executive summary available at:
http://www.nap.edu/catalog.php?record_id=11764 or a nearly-complete version on Google Books,
http://books.google.com/books?id=AZAnasHRoZsC&printsec=frontcover&source=gbs_v2_summary_r&cad=0.
See in particular Chapter 3, "Methods for Addressing Erosion": http://books.nap.edu/openbook.php?record_id=11764&page=44.

[5] http://seagrant.gso.uri.edu/ccd/slr/SLR_policies_summary_Mar6_final.pdf.

While not mentioning sea level rise, this study presents a comprehensive review of wetland protection programs of each state using the EPA criteria of seven core elements: regulation, water quality standards, monitoring and assessment, restoration programs and activities, public-private partnerships, and coordination among state and federal agencies.

C. Hendrick. "State, Territory, and Commonwealth Beach Nourishment Programs: A National Overview." Office of Ocean & Coastal Resource Management Program Policy Series Technical Document No. 00-01. March 2000.

Beach nourishment is an effective but expensive management option for coastal erosion (erosion is related to but not synonymous with sea level rise[7]). This is relevant to our survey because when done correctly, beach ecosystems can benefit from nourishment. While this study is several years old now, it provides a comprehensive summary of the program in each state.

[6] http://www.eli.org/Program_Areas/state_wetlands.cfm.
Summary Report at http://www.elistore.org/reports_detail.asp?ID=11279.
[7] Zhang et al, "Global Warming and Coastal Erosion." *Climatic Change* 64 (2004): 41–58.
http://www.springerlink.com/content/w072202jr03xh214/BodyRef/PDF/10584_2004_Article_5149871.pdf

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Alabama

Research

1 A 1990 study by the Mississippi-Alabama Sea Grant Consortium (MASGC) used data from 1940 to 1990 to calculate sea level rise at the Alabama State Docks in Mobile, Alabama. The estimated rate of rise was 0.005 ft/yr (1.5 mm/yr).[8]

2 Using available data from 1979 to 2005 for 98 reference points along the Alabama coastline, the Geological Survey of Alabama and the State Lands Division of the Alabama Department of Conservation and Natural Resources found recession rates for Perdido Pass (2 ft/yr), Little Lagoon Pass (6 ft/yr), the west end of Morgan Peninsula (10 to 44 ft/yr), Eastern Dauphin Island (7 to 14 ft/yr), and West Dauphin Island (6 ft/yr).[9]

3 In 2007, the Alabama Department of Conservation and Natural Resources reported that unlike Louisiana and Texas' coastal resources, Alabama's major estuarine system was sediment rich and stable from erosion. Hence, relative sea level rise was not considered a large concern for Alabama.[10] Similarly, the Alabama Department of Conservation and Natural Resources ranks sea level rise as "Low Risk" (on a scale of low, medium and high).[11]

4 The EPA administered and funded but non-regulatory Mobile Bay National Estuary Program has concerns about the loss of wetlands due to shoreline armoring. 50% of Alabama's coastal wetlands have been lost, and projections estimate that half of the shoreline will be armored by 2010.[12]

5 According to a 2008 NOAA workshop,[13] the Center for Sponsored Coastal Ocean Research (CSCOR) will begin to study sea level rise in Alabama and the Florida Panhandle beginning in 2010.

6 On March 10 and March 11, 2009, government agencies held two workshops in Biloxi, Mississippi. Here, Mississippi and Alabama professionals expressed a need for models of sea level rise and climate change to allow risk assessment. According to MASGC, a federal group will begin to customize and deliver tools to Mississippi and Alabama within three to six months of the workshops.[14]

Policy

1 Currently none explicitly addressing habitat loss from sea level rise.[15]

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[8] "Long Term Implications of Sea Level Change for the Mississippi and Alabama Coastlines: Proceedings of a Conference Presented in Biloxi, Mississippi" (September 1990): 40. http://www.masgc.org/pdf/masgp/90-015.pdf

[9] R. Swann et al, "State of Mobile Bay: A Status Report on Alabama's Coastline from the Delta to Our Coastal Waters," Mobile Bay National Estuary Program, Science Advisory Committee. (November 2008): p 20. http://www.mobilebaynep.com/site/news_pubs/Publications/Indicator_Report-Final.pdf

[10] P. Rubinoff et al, "Summary of Coastal Program Initiatives that address Sea Level Rise as a result of Global Climate Change" (February 2008): 5, 32. http://seagrant.gso.uri.edu/ccd/slr/SLR_policies_summary_Mar6_final.pdf

[11] Alabama Department of Conservation and Natural Resources, "Alabama Coastal Area Management Program, Section 309: Enhancement Grant Program Assessment and Strategy" (February 2006): 6, 32. http://www.dcnr.state.al.us/public-lands/stateLands/landsCoastal/309%20Assessment%202006%20Final.pdf.

[12] T. Herder, "Living Shorelines as Alternatives to Bulkheading/Shoreline Hardening," Alabama Current Connection (Spring 2007): 1. http://www.mobilebaynep.com/site/news_pubs/AL-Current-V2-Issue1-2007-1.pdf,

[13] National Oceanic and Atmospheric Administration, "White Paper: Summary of the NOAA Workshop 'Ecological Effects of Sea Level Rise in the Florida Panhandle and Coastal Alabama: Research and Modeling Needs'," Center for Sponsored Coastal Ocean Research, National Oceanic and Atmospheric Administration (2008). http://www.cop.noaa.gov/stressors/climatechange/workshops/slr-fl-al-2008.pdf

[14] Mississippi-Alabama Sea Grant Consortium, "Press Release: Leaders ask for reliable models to predict sea-level rise, flooding," (March 25, 2009). http://www.masgc.org/page.asp?id=402

[15] Environmental Law Institute, "State Wetland Protection Status, Trends & Model Approaches; Appendix: State Profiles, Alabama" (2008): 5. http://www.eli.org/pdf/core_states/Alabama.pdf

2 The Alabama Department of Environmental Management's Nonpoint Source Management Program has the follow policy for management of eroding streambanks or shorelines: "Where streambank or shoreline erosion is a nonpoint source pollution problem, streambanks and shorelines should be stabilized. Vegetative methods are strongly preferred unless structural methods are more cost effective considering the severity of wave and wind erosion, offshore bathymetry, and the potential adverse impact on other streambanks, shorelines, and offshore areas".[16]

3 The State Code of Alabama regulates coastal resources in Title 9 "Conservation and Natural Resources," Chapter 7 "Preservation, Development, Etc., of Coastal Areas." §9-7-13(3) requires that "construction and maintenance of piers, boathouses and similar structures shall be on pilings that permit a reasonably unobstructed ebb and flow of the tide." Beyond this, the state code charges the Coastal Area Board and the Department of Environmental Management with regulation.[17]

4 See Mississippi-Policy-2.

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. As cited in Alabama-Research-4 above, half of Alabama's shoreline may be armored by 2010.

[16] Alabama Department of Environmental Management, "Nonpoint Source Management Program, Part II: Hydrologic / Habitat Modification" (1999): 14 (II.A.1). http://www.adem.state.al.us/Education%20Div/Nonpoint%20Program/Mgt/partIIhy.pdf

[17] The Code of Alabama 1975. http://www.legislature.state.al.us/CodeofAlabama/1975/coatoc.htm http://www.legislature.state.al.us/CodeofAlabama/1975/9-7-13.htm

Alaska

Research

1 In 2005, the state conducted a Baseline Erosion Assessment to address a lack of a coordinated formal state erosion control program.[18] The Assessment was charged with coordinating, planning, and prioritizing appropriate responses to erosion in Alaska.[19]

In a survey of local initiatives, the study found that individual communities use sandbags, 55-gallon drums, old construction equipment, abandoned cars, and broken heavy machinery to slow erosion. The State often provided funding and assistance for more comprehensive local projects. Federal agencies played a similar role, where the Army Corps of Engineers taking actions such as constructing bank protection (riprap revetment and tie protection, pipe-pile bulkheads strengthened by steel tieback rods, brush and natural timber fascines).

A majority of 127 communities that completed a survey reported experiencing river/stream or beach erosion. The major cause of coastline erosion was storm surges, and the next most frequent cause was wind, waves and high tides. Erosion was both gradual and from discrete events. Most communities managed it using fill, concrete blocks, 55-gallondrums, dikes, and tree branches. Less common was beach nourishment, and surveyed communities generally lacked funding for more permanent structures. The measures taken had mixed success, slowing but not stopping erosion.[20]

Suggested shoreline protection measures

[18] U.S. Army Corps of Engineers, Alaska District, "Study Findings and Technical Report: Alaska Baseline Erosion Assessment" (March 2009): ES-2. http://www.climatechange.alaska.gov/docs/iaw_USACE_erosion_rpt.pdf

[19] Ibid., 1:1.

[20] Ibid., 2:1 - 2:5.

"include (1) engineered geotextile sandbag revetment, (2) beach nourishment, and (3) modified geotextile wrap revetment. Significant investments are required to achieve the durability needed to resist even the smallest wave climate. These methods are only suggestions and should be carried forward after considering all available options. Any method of shore protection, if properly implemented, is expensive. In some instances, constructing a shoreline protection structure or hardening the shoreline can exacerbate erosion problems rather than mitigate them. Erosion problems are often caused by failure to recognize that shorelines have always been areas of continuous and sometimes dramatic change."[21]

2 Sea level rise is not mentioned as a problem facing Alaska in the 2009 NOAA Climate Impacts Report. In fact, the most densely populated parts of Alaska in the south and southeast are, because of glacial isostatic adjustment, rising faster than the sea level.[22] Yet problems stemming from rising temperatures present Alaska with challenges similar to those posed by sea level rise. On the coast, melting ice and permafrost has exposed coastlines to erosion from wind and water. The rates of coastal erosion have doubled in the past 50 years, with some coastlines now loosing an average of tens of feet per year. The lands of several native communities are 'literally crumbling into the seas;' and coastal floods have inundated the downtown streets of the city of Nome. Decreasing air pressure as well as more available heat and moisture is likely to cause more frequent and/or intense storms.[23]

[21] Ibid., 5:7, 5:8.
[22] Ocean Studies Board, "Mitigating Shore Erosion along Sheltered Coasts" (2007): 36. http://books.nap.edu/openbook.php?record_id=11764&page=36
S. Julius, J. West et al, "Final Report, Synthesis and Assessment Product 4.4: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources," U.S. Climate Change Science Program and the Subcommittee on Global Change Research (June 2008): 5:20. http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-all.pdf
[23] U.S. Global Change Research Program, "Global Climate Change Impacts in the United States" (2009): 147. http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

Policies

1 The Alaska Coastal Program has regulations to protect specific natural processes as "natural hazard areas," which allows the prevention of development.[24]

2 On September 14, 2007, Governor Palin administered Administrative Order 238, creating the Alaska Climate Change Sub-Cabinet. This is a workgroup consisting of federal, state and local representatives to advise the Office of the Governor on the preparation and implementation of a climate change strategy.

The Order cites the existence of scientific evidence that Alaska is undergoing a warming trend at a faster pace than any other state that will cause coastal erosion, thawing permafrost, retreating sea ice, and record forest fires, among other effects. It states, "Alaska needs a strategy to identify and mitigate potential impacts of climate change and to guide its efforts in evaluating and addressing known or suspected causes of climate change. Alaska's climate change strategy must be built on sound science and the best available facts and must recognize Alaska's interest in economic growth and the development of its resources. Commercializing Alaska's great natural gas reserves through a new pipeline will improve the nation's energy security while providing a clean, low carbon fuel to help the nation reduce its overall greenhouse gas emissions."[25]

3 On September 21, 2007, Governor Palin signed Alaska as an 'Observer' to the Western Climate Initiative (WCI), "a collaboration launched in February 2007 between the Governors of Arizona, California, New Mexico, Oregon and Washington to meet regional challenges raised by climate change. Other States and Canadian Provinces have

[24] Rubinoff 30.
[25] Sarah Palin, "Administrative Order No. 238," State of Alaska Office of the Governor (June 23, 2009). http://www.gov.state.ak.us/admin-orders/238.html

joined, some as partners, some as observers."[26]

4 In December 2007, the City of Homer issued a Climate Action Plan. The Plan includes criticism of state-level inaction, including a criticism of the Climate Change Sub-Cabinet as having done nothing significant to that point and not having regulatory power. The plan focused mainly on reducing greenhouse gas emissions.[27]

5 In July 2008, Governor Palin mailed a pamphlet to all Alaskans to inform them about the risks of climate change and the actions being taken by the state.

Acting on the recommendations of the Sub-Cabinet, included in the 2009 budget was funding for the construction within 18 months of additional flood protection structures in Kivalina and Unalakleet, and an evacuation road and shelter for Newtok, a village that will not be able to be protected and must be moved. Also included in the budget is a grant program to provide at-risk communities professional planning and engineering services to evaluate needs and options. The pamphlet includes a figure that "flooding and erosion affect 184 out of 213, or 86 percent of Alaska Native villages to some extent."

Also mentioned is a workgroup looking at ways that federal, state and local governments can "save the taxpayers money while reducing government's carbon footprint… commercialization of [Alaska's] vast North Slope Natural Gas reserves, to assist the rest of the country in securing a steady, affordable, low-carbon energy source… will be an element of our climate change strategy."[28]

6 The Sub-cabinet initiated a stakeholder process, and the final recommendations of the stakeholder groups will be delivered in a written to the sub-cabinet in early fall 2009.[29]

7 The Research Needs Work Group (RNWG) of the Sub-cabinet issued a draft report of its recommendations in June 2009. The RNWG included a Natural Systems Technical Working Group, which developed a catalog of research needs related to adaptation options for expected effects of climate change on Alaska's natural systems. Included were the needs to "identify and research laws, policies, and regulations that could be modified to better support adaptation," to research changes to vital ecosystems including possible tipping points, to map and characterize the coastline, and to asses, model and monitor coastal impacts of sea level changes.[30]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. For a summary of actions taken in individual towns and by various agencies, see the May 2009 Final Report of the Immediate Action Workgroup.[31] This report also includes individual suggested immediate actions for each town and government agency. This report contains detailed listings about necessary actions, associated costs, and sources of funding, but the focus is entirely on human life and infrastructure (for example, community profiles mention natural resources only as a subset of economy, and threats to "critical habitat and/or use areas" are a subset of "Subsistence and Shoreline Use" in a draft

[26] Climate Change Sub-Cabinet, "Alaska Climate Change Strategy." http://www.climatechange.alaska.gov/
[27] Global Warming Task Force, "City of Homer Climate Action Plan: Reducing the Threat of Global Climate Change Through Government and Community Efforts" (December 2007): 14. http://www.ci.homer.ak.us/CLPL.pdf
[28] "Governor Sarah Palin's Report on Climate Change Sub-Cabinet" (July 2008). http://www.climatechange.alaska.gov/docs/govrpt_jul08.pdf
[29] J. Poston, "Press Release: Sub-cabinet marks milestones in development of Alaska Climate Change Strategy" (June 23, 2009). http://www.climatechange.alaska.gov/docs/pr_23jun09.pdf
[30] Research Needs Work Group, "Recommendations on Research Needs Necessary to Implement an Alaska Climate Change Strategy" (June 2009): 50-54. http://www.climatechange.alaska.gov/docs/rn_12jun09_dftrpt.pdf
[31] Immediate Action Workgroup, "Recommendations to the Governor's Subcabinet on Climate Change" (March 2009). http://www.climatechange.alaska.gov/docs/iaw_finalrpt_12mar09.pdf

of a "Rating Criteria for Severity of Damage Evaluation Factors."[32]).

Note that coastal wetlands coming under threat from sea level rise is not a high concern in Alaska as for coastal states of the continental US for several reasons. First, Alaska does have huge tracts of threatened wetlands, but they are in the state's interior; second, Alaska is not experiencing significant sea level rise; and most importantly, there are certain Alaskan communities, such as Kivalina,[33] Koyukuk, Newtok,[34] Shaktoolik,[35] Shishmaref[36] and Unalakleet that are under very real danger of being completely destroyed by erosion in the near future. Understandably, the focus of coastal climate change initiatives is on the protection, evacuation, and relocation of the people who live in these communities.

2 * In 2008, the Inupiat Eskimo village of Kivalina, with a population of about 390 people, sued Exxon Mobil Corp., BP PLC, seven other oil companies, fourteen power companies and one coal company. Kivalina has claimed that the greenhouses gases emitted by these companies contribute to the global warming that is melting the sea ice that has protected the community. The grounds given are the federal common law of public nuisance, which could make liable every entity that contributes to the global warming harming the village. This was the first lawsuit filed for damages from global warming with a specifically identifiable victim.[37]

[32] Ibid., 92, 96.
[33] US Army Corps of Engineers Civil Works Branch Alaska District, "Kivalina Relocation Master Plan Final Report" (June 2006). http://www.poa.usace.army.mil/en/cw/Kivalina/Kivalina.html
[34] Alaska Division of Community and Regional Affairs, "Newtok Planning Group" (May 2006). http://www.commerce.state.ak.us/dca/planning/Newtok_Planning_Group_Webpage.htm
[35] Kawerak Transportation Program, "Shaktoolik Evacuation Road Project: Route Reconnaissance Report" (December 2008). http://www.climatechange.alaska.gov/docs/iaw_shakt_evac_rd_sht.pdf
[36] Shishmaref Erosion and Relocation Coalition, "Shishmaref Erosion and Relocation Activities" (April 2009). http://www.shishmarefrelocation.com/activities.html
[37] Associated Press, "Eroding Alaska town sues oil, power firms" (February 2008). http://www.msnbc.msn.com/id/23367934/

California

Research

1 "In the early 1800s, before diking and filling had begun, tidal marshes covered some 190,000 acres on the fringes of the Bay. Tidal marsh bordering the Bay now totals approximately 40,000 acres—a loss of approximately 80 percent of the Bay's historic tidal marshes."[38]

2 * In 2001, the California Coastal Commission staff prepared a document investigating possible effects to the California coast from accelerating sea level rise, entitled "Overview of Sea Level Rise and Some Implications for Coastal California." NOAA records show a rise of 0.0043 ft/yr (1.3 mm/yr) in San Francisco from 1955 to 1980. However, the study notes, "If the concern is with the future viability of a wetland, the project should be considered in light of the changes to the tidal range between lower low water and higher high water. Project studies should look at the changes to these components in addition to, or possibly in place of, the changes to mean sea level."

Both diurnal and mean tide ranges have increased since 1900: "The diurnal range increased at a rate of 0.199 ft/100 yr (0.061 m/100 yr), and the mean range at a rate of 0.192 ft/100 yr (0.0585 m/100yr). The rise in mean sea level has been about 0.72 ft/100 yr (0.219m/100 yr) while the rise in MHHW and MHW for the same period have been 0.85 ft/100 yr (0.259 m/100 yr) and 0.82 ft/100 yr (0.250 m/100 yr)."[39]

The report notes that the consequences for coastal wetlands will vary by local topography and whether or not there is fixed development preventing migration upward and landward. Another change to wetlands from sea level rise will be an increase in tidal currents, bringing a potential for increased scour. For estuarine systems, the salt water-freshwater interface will shift, and the zone of brackish water will move inland.[40]

In discussing possible "Responses to Sea Level Rise," the Commission considers hard and soft engineering measures, accommodation/adaptation, and retreat, but only with regards to protecting human development. However, in discussing "Planning and Regulator Responses for Sea Level Rise," the document notes that the Commission can establish wetland buffers to allow future inland or upland migration of wetlands.[41]

The document briefly looks to other coastal states: "States have not passed special regulations to address sea level rise. Most coastal states have coastal programs that address sea level rise in a manner that is similar to California's -- they modify or adapt current regulatory mechanisms to cover the effects of sea level rise."[42] Mentioned examples are the rolling easements of Texas, the prohibitions on any hard shoreline armoring by North Carolina, South Carolina and Massachusetts, and regulations prohibiting rebuilding damaged structures in Maine.[43]

3 A 2006 report from the California Climate Change Center, entitled "Projecting Future Sea Level Rise," considers a range of projected future sea level rises. Although the rate of rise at California tide gauges has flattened since the 1980s, the study gives priority to global projections. In addition to global sea level rise, the study considers weather events that have previously coincided with higher coastal sea levels, such as El Niño,

[38] San Francisco Bay Conservation and Development Commission, "San Francisco Bay Plan" (January 2008): 22. http://www.bcdc.ca.gov/pdf/planning/plans/bayplan/bayplan.pdf

[39] California Coastal Commission, "Overview of Sea Level Rise and Some Implications for Coastal California" (June 2001): 8. http://www.coastal.ca.gov/climate/SeaLevelRise2001.pdf

[40] Ibid., 17.

[41] Ibid., 20-27.

[42] Note that this statement is not accurate; in particular, Maine had by this time developed regulatory mechanisms specifically in response to sea level rise.

[43] Ibid., 27.

from periods a season in length to those with a period of decades. The study estimated mean sea level rise values will range from 10-80 cm between 2000 and 2100. The middle to higher range exceeds the historical rate of sea level rise of 15-20 cm per century, as recorded from San Francisco and San Diego.[44]

4 A July 2006 technical memorandum report from the California Department of Water Resources, entitled "Progress on Incorporating Climate Change into Management of California's Water Resources," created preliminary models for salt water inundation. While it looked mainly at chloride concentrations in municipal and industrial intake, it also notes, "a possible result of climate change is that Delta smelt will have little or no suitable habitat in summer. Waters in the lower Delta may be too salty and lacking in food, while fresh water in the upper Delta may be too warm. Thus, the species may become much less numerous or may even go extinct."[45]

The report also includes summaries of data for sea level rise from various sites around California with some tide gauges measurements dating to 1906. In Crescent City, the sea level is dropping at a rate of 0.16 ft/century, but elsewhere else it is rising. In San Francisco, the rate of rise is 0.70 ft/century; Los Angeles, 0.28 ft/century; and San Diego, 0.71 ft/century.[46]

5 "How to restore coastal habitat in the face of sea level rise," a PowerPoint presentation by Natalie C-Manning, Restoration Specialist at the NOAA Fisheries Restoration Center in Santa Rosa, CA, asks, "will current restoration projects succeed in the face of sea-level rise?" The presentation cites over 100 ongoing restoration efforts around the bay, covering 18,000 acres of tidal marsh, 10 acres of eelgrass and native oyster reefs, 20 freshwater stream miles, and 50 acres of riparian habitat. These projects are the efforts of state, federal and local agencies, non-profits, private funds, and over 100 active community groups.

The risks from rising sea level include possibly expanded habitat for invasive species, wasted money and effort, and alteration of habitat characteristics, including depth, light, and sedimentation changes. However, there are benefits as well, as newly inundated shoreline increases potential habitat areas, and invasive species might retreat. Sea level rise is an opportunity to reclaim historic tidal habitat, and the presentation encourages viewing it as an opportunity to acquire property, apply new techniques, engage the community, and expedite efforts to clean up contaminated sediments and hazardous debris. It also encourages viewing the need to protect property as an opportunity to create 'living shorelines' from marsh plants, eelgrass and native oysters, which will also serve as habitat restoration.[47]

6 In 2008, the California Coastal Commission issued a brief document entitled "Climate Change and Research Considerations" as a follow-up to the 2001 "Overview of Sea Level Rise." The 2008 document presents an organized list of research needs, mostly relating to data gathering and mapping.[48]

7 A 2009 report from the California Climate Change Center, entitled "Potential Inundation Due to Rising Sea Levels in the San Francisco Bay Region," studies potential inundations associated with a continued acceleration of sea level rise. The study assembled the highest available resolution elevation data from various sources, and created a hydrodynamic model of the San Francisco Estuary from hourly water level measurements, as well as astronomical, storm surge, El Niño, and long-term sea level rise influences. The data will be used for, among other things, designing wetland restoration efforts with the ability to

[44] California Climate Change Center, "Projecting Future Sea Level Rise" (March 2006): *ix-x*. http://www.energy.ca.gov/2005publications/CEC-500-2005-202/CEC-500-2005-202-SF.PDF

[45] California Department of Water Resources, "Progress on Incorporating Climate Change into Management of California's Water Resources" (July 2006): Chapter 2 p 73. http://www.climatechange.ca.gov/publications/2006-07_DWR_CLIMATE_CHANGE_FINAL.PDF

[46] Ibid., Chapter 2 p 43.

[47] Privately provided.

[48] California Coastal Commission, "Climate Change and Research Conditions" (September 2008). http://www.coastal.ca.gov/climate/ccc_whitepaper.pdf

adapt to future changes. The data is available online.[49] The study notes limitations, stating, "this study addresses only the question of which areas are vulnerable to inundation, as opposed to quantifying the actual risk of inundation under a future scenario… shoreline erosion and the potential accumulation of sediment and organic matter with sea level rise are not accounted for here."[50]

The study found: "In the North Bay, wetland survival and developed fill areas are at risk. In Central and South bays, a key feature is the bay-ward periphery of developed areas that would be newly vulnerable to inundation. Nearly all municipalities adjacent to South Bay face this risk to some degree. For the Bay as a whole, as early as 2050 under this scenario, the one-year peak event nearly equals the 100-year peak event in 2000."

8 A 2009 study from the California Climate Change Center, entitled "The Impacts of Sea-Level Rise on the California Coast," focuses on human impacts but also studies habitats for their economic value. The study uses GIS data from the National Wetlands Inventory to map the current spatial extent of wetlands along the California Coast and San Francisco Bay, but notes that without field work carried out by experts, any datasets will likely underestimate the actual extent of wetlands. The study also notes that it does not make a clear distinction between coastal and upland wetlands, and does not take into account possible vertical accretion or landward migration.

The study attempted to loosely determine what areas of wetland will be lost by comparing wetland elevations to future tide elevations, and then assuming that permanently inundated areas will have converted to open water, but reports that the data limitations were insufficient even to carry this out.[51] The study's best estimates are that "550 square miles, or 350,000 acres, of wetlands exist along the California coast… [and] a sea-level rise of 1.4 m would flood approximately 150 square miles of land immediately adjacent to current wetlands, potentially creating new wetland habitat if those lands are protected from further development." [52]

9 A 2009 California Climate Change Center study, entitled "Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment," selected, evaluated, and compared the results of 12 climate change model simulations. For sea level rise, as decades proceed, all simulations contain an increasing tendency for heightened sea level events to persist for more hours. The models predict this will be due to mean sea level rise and not to weather events. By 2050, sea level increases from 2000 levels range from 30 cm to 45 cm over 2000 levels.[53]

Policy

1 The California Coastal Commission derives its legal authority and responsibilities from the California Coastal Act of 1976. A document by the Commission includes a summary of the provisions of this law.[54]

2 The California Coastal Commission, in 1989, produced a draft report, "Planning for an Accelerated Sea Level Rise along the

[49] U.S. Geological Survey, "CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem" (June 2009). http://cascade.wr.usgs.gov/

[50] N. Knowles, "Potential Inundation Due to Rising Sea Levels in the San Francisco Bay Region," California Climate Change Center (March 2009): *vii*, 1. http://www.energy.ca.gov/2009publications/CEC-500-2009-023/CEC-500-2009-023-D.PDF

[51] Heberger et al, "The Impacts of Sea-Level Rise on the California Coast," California Climate Change Center (May 2009): 27-33. http://www.pacinst.org/reports/sea_level_rise/report.pdf, and site at http://www.pacinst.org/reports/sea_level_rise/index.htm.

[52] Ibid., 3.

[53] Cayan et al. "Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment," California Climate Change Center (March 2009): 29-34. http://www.energy.ca.gov/2009publications/CEC-500-2009-014/CEC-500-2009-014-D.PDF

[54] California Coastal Commission Staff Climate Change Task Force, "A Summary of the Coastal Commission's Involvement in Climate Change and Global Warming Issues" (December 2008): 9-13. http://documents.coastal.ca.gov/reports/2008/12/F3.5-12-2008.pdf

California Coast." This does not currently appear to be accessible online anywhere.

3 Executive Order EOS-13-08, issued on November 14, 2008, focuses on sea level rise and represents California's first comprehensive climate adaptation strategy: "Given the serious threat of sea level rise to California's water supply and coastal resources and the impact it would have on our state's economy, population and natural resources, Governor Arnold Schwarzenegger today [11/14/2008] issued an Executive Order (EO) S-13-08 to enhance the state's management of climate impacts from sea level rise, increased temperatures, shifting precipitation and extreme weather events."[55]

The Executive Order recognizes that California's efforts to mitigate and reduce greenhouse gas emissions (such as from the 2006 Global Warming Solutions Act), coupled with those around the world, will slow but not stop climate impacts to California. It cites 'valuable natural habitat areas' as especially vulnerable to sea level rise.

The order calls for several actions, including:
– request that the National Academy of Sciences convene an independent panel to complete a California Sea Level Rise Assessment Report;
– have state agencies hold a public workshop to gather policy-relevant information by March 31, 2009; and
– complete a final Sea Level Rise Assessment Report no later than December 1, 2010. This should include sea level rise projections, range of uncertainties, synthesis of information on projected sea level rise impacts, discussion of future research needs, and advice for California about how to prepare for future sea level rise.

4 The "San Francisco Bay Plan," first completed and adopted in 1968, has been periodically updated, with the most recent update and reprint in January 2008. The Plan recognizes that sedimentation in the Bay will likely not be able to keep pace with accelerating sea level rise, as there is less sediment entering from the Sacramento and San Joaquin Delta, which will adversely affect the sustainability of future wetland restoration projects.[56] As of 2002, the Plan's policy included the effects of relative sea level rise in project design and evaluation.[57]

The Plan sets policies anticipating that global sea level rise will contribute an increase of between 4 and 5 inches in the next 50 years, and between 1.5 and 5 feet by 2100, with the range depending on how much the greenhouse effect accelerates sea level rise. Relative sea level rise is dependent on area; for example, Sausalito's land area is gradually lifting and so sea level rise will be relatively lower, while excessive pumping of underground water from the South Bay fresh water reservoirs has caused extensive subsidence in the San Jose area. If heavy pumping continues indefinitely, ground that has subsided seven feet from 1912 could subside up to seven feet more.[58]

Over 137,000 acres of the San Francisco Bay, its tidal marshes and tidal flats have been diked from tidal action. The area includes managed wetlands, agricultural baylands, salt ponds, and wastewater treatment ponds. The Plan states, "Where and whenever possible, former tidal marshes and tidal flats that have been diked from the Bay should be restored to tidal action in order to replace lost historic wetlands or should be managed to provide important Bay habitat functions, such as resting, foraging and breeding habitat for fish, other aquatic organisms and wildlife. As recommended in the Baylands Ecosystem Habitat Goals report, around 65,000 acres of areas diked from the Bay should be restored to tidal action. Further, local government land use and tax policies should not lead to the conversion of these restorable lands to uses

[55] Office of the Governor, "Gov. Schwarzenegger Issues Executive Order Directing State Agencies to Plan for Sea Level Rise and Climate Impacts" (November 14, 2008). http://gov.ca.gov/press-release/11035/

[56] San Francisco Bay Conservation and Development Commission, "San Francisco Bay Plan" (January 2008): 22. http://www.bcdc.ca.gov/pdf/planning/plans/bayplan/bayplan.pdf

[57] Ibid., 23, 28.

[58] Ibid., 31-32.

that would preclude or deter potential restoration. The public should make every effort to acquire these lands from willing sellers for the purpose of restoration."[59]

The Plan also notes that dredged material can be reused, among other uses, to restore marshes and wetlands. In the past the dredged material was treated as waste, but more reuse options are now available and the material should be especially used to enhance seasonal wetlands or restore tidal wetlands.[60]

5 A 2008 by the Climate Change Task Force made up of staff from the California Coastal Commission, "A Summary of the Coastal Commission's Involvement in Climate Change and Global Warming Issues," summarizes the actions taken by the Task Force since its inception in 2006 and future goals.

Most of all, the summary laments that budget shortfalls and budget cuts constrain staff work. In FY 2008-2009, the budget was cut $617,000, nine positions were cut, and several key members left for other jobs. As a result of remaining staff members needing covering additional workload, participation in the Task Force is reduced, the Commission is often not represented at key working groups, and is not able to provide support for other state and local government efforts.[61]

The summary of actions already taken is similar to the 2006 document discussed below in California-Actions-1.

The Commission's future goals continue along the same lines as the 'potential actions' discussed in the 2006 document, including actions such as updating permits to assist with green building, requiring greenhouse gas analysis, developing written guidance and permit checklists, continuing to assist Local Coastal Programs, and continuing to coordinate with other agencies and initiatives.[62]

6 * In response to Executive Order S-13-08's request for the California Natural Resources Agency to identify how state agencies can respond to climate change impacts (including sea level rise), on August 3, 2009, the Agency released a Discussion Draft of a "2009 California Climate Adaptation Strategy." The release sets in motion a 45-day public comment period.

Chapter VI, 'Ocean and Coastal Resources,' deals with habitat below high tide, including bays, estuaries, and coastal wetlands. Noting that the annual sediment deposit in the San Francisco Bay-Delta region is approximately 1 mm/yr, so wetlands will likely not be able to accrete vertically to keep pace with the projected sea level rise of 2-3 mm/yr. The report also notes the barrier to migration posed by human structures.[63]

Under 'state policies to protect critical habitat,' in the near term, "State agencies should identify key habitats that may require more protection as a result of climate change impacts and should plan additional buffer areas where necessary to allow for climate change induced phenomena, such as wetland migrating upland as sea level rises." In the long term, state agencies should coordinate policy implementation.

Under 'statewide guidance for protecting existing critical ecosystems,' in the near term, the Ocean Protection Council and state resource agencies should develop a statewide framework for construction guidelines that discourages hard protection solutions. In the long term, agencies should develop pilot studies to examine the efficacy and utility of the frameworks developed.

Under 'preparing for sea-level rise and climate

[59] Ibid., 21-23.
[60] Ibid 36, 38.
[61] California Coastal Commission Staff Climate Change Task Force, "A Summary of the Coastal Commission's Involvement in Climate Change and Global Warming Issues" (December 2008): 1-2. http://documents.coastal.ca.gov/reports/2008/12/F3.5-12-2008.pdf

[62] Ibid., 28-31.
[63] California Natural Resources Agency, "2009 California Climate Adaptation Strategy: Discussion Draft" (August 2009): 69-70. http://www.climatechange.ca.gov/adaptation/index.html

adaptation plans,' in the near term, state agencies responsible for management and regulation of resources subject to potential sea level rise should prepare agency-specific adaptation plans, guidance and criteria by September 2010. In the long term, these adaptation plans should be updated. Agencies cited for action include the Coastal Commission, the San Francisco Bay Conservation and Development Commission, the Coastal Conservancy, the State Lands Commission the Ocean Protection Council, and the Wildlife Conservation Board.

Under 'supporting local planning for addressing sea-level rise impacts,' in the near term, the Ocean Protection Council in coordination with other agencies should conduct public outreach with public meetings, identify potential funding sources, amend local coastal plans by 2011 (a year after the guidance framework and tools are developed in September 2010), and provide local guidance for setbacks, additional buffer areas, clustered coastal development, rebuilding restrictions, new development techniques, relocation incentives, rolling easements, and engineering solutions. In the long term, the Ocean Protection Council and other state agencies should produce a vulnerability assessment every five years.

Under 'essential data collection and information sharing,' in the near term, the state and federal partners should pursue collecting high-resolution LiDAR mapping, tidal datum, ecosystem research, and coastal and wetland process studies. In the long term, the Ocean Protection Council should work with appropriate partners, including nongovernmental organizations and academia, to share necessary data.[64]

7 * In April 2009, the staff of the San Francisco Bay Conservation and Development Commission made proposals for amendments to the Bay Plan. Many of the proposed changes explicitly address threat to habitats from sea level rise.

The staff recommends adding a new Bay Plan "Climate Change" policy section that includes the language, "The goals of the strategy should be to… protect the Bay ecosystem (e.g., Bay habitats, fish, wildlife and other aquatic organisms) with particular emphasis on identifying opportunities for tidal wetlands and tidal flats to migrate landward, managing adequate volumes of sediment for marsh accretion, developing and planning for natural flood protection, and maintaining sufficient upland buffer areas around tidal wetlands."

Another recommendation is to add to the "Protection of the Shoreline" policy section the language, "Structural shoreline protection can further cause erosion of tidal wetlands and tidal flats, prevent wetland migration to accommodate sea level rise, and create a barrier to physical and visual public access to the Bay, and may have cumulative impacts. As the rate of sea level rise accelerates and the potential for shoreline flooding increases, the demand for new shoreline protection projects will likely increase. Some projects may involve extensive amounts of fill."

For the "Safety of Fills" policy section, the staff recommends changing "If [subsidence] occurs, more extensive levees may be needed to prevent inundation of low-lying areas by the extreme high water levels" to read "Where subsidence occurs, more extensive shoreline protection and wetland restoration projects may be needed to minimize flooding of low-lying areas by the extreme high water levels."

To the "Tidal Marshes and Tidal Flats" policy section, the staff recommends adding the language, "As sea level rises, high-energy waves erode inorganic mud from tidal flats and deposit that sediment onto adjacent tidal marshes. Marsh plants trap sediment and contribute additional sediment from the accumulation of material. Tidal habitats respond to sea level rise by moving landward, a process referred to as transgression or migration. Low sedimentation rates, natural topography, and shoreline protection can

[64] Ibid., 71-76.

block wetland migration."[65]

The Commission has just completed holding three public hearings from May to July 2009 to solicit public input, and the Commission has directed staff to complete a revised version of their preliminary recommendations and schedule a public hearing in the fall.[66]

Accompanying the recommended language changes in policy is a report, "Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline." With regards to sea level rise and habitat protection, this report states, "higher rates of sea level rise may jeopardize efforts to restore tidal wetlands and maintain the current form of the Bay-Delta estuary. Erosion of subtidal areas may also expose mercury-laden sediment and impact circulation patterns in the Central Bay, possibly contributing to scour of bottom sediment, a primary physical control on habitats in subtidal regions of the Bay (NOAA 2007). The erosion of tidal flats and tidal marshes would result in additional loss of recreational, flood protection, and water quality benefits. In order for estuarine migration to occur, gently sloping areas of transitional habitat containing a combination of wetland and upland features are needed. These wetland-upland transition zones are high in species diversity and also provide refuge for endangered species like the salt marsh harvest mouse and the California clapper rail during high tides. These areas could potentially evolve into tidal marsh habitat as sea level rises. However, wetland-upland transition zones have been almost entirely eliminated due to development of the Bay shoreline in close proximity to the upland edge of tidal habitats. In many areas, the upland-wetland transition zone consists of only a few feet of vegetation along the steeply sloping side of a levee."

The report also includes analysis of challenges by region, as well as a preemptive critique of proposal for a tidal barrage (a barrier or dam) across the Golden Gate as an alternative to extensive shoreline protection structures. A precedent would be how the Dutch "sacrificed entire estuaries" to build protection structures after the North Sea flood of 1953. The report argues, "constructing a barrage at the mouth of San Francisco Bay would likely be physically and economically impractical, as well as ecologically damaging. The ecological consequences of the barrage would likely be very high. It would affect sedimentation, wetlands, fresh and salt water mixing, animal migration, and endangered species. More than likely it would change the landscape of the Bay Area, affecting the North Bay and South Bay most heavily."[67]

Actions

1 A December 2006 discussion draft of the California Coastal Commission's "Global Warming and the California Coastal Commission" summarizes the actions taken and planned by the Commission. This draft is the product of the first of three workshops "intended to inform the Commission and public about the effects of global warming on coastal resources and how the Commission might address global warming." This first workshop focuses on the effects of greenhouse gas emissions on the marine environment.[68]

The draft includes a discussion of how the existing Coastal Act gives the Commission

[65] W. Travis and L. Lacko, "Draft Staff Report and Preliminary Recommendation for Proposed Bay Plan Amendment 1-08 Concerning Climate Change," San Francisco Bay Conservation and Development Commission (April 2009): 8, 9, 14, 16. http://www.bcdc.ca.gov/proposed_bay_plan/bp_1-08_cc_draft.pdf

[66] San Francisco Bay Conservation and Development Commission, "Draft Staff Report and Preliminary Recommendation for Proposed Bay Plan Amendment 1-08 Concerning Climate Change" (2009). http://www.bcdc.ca.gov/proposed_bay_plan/bp_amend_1-08.shtml

[67] San Francisco Bay Conservation and Development Commission, "Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline, Draft Staff Report" (April 2009): 100, 108. http://www.bcdc.ca.gov/proposed_bay_plan/bp_1-08_cc_pre.pdf

[68] California Coastal Commission, "Global Warming and the California Coastal Commission" (December 2006): 1. http://documents.coastal.ca.gov/reports/2006/12/Th3-12-2006.pdf

authority to address global warming. It also notes that recent legislation, such as the California Global Warming Solutions Act of 2006, demonstrates that for the Commission to take action on climate change would be consistent with the goals of the State Legislature and Governor. It interprets that its jurisdiction extends to protection of marine and terrestrial coastal resources, energy consumption, and hazard planning; i.e., the Commission takes action not just for hazard mitigation and resource protection, but action towards reducing greenhouse gas emissions as well. [69]

Actions are divided into three categories: (A) Reduce Greenhouse Gas Emissions, (B) Adapt to Consequences of Global Warming, and (C) Increase education and awareness of Global Warming issues.

On-going actions, with their respective category, include:
– Placing conditions on permits to held reduce greenhouse gas emissions by reducing energy and water consumption (through use of native vegetation, clustering of development, and limiting size of development pads) (A);
– Requiring applications for new shorefront development to, in the examination of flooding and wave hazards, consider an increase in sea level similar or slightly higher than historical trends (B);
– Increasing setbacks in bluff erosion setback criteria (B);
– Participating in the State's Multi-Hazard Mitigation Plan (B); and
– Actions to increase education and awareness of Global Warming issues (C).

Potential actions include:
– Reducing vehicle miles through clustering development, mixed land use development, use of transit, recycling of existing building stock (A);
– Reduce energy use during and after construction through use of recycled building materials, green building practices, and native vegetation (A);
– Require that all development projects calculate greenhouse gas emissions ('carbon footprint') and implement techniques to reduce emissions (A); and
– Requiring applicants to consider a range of potential future changes (B).[70]

[69] Ibid., 2-6.

[70] Ibid., 6-8.

Connecticut

Research

1 A study from 1994 using stratigraphic studies in peat cores estimated that for the past 1000 years, the ratio of the rate of relative seal level rise to the marsh-accretion rate has been 1.15, increasing to 1.5 in the past 200 years.[71] Thus, marshes have been shrinking even before the effects of human-induced climate change. Not only does climate change threaten to accelerate the rate of sea level rise, but also the rate of marsh accretion is now often severely limited by human development. Even by 1997, "on Connecticut's western shore, with a tidal range of up to two meters, extensive areas of low marsh vegetation [had] been drowned (e.g. Five-mile River, Norwalk)."[72]

2 An Environmental Defense report recognizes that "future sea-level rise will play an increasing role in the loss of coastal wetlands" and presents a simple model to assess the vulnerability of wetlands. The study uses NOAA data showing relative rates of sea level rise of 0.08 in/yr (2.0 mm/yr) in New London and 0.10 in/yr (2.5 mm/yr) in Bridgeport, and creates projections of sea level rise under two scenarios of CO_2 emissions.

The study's results "suggest that salt marshes with moderate-to-high accretion rates would generally be able to keep pace with current rates of sea-level rise throughout this century. However, with the projected increased rates of sea-level rise, only marshes with high accretion rates could survive through mid-century, and even they would be completely submerged by the 2080s."[73]

3 The Connecticut Department of Environmental Protection's 2007 "Protecting and Restoring Our Environment" annual report states that "There is a concern that sea level rise threatens to adversely impact tidal marshes. Prioritizing the restoration of marsh habitat that is at a higher elevation may become a more significant consideration in coastal hazards and tidal marsh restoration planning." The Department's Coastal Management Program is using recent LIDAR elevation data obtained from FEMA in 2007 to better model vulnerabilities, which will then be used for local and municipal planning for coastal hazards.[74]

4 "Facing Our Future," a document issued by the Department of Environmental Protection in May 2009, summarizes the threats to Connecticut's coastline from sea level rise.[75] As examples: if beaches cannot migrate landward to keep pace with sea level rise, it endangers rare plant communities and endangered bird species like piping plovers. In Stonington, at the edge of the Barn Island wetlands, a forest of black gum trees—which are not adapted for a high level of salt around their roots—is threatened as it is inundated more frequently by high ride events. The Barn Island Tidal Marshes have persisted under the two-millimeter sea level rise of the past century, except for areas in western Long Island Sound where the lower elevation grasses have been converting to mudflat over several decades.

In the future, the highest forecasts of 15 mm/yr (0.6 in/yr) are very likely to outpace the rate of inland migration and cause marsh

[71] K.R. Nydick et al, "A Sea-level Rise Curve From Guilford, Connecticut, USA" *Marine Geology* 124 (1995): 137-159. http://ethomas.web.wesleyan.edu/Nydicketal.pdf.

[72] http://camel2.conncoll.edu/ccrec/greennet/arbo/publications/34/CHP6.HTM, 1997.

[73] Environmental Defense, "Bracing for Climate Change in the Constitution State: What Connecticut Could Face" (2004): 30. http://depweb.dms.uconn.edu/docs/CT_CC_envDef.pdf

[74] State of Connecticut Department of Environmental Protection, "Protecting and Restoring Our Environment: Annual Report 2007" (2007): 28. http://www.ct.gov/dep/lib/dep/enforcement/reports/2007annualreport.pdf

[75] State of Connecticut Department of Environmental Protection, "Facing Our Future: Adapting to Connecticut's Changing Climate" (March 2009): FS-003 1. http://www.ct.gov/dep/lib/dep/air/climatechange/adaptation/090320facingourfuture.pdf

grass drowning, making future tidal wetlands only narrow fringes. Bulkheads and seawalls further limit the wetland's ability to migrate inland. The freshwater tidal marshes of the Connecticut River depend on melted snowfall; if the snowfall decreases and other sources do not compensate, salt water will move upriver and convert the freshwater marshes to brackish marshes. Other vulnerable species include the saltmarsh sharp-tail sparrow and the seaside sparrow. The sharp-tail sparrow only breeds in high parts of high marsh in short grass. Changing hydrology could eliminate this narrow band of breeding habitat, or could wash eggs out of the nests. The seaside sparrow's habitat might similarly be lost when the sea level rises.[76]

Policies

1 While municipalities have responsibility over regulating inland wetlands, the Department of Environmental Protection exclusively regulates tidal wetlands.[77] The DEP's jurisdiction is defined by the 1969 Tidal Wetlands Act, Connecticut General Statues Title 22a, Chapter 440, § 22a-28 to 22a-45d,[78] an Act protecting wetlands from destruction from draining, dredging, dumping and filling. § 22a-35a authorizes the Commissioner of Environmental Protection to "conduct wetland restoration and enhancement projects… [to] maximize successful recolonization of tidal wetland vegetation".

2 The Coastal Management Act, Chapter 444, also allows structural solutions "when necessary and unavoidable for the protection of infrastructural facilities, water-dependent uses, or existing inhabited structures, and where there is no feasible, less environmentally damaging alternative and where all reasonable mitigation measures and techniques have been provided to minimize adverse environmental impacts" in § 22a-92(2)(J).[79] Chapter 444 also encourages "the restoration and enhancement of disturbed or modified beach systems…" and "the rehabilitation and restoration of degraded tidal wetlands and where feasible and environmentally acceptable" in § 22a-92(2)(C), (E).

3 The Natural Coastal Shoreline Environment chapter of the May 2009 "Facing Our Future" document suggests "establishing clear standards and encouraging sustainable and economically viable outcomes regarding shoreline armoring versus retreat, proactively protecting habitats and ensuring responsible growth."[80]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. The Department of Environmental Protection summarizes general tidal wetland conservation efforts on its website.[81]

[76] Ibid., 2-3.
[77] State of Connecticut Department of Environmental Protection, "Inland Wetlands Management." http://www.ct.gov/dep/cwp/view.asp?A=2720&Q=325684
[78] General Status of Connecticut, "Title 22a: Environmental Protection, Chapter 440: Wetlands and Watercourses" (Revised to January 1, 2005). http://www.cga.ct.gov/2005/pub/chap440.htm,
[79] General Status of Connecticut, "Title 22a: Environmental Protection, Chapter 444: Coastal Management" (Revised to January 1, 2005). http://www.cga.ct.gov/2007/pub/Chap444.htm,
[80] State of Connecticut Department of Environmental Protection, "Facing Our Future: Adapting to Connecticut's Changing Climate" (March 2009): FS-003 3. http://www.ct.gov/dep/lib/dep/air/climatechange/adaptation/090320facingourfuture.pdf
[81] State of Connecticut Department of Environmental Protection, "Connecticut Coastal Habitat Restoration Programs." http://www.ct.gov/dep/cwp/view.asp?a=2705&q=323538&depNav_GID=1622&depNav=|

Delaware

Research

1 * A 2002 study examined the effect of beach nourishment on horseshoe crab spawning in the Delaware Bay (which has the world's largest population of spawning horseshoe crabs). It points out that "Beach nourishment is a widespread practice for shoreline protection, but projects that use beach nourishment to create a veneer of sediment to improve habitat are rare." The study was inspired by an observation that, after a 1998 nourishment project which converted a coarse sand/gravel beach into a wider and more finely grained sand beach, spawning counts increased in the immediate aftermath but subsequently suffered a dramatic drop not observed in neighboring beaches. The study concludes that
(1) small volumes of nourished sediment do not have a significant effect;
(2) that the effects of adding small amounts of gravel is temporary;
(3) that greater water retention of finer grain sizes is important for egg viability;
(4) that the deposited sediment should have a gravel subfraction (because finely-grained sand acts as a solid when saturated and makes burrowing difficult) and a mean sediment size of 0.35 to 0.50 mm; and
(5) that beach nourishment can have a positive effect but more research is required to determine optimum fill sizes and the best times for nourishment operations.

The study hoped to present recommendations for when horseshoe crab spawning is an objective or a constraint, but concluded that the results were not specific enough to allow the formation of detailed guidelines.[82]

2 A 2002 report from the University of Maryland showed that between 1984 and 1993, the proportion of tidal marshes with degraded conditions increased from 25 to 54 percent. More recently, in 2007 the Delaware Department of Natural Resources and Environmental Control (DNREC) reported incidences of sudden wetland dieback in 2006. The increasing pace of sea level rise may be an important factor in wetland deterioration.[83]

3 James Titus reports that while sea level rise is a serious threat, Delaware's wetlands are probably less vulnerable than most. "With tide ranges of 1–3 feet, a rise in sea level of 6-18 inches would threaten many wetlands in Chesapeake Bay and the Atlantic Coastal Bays. The 6–8 foot tide range of Delaware River and Bay, by contrast, implies that the sea would have to rise 3–4 feet to have a similar impact." Also, Delaware will be aided by its strong commitment to beach nourishment, unlike neighboring New Jersey, where bulkheads have caused the beach to become completely submerged at high tide. Local planners estimate that less than 50% of the Delaware Estuary shore would be armored, allowing for inland migration of wetlands.[84]

4 A report issued by the Delaware Department of Natural Resources and Environmental Control (DNREC) for public education reviews four management options for erosion and sea level rise: no action, shoreline hardening, strategic retreat and beach nourishment. However, all options focus on protecting or managing human development, only mentioning possible negative environmental impacts. The report states, "Based on analyses that have been conducted, the cost associated with buy-out of oceanfront property [i.e., strategic retreat] is extremely

[82] D. Smith et al. "Beach Nourishment on Delaware Bay Beaches to Restore Habitat for Horseshoe Crab Spawning and Shorebird Foraging" (December 2002): 2-3, 8, 48-49. http://el.erdc.usace.army.mil/tessp/pdfs/New%20Horseshoe%20Crab%20Habitat.pdf

[83] D. Kreeger, "Climate Change as it Relates to Sea Level Rise," Partnership for the Delaware Estuary *Estuary News* 17:2 (Winter 2007): 4-5. http://www.delawareestuary.org/pdf/EstuaryNews/2007/WinterNews07.pdf

[84] J. Titus, "Is Rising Sea Level a Problem for the Delaware Estuary?" Delaware Estuary Program *Estuary News* 13:4 (Summer 2003): 1-3. http://www.delawareestuary.org/pdf/EstuaryNews/2003/summernews03.pdf

high and exceeds the cost of periodic nourishment."[85]

5 The Partnership for the Delaware Estuary reports that 50% of Delaware's natural marshes have been lost over the past 300 years because of development, conversion, or degradation associated with human activities, and 12% of tidal marshes have been lost in the previous decade. Varying percentages in watershed regions are unavailable for marsh encroachment due to development, as measured by a one-kilometer buffer landward of tidal marshes. Percentages range from 9% to 17% in the regions of the Delaware Bay; 15% to 75% in the regions of the Lower Estuary; and 58% to 81% in the regions of the Upper Estuary.[86]

6 The Partnership for the Delaware Estuary states that "Indicators that specifically monitor the effects of warming and stress in the Delaware Estuary are needed," and recommends an ecosystem-based monitoring approach as a first step, followed by "predictive modeling of future changes in temperature, sea level, and shifting ranges of plant and animal communities," and then using this data towards efforts to "protect and build system resilience through… preserving and enhancing buffers and function."[87]

Policies

1 The "Inland Bays / Atlantic Ocean Basin Assessment Report" of 2002 set out to create a "Whole Basin Management" approach, recognizing that "To date [2002], a comprehensive management and protection scheme to protect and manage the tidal estuaries of the Inland Bays region has never emerged. While there are laws and regulations that afford some protection and management, the strategy is fragmented and utilizes a piecemeal approach for only segments of the estuary or its biota."[88]

2 The 1973 "Wetlands Act," Chapter 66 of Title 7 "Conservation" of the Delaware Code,[89] has been effective in reducing the loss rate of Delaware's remaining tidal wetlands. For example, from 1995 through 1996, the permitting process let less than one acre of tidal wetlands be permanently displaced.[90]

3 The Wetlands Act focuses on the threat of "unregulated dredging, dumping, filling and like activities" for its regulations.[91] Sea level rise is recognized as a threat to beaches under Chapter 68, "Beach Preservation."[92] Chapter 70, the "Coastal Zone Act," bans any new heavy industry in coastal areas.[93] Chapter 75, the "Delaware Land Protection Act," charges state agencies to acquire lands for public recreation and conservation of natural resources, recognizing the threat from urban encroachment.[94]

4 The "Basin Assessment Report" lays out general policy recommendations. While it does not recommend specific techniques, it is heavily directed towards land acquisition. It recommends the following as high priority: to "Promote the acquisition and protection of wetlands and natural heritage sites," to adopt a department-wide comprehensive wetland plan, to delineate protection areas, to restrict placement of dicks, piers and ramps, to limit

[85] Delaware Department of Natural Resources and Environmental Control, "Striking a Balance: A Guide to Coastal Dynamics and Beach Management in Delaware" (2004): 38. http://www.swc.dnrec.delaware.gov/SiteCollectionDocuments/Soil/Shoreline/StrikeBalance.pdf

[86] "State of the Delaware Estuary," Partnership for the Delaware Estuary *Estuary News* 18:3 (Summer 2008): 30-31. http://www.delawareestuary.org/pdf/EstuaryNews/2008/SummerNews08.pdf

[87] Ibid., 32.

[88] Delaware Department of Natural Resources and Environmental Control, "Inland Bays/Atlantic Ocean Basin Assessment Report," Doc. No. 40-01/01/01/02 (June 2001): 49. http://www.dnrec.state.de.us/dnrec2000/admin/wholebasin/inlandbays/assessment/DOCUMENT/CHAPTERS/CHAPTERS%20TEXT%20ONLY/Title%20Page,%20Acknowledgements,%20Contents%20.pdf

[89] The Delaware Code, "Title 7: Conservation and Natural Resources, Chapter 66: Wetlands." http://delcode.delaware.gov/title7/c066/index.shtml

[90] Inland Bays Assessment 65-66.

[91] The Delaware Code, "Chapter 66: Wetlands." http://delcode.delaware.gov/title7/c066/index.shtml

[92] The Delaware Code, "Chapter 68: Beach Preservation." http://delcode.delaware.gov/title7/c068/index.shtml

[93] The Delaware Code, "Chapter 70: Coastal Zone Act." http://delcode.delaware.gov/title7/c070/index.shtml

[94] The Delaware Code, "Chapter 75: Delaware Land Protection Act." http://delcode.delaware.gov/title7/c075/index.shtml

further human disturbance of Delaware's remaining Coastal Plain ponds, to adopt statewide wetland mitigation policy including the concept of "Land Banking," to establish wellhead protection ordinances, revise the subaqueous land statue to be 50 feet beyond the high-water line, and to create "management plans to designate and develop riparian buffers and establish habitat criteria for maintaining said buffers."

The Report also designates as high priority completing the recharge-potential mapping of the entire state, and developing depth-to-ground-water maps to identify areas with an extremely shallow water table.[95]

5 A proposal submitted in 2007 by the Delaware Coastal Programs to NOAA's Coastal Services Center requested a 2008-2010 Coastal Management Fellowship to help develop an adaptation plan for sea level rise for Delaware. It states that "the development of a sea level rise adaptation plan for the State" is "one of Delaware's most pressing issues." "The major objectives of the project are to:
– Research and evaluate sea level rise management strategies and tools used at the federal level and in other states to identify potential models for Delaware.
– Review and prioritize sea level rise issues in Delaware and develop a report on the state of the science, policy, and regulatory environment.
– Develop recommendations for comprehensive sea level rise adaptation planning and management strategies and regulatory revisions.
– Develop an implementation plan for these recommendations."[96]

6 Delaware is currently developing a "Statewide Adaptation Plan for Sea Level Rise." "The adaptation plan, when complete, will recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. The plan will be developed with a team of stakeholders from a diverse network of interests including municipal governments, highway planners, landowners, emergency managers, wildlife managers, agricultural professionals, insurance agents, and tourism officials." An initial workshop was held in March 2009.[97]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. However, the Partnership for the Delaware Estuary has a pilot program, the Delaware Estuary Living Shoreline Initiative (DELSI), which has targeted sites between Maurice River and Cohansey River watersheds of southern New Jersey. In 2008, treatments consisting of coconut-fiber logs and mats were deployed at sites experiencing various types of erosion along the Maurice River. "Tests reveal that mussels attach to the fibers of these products similar to the way they attach to marsh plants. In addition, bagged oyster and clam shells and coated wooden stakes are also being tested as potential treatments… Beginning in 2009, scientists will conduct tests to determine if living-shoreline development can be accelerated by 'seeding' treatments with hatchery-born mussels and plants salvaged from marsh clumps that have already eroded away."[98]

[95] Inland Bays Assessment 173, 177.

[96] D. Carter, "Development of a Sea Level Rise Adaptation Plan for the State of Delaware: A Response to NOAA's Coastal Services Center Announcement for Coastal Management Fellowship," Delaware Coastal Programs (October 2007): 2-3. http://www.swc.dnrec.delaware.gov/coastal/Documents/Delaware%20Sea%20Level%20Rise%20Adaptation%20Plan%20Proposal.pdf

[97] Delaware Coastal Programs, "Sea Level Rise Adaptation," Delaware Department of Natural Resources and Environmental Control (2009). http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx

[98] Partnership for the Delaware Estuary, "Living Shorelines." http://www.delawareestuary.org/science_projects_living_shoreline.asp
E. Powell, "2005 Shell-Planting Program in Delaware Bay," Report to the U.S. Army Corps of Engineers (2005). http://www.delawareestuary.org/pdf/Oyster%20Publications/OysterPlantResults.pdf.

Florida

Research

1 A 1994 paper shows that South Florida has seen a 9 inch rise in sea level since the 1930s, meaning that relative sea-level rise in parts of Florida have already outpaced the global average.[99]

2 * The South Florida Regional Planning Council has undertaken a continuing study to predict impacts on South Florida. The study aims to paint a picture of what South Florida may look like in 200 years in terms of land use protection, based on current predictions of global warming and rising sea levels. The study used a higher-end estimate of a sea level rise of 5 feet in 200 years. The probability of this is estimated at 30%, with the mean probability sea level rise estimated at closer to 3.75 feet.

The study adopts an interesting approach. Instead of trying to determine the areas most threatened by sea level rise, the study looks at likely future land-use patterns. It attempts to determine the likelihood that external, non-conservationist actors will protect a given area of land, and then it uses this information to make recommendations about which areas would be the most practical targets for use of funds on actions like buyouts. For example, areas where property owners already have and will likely continue to invest significant amounts of money in protecting shorelines are not efficient targets for conservation efforts.

The study mapped four categories of protection onto a map of South Florida: Almost Certain, Reasonably Likely, Unlikely, or No Protection. Protection was predicted as 'almost certain' for existing coastal development and undeveloped land in designated growth areas, much of which has property values that are higher than the costs of shore protection. Identifying areas where protection are 'reasonably likely' is important because such areas would be better candidates for wetland migration than areas where protection is almost certain.

The report recommends, "Properties not connected to water and sewer often have a sufficiently low investment in infrastructure that buy-outs might be feasible if land owners are faced with increasing floods, or if purchases for other public purposes prevail. Land covered by the Coastal Barrier Resources Act are ineligible for federal subsidies of flood insurance, mortgages, and beach nourishment. Therefore, if flood risks or beach nourishment costs increase, those lands might be allowed to follow natural processes." Examples of such areas would be places where the costs of protection exceed property values, currently undeveloped lands that do not yet have significant infrastructural investments, and agricultural land such as 60,000 acres in Miami-Dade County that is protected due to its location within an existing levee system. Military lands outside of urban areas were also included in this category of uncertainty, because rural military bases often have environmental programs to preserve wetlands in portions of the base, and if they close their land holdings are sometimes transferred to environmental agencies.

Identifying areas where protection is 'unlikely' is nearly synonymous with identifying areas where the land will eventually be inundated by rising sea levels. In these places, conservation easements should be relatively inexpensive, and environmental planners can assume that wetlands and beaches will migrate inland. Unfortunately, in coastal counties, relatively little land falls into this category, but there are some privately-held land and agricultural areas (especially land outside the protection of levees) that are unlikely to be protected. The maps also chart places where there will be 'no

[99] Florida Coastal and Ocean Coalition, "Preparing for a Sea Change in Florida: A Strategy to Cope with the Impacts of Global Warming on the State's Coastal and Marine Systems" (2008): 13. http://www.flcoastalandocean.org/PreparingforaSeaChange/Climate_Change_Guide_for_Florida_Preparing_for_a_Sea_Change.pdf

protection,' generally because the land is already managed for conservation purposes.[100]

3 In 2006, the Coastal and Marine Geology Program of the U.S. Geological Survey generated a comprehensive database of digital vector shorelines and shoreline change rates for the U.S. Southeast Atlantic Coast (Florida, Georgia, South Carolina, North Carolina). Data is provided as single-point vector datasets with metadata, and organized into layers by state. This information is available online.[101]

4 In 2007, Florida Atlantic University's Center for Urban and Environmental Solutions (CUES) in the College of Architecture, Urban and Public Affairs, in partnership with the National Commission on Energy Policy (NCEP), released a guide for policymakers entitled "Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change." The guide includes specific though not detailed policy recommendations. For conservation, the guide primarily identifies several existing government programs, both regulatory agencies and survey/monitoring projects, and recommends that they be made permanent and that funding be secured for them. It also singles out the Florida Keys as lacking and especially in need of a climate protection and adaptation strategy. For beach management, aside from recommending limiting shoreline hardening and relying on beach nourishment when possible, the guide recommends that "with enough lead time for implementation, and a 'no fault' compensation program for innocent victims, Florida could ensure sensible responses to climate change without causing a rupture in its beach-dependent economy or a property owner's backlash."[102]

5 Wetlands (marshes, tidal flats, swamps, mangroves, and wetland forests) make up two-thirds of the total land area in Florida vulnerable to sea level rise. Rising sea level would convert these wetlands to open water too deep for current vegetation to survive. As examples of likely effects, one-third of Florida's marshlands, 99 percent of the state's mangroves, and more than half of Florida's beach land area will all be flooded.[103]

6 The 'Florida Coastal and Ocean Coalition,' a consortium of the Caribbean Conservation Corporation, Environmental Defense Fund, Gulf Restoration Network, Natural Resources Defense Council, National Wildlife Federation, Ocean Conservancy, Reef Relief, and The Surfrider Foundation, issued a report in 2008 titled "Preparing for Sea Change in Florida." The report provides a qualitative but detailed summary of the challenges facing coastal Florida from climate change and recommendations about solutions. However, it explicitly says that it is only an initial list of possibilities, and "no attempt has been made to rank, order, or prioritize these policy options in terms of expected costs or effectiveness."[104]

On the issue of sea level rise, it issues three recommendations:
(1) "the state should undertake a comprehensive reevaluation of the Coastal Construction Control Line regulatory program to ensure that it is accomplishing the intended goals of protecting life, property, and the beach/dune system;"
(2) the Florida Department of Environmental Protection and other relevant agencies should "develop state wetlands conservation and restoration plans that promote designation of wetland migration as sea levels rise, thereby protecting the valuable benefits they provide"; and
(3) "federal, state, and local governments

[100] South Florida Regional Planning Council, "Sea Level Rise Project Final Report" (September 2005). http://www.sfrpc.com/gis/SFRPC%20SLR%20Study%20(September%202005).pdf
[101] T. Miller et al. "The National Assessment of Shoreline Change: A GIS Compilation of Vector Shorelines and Associated Shoreline Change Data for the U.S. Southeast Atlantic Coast," USGS Open File Report 2005-1326 (February 2006). http://pubs.usgs.gov/of/2005/1326/
[102] Florida Atlantic University, "Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change" (2007): 35-40. http://www2.nos.noaa.gov/gomex/coastal_resil/fl_resilcoast.pdf
[103] E. Stanton and F. Ackerman, "Florida and Climate Change: The Costs of Inaction," Tufts University (November 2007): 14. http://ase.tufts.edu/gdae/Pubs/rp/Florida_lr.pdf
[104] Ibid., 3.

should replace economic incentives for private development in high risk coastal areas with incentives to relocate and build in other areas and invest in coastal conservation."[105]

7 An April 2008 report by the Miami-Dade County Climate Change Advisory Task Force, (a task force established in 2006 by the Board of County Commissioners of Miami-Dade County), cites a study presented at the Everglades Modeling Symposium. The study used archival tidal gauge data from Miami Harbor Entrance, Key West and Naples collected and provided online by the National Oceanic and Atmospheric Administration, National Oceans Services to conclude that since 1932, south Florida has had about a 9 inch relative rise of sea level, a rate of one foot per century and about 8 times the average rate over the past 2,500 years. The Task Force found that "developed Miami-Dade County as we know it will significantly change with a 3-4 foot sea level rise. Spring high tides would be at about + 6 to 7 feet; freshwater resources would be gone; the Everglades would be inundated on the west side of Miami-Dade County; the barrier islands would be largely inundated; storm surges would be devastating; landfill sites would be exposed to erosion contaminating marine and coastal environments. Freshwater and coastal mangrove wetlands will not keep up with or offset sea level rises of two feet per century or greater. With a five foot rise (spring tides at nearly +8 feet), Miami-Dade County will be extremely diminished." The report adds, "the highly porous limestone and sand substrate of Miami-Dade County (which at present permits excellent drainage) will limit the effectiveness of widespread use of levees and dikes to wall off the encroaching sea."[106]

[105] Florida Coastal and Ocean Coalition, "Preparing for a Sea Change in Florida: A Strategy to Cope with the Impacts of Global Warming on the State's Coastal and Marine Systems" (2008): 10. http://www.flcoastalandocean.org/PreparingforaSeaChange/Climate_Change_Guide_for_Florida_Preparing_for_a_Sea_Change.pdf

[106] Miami-Dade County Climate Change Advisory Task Force. "CCATF Science Committee Report: Statement on Sea Level In the Coming Century." Appendix 1 of "Second Report and Initial Recommendations: Presented to The Miami-Dade Board of County Commissioners" (April 2008): 1-4. http://www.miamidade.gov/derm/library/08-10-04_CCATF_BCC_Package.pdf

Policy

1 Florida's rules[107] and laws[108] relating to beach management are available online.

2 The Comprehensive Everglades Restoration Plan (CERP) project, whose $11 billion projected cost will be split between the state and federal governments, covers 18,000 square miles and is "the largest such project in world history."[109]

3 Florida governor Charlie Crist, in a keynote speech delivered at his July 2007 "Serve to Preserve" Summit on Global Climate Change, stated that "I am persuaded that global climate change is one of the most important issues that we will face this century. With almost 1,200 miles of coastline and the majority of our citizens living near that coastline, Florida is more vulnerable to rising ocean levels and violent weather patterns than any other state… Florida will provide not only the policy and technological advances, but the moral leadership, to allow us to overcome this monumental challenge."[110]

4 An April 2008 report released by the Miami-Dade County Climate Change Advisory Task Force states that "there is a very high likelihood that there will be at least a further 3-5 feet of sea level rise during this century. This rise will most certainly continue at an accelerated rate into the following century. Miami-Dade County will not be able to defend against such a rise and must begin a responsible and serious re-evaluation of all

[107] Bureau of Beaches and Coastal Systems, "Beach Management Rules," Florida Department of Environmental Protection (July 2009). http://www.dep.state.fl.us/beaches/publications/gen-pub.htm#Rules

[108] 2003 Florida Statues, "Chapter 161: Beach and Shore Protection." http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&URL=Ch0161/titl0161.htm&StatuteYear=2003&Title=-%3E2003-%3EChapter%20161

[109] Florida Atlantic University, "Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change" (2007): 36. http://www2.nos.noaa.gov/gomex/coastal_resil/fl_resilcoast.pdf

[110] Ibid., 73.

aspects of its present laws and approaches to growth, development, permitting, zoning, infrastructure, waste disposal and pollution, adaptation, and natural area preservation."

For "Natural Systems Adaptations," it offer several recommendations:
(1) support the Comprehensive Everglades Restoration Plan (CERP), which fulfills the primary function of providing "proper quantity, quality, timing, and distribution of water to both reduce the potential for saltwater intrusion into the Biscayne Aquifer," and increase funding and resources for other such efforts;
(2) increase funding and resources for land acquisitions and management programs, including exploring "new and creative mechanisms to boost funding, such as the creation of a County administered "carbon credit purchasing" program, as a potential alternative to current development, industry, and government mitigation requirements";
(3) acquire all undeveloped lands needed for restoration purposes, especially to provide transition zones to accommodate retreat or spatial shifts in areas such as coastal wetlands or freshwater marshes;
(4) create a plan that uses development setbacks and limits on density and infrastructure to locate infrastructure and development outside coastal or flood hazard prone areas. The areas will be identified using sea level rise projections, including protection of transitional zones between a hazard and built area;
(5) "continue funding the County Agriculture Purchase of Development Rights Program beyond current funding levels to maintain open lands for aquifer recharge, habitat, and buffers";
(6) provide incentives to study and develop best agricultural management practices for carbon sequestration and greenhouse gas emission reductions;
(7) review current stormwater management operations to eliminate unnecessary over-drainage and limit saltwater intrusion into ground and surface water resources. Also, require water conservation measures for all users of the Biscayne Aquifer, in order to preserve freshwater in the aquifer so that its head pressure will slow brackish water intrusion;
(8) establish a multi-agency task force and develop a collaborative and integrated approach involving universities, government agencies, landowners, botanic gardens, zoos, and non-governmental organizations;
(9) develop a 'vital signs' monitoring program on the model of the National Park Service. This would be a multi-parameter ecosystem monitoring program including rate of sea level rise, saltwater intrusion boundary and monitoring wells, landscape-level vegetations patterns, percent coral cover in offshore reef zones, water temperature in reef areas, and occurrence and range of invasive plant and animal species; and
(10) establish both formal and informal partnerships with other governmental agencies at all levels, the private sector, non-governmental organization, and other stakeholders, in order to coordinate restoration efforts.[111]

5 Florida's "Energy and Climate Change Action Plan" of 2008 contains an "Adaptation and Planning Framework for Florida." For uplands, freshwater and marine systems threatened by sea level rise, it recommends that
– the DEP and other relevant agencies clearly designate wetland migration corridors;
– the legislature place a priority on coastal land acquisition through the 'Florida Forever' program or other means; and
– the legislature provide greater incentives for local governments and private organizations to acquire and manage ecologically important coastal lands including upland buffers.

For beaches, the Planning Framework recommends
– reducing and discouraging reliance on shoreline hardening;
– estimating ecological value of beach resources to prioritize protection efforts;
– funding the DEP to undertake all

[111] Miami-Dade County Climate Change Advisory Task Force. "Second Report and Initial Recommendations: Presented to The Miami-Dade Board of County Commissioners" (April 2008): 'Statement of Sea Level Rise' 11-14. http://www.miamidade.gov/derm/library/08-10-04_CCATF_BCC_Package.pdf

reasonable efforts to maximize inlet sand bypassing in order to minimize conditions inhibiting natural long-shore sand movement;
– requiring the state Acquisition and Restoration Council to conduct a review of management plans for those lands under its authority every 10 years (include considering a Full Disclosure Law that alerts buyers of coastal property about erosion rates, storm history, SLR concerns, and other relevant information);
– having state and local government establish clear policies and regulations regarding when, how, where and under what circumstances beach stabilization is allowed;
– having state and local government establish policies and regulations about when vulnerable structures will have to be abandoned;
– having state and local governments establish policies and regulations to protect coastal resources from contamination resulting from sea level rise or storm events;
– incorporating a range of sea level rise scenarios over at least a 50 year time horizon in the DEP's Strategic Beach Management Plan; and
– providing incentives to encourage public and local governments to build structures and infrastructure away from areas at high risk from climate change and sea level rise.[112]

6 In the Charlotte Harbor National Estuary Program's conservation and management plan, last updated in 2008, a strategy point is to "Conduct an initial overview of the significant potential human and ecological effects related to climate change from sea level rise… [and] Seek assistance from EPA's Office of Atmospheric Programs (OAP), Climate Change Division (CCD), to assess vulnerabilities to sea level rise and integrating information on climate science, impacts and adaptation."[113]

7 * "In a groundbreaking decision, an administrative law judge in Florida issued a ruling on March 2, 2009 against a beach nourishment project because it posed a threat to the health of the offshore reef ecosystem (Recommended Order, Surfrider Foundation v. Town of Palm Beach, FL; Case No. 08-1511). The court recognized the potential negative environmental effects of the proposed nourishment project and conceded the modeling system used by many coastal engineers and the U.S. Army Corps of Engineers (COE) to predict sand distribution was flawed. While many environmental groups hail the decision as a victory, some scientists are concerned it will only push communities to rely more on sea walls and other hard structures (New York Times, 2009)."[114]

Actions

1 The state's "Florida Forever" program is "the world's largest land acquisition program." In the decade prior to 2007, the program had spent $3 billion and preserved over 2.3 million acres. The state's "Everglades Forever" pollution clean-up program has spent more than $2 billion, which includes the costs of constructing 36,000 acres of wetlands to naturally filtrate phosphorus out of the water before it enters the Everglades.[115]

2 "[The Florida Department of Environmental Protection] includes in its annual 'Florida Forever Work Plan' a list of lands that sequester carbon, provide habitat, protect coastal lands or barrier islands, and otherwise mitigate and help adapt to the effects of SLR. DEP's Office of Coastal and Aquatic Managed Areas (CAMA) has 42 aquatic

[112] 2008 Center for Climate Strategies, "Florida's Energy and Climate Change Action Plan, Appendix F: Adaptation (ADP) Planning Framework for Florida" (2008): 16-19. http://www.dep.state.fl.us/climatechange/files/action_plan/app_f_adaptation.pdf
[113] Charlotte Harbor National Estuary Program, "Committing to Our Future: A Comprehensive Conservation and Management Plan for the Greater Charlotte Harbor Watershed from Venice to Bonita Springs to Winter Haven Update 2008" (March 2008): 137. http://www.chnep.org/CCMP/CCMP2008.pdf
[114] M. McPherson, "Adaptation to Sea-Level Rise in North Carolina," Masters of Environmental Management project, Duke University (2009): 22. http://hdl.handle.net/10161/958
[115] Florida Atlantic University, "Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change" (2007): 36. http://www2.nos.noaa.gov/gomex/coastal_resil/fl_resilcoast.pdf

preserves around the state that are managed to protect natural values. CAMA also comanages with the National Oceanic and Atmospheric Administration (NOAA) the Florida Keys National Marine Sanctuary, and three National Estuarine Research Reserves. The Florida Fish and Wildlife Conservation Commission (FWC) overseas the Florida Wildlife Legacy Initiative; which includes major terrestrial, freshwater, and marine systems and strives to keep common species common. In addition, DEP (state parks), (DOF), the Florida Fish and Wildlife Conservation Commission (FWC), and other state agencies have ongoing programs to maintain natural systems in a healthy state. On a parallel track, federal and local governments and private organizations, such as The Nature Conservancy and the Audubon Society, maintain parks, and natural areas."[116]

[116] 2008 Center for Climate Strategies, "Florida's Energy and Climate Change Action Plan, Appendix F: Adaptation (ADP) Planning Framework for Florida" (2008): 16. http://www.dep.state.fl.us/climatechange/files/action_plan/app_f_adaptation.pdf

Georgia

Research

1 A 1997 publication of the EPA Office of Policy, Planning and Evaluation, "Climate Change and Georgia," reports sea level rising at 13 inches per century at Fort Pulaski, and likely to rise another 25 inches by 2100. It estimates that the cumulative cost of sand replenishment to protect from a 20-inch sea level rise by 2100 as between $154 million and $1.3 billion.[117]

2 As part of the Coastal Incentive Grant Program, the Department of Natural Resources' Coastal Management Program awarded the University of Georgia a grant of $69,246 in FY 2008-2009 for a proposal entitled, "Planning for Sea Level Rise." There is currently no final report posted for this (or any project awarded a grant in this fiscal year).[118]

3 A 2009 article, "Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services," presents the results of a study of the Georgia coast. "We used field and laboratory measurements, geographic information systems, and simulation modeling to investigate the potential effects of accelerated sea-level rise on tidal marsh area and delivery of ecosystem services along the Georgia coast. Model simulations using the Intergovernmental Panel on Climate Change (IPCC) mean and maximum estimates of sea-level rise for the year 2100 suggest that salt marshes will decline in area by 20% and 45%, respectively. The area of tidal freshwater

[117] Environmental Protection Agency, "Climate Change and Georgia," Office of Policy, Planning and Evaluation, EPA 230-F-97-008j (September 1997): 3. http://www.epa.gov/climatechange/effects/downloads/ga_impct.pdf

[118] Coastal Resources Division, "Previously Awarded Coastal Incentive Grants and link to Final Reports Cycle XI (FY 2008-2009)," Georgia Department of Natural Resources (2009). http://crd.dnr.state.ga.us/content/displaycontent.asp?txtDocument=96&txtPage=12.

marshes will increase by 2% under the IPCC mean scenario, but will decline by 39% under the maximum scenario. Delivery of ecosystem services associated with productivity (macrophyte biomass) and waste treatment (nitrogen accumulation in soil, potential denitrification) will also decline. Our findings suggest that tidal marshes at the lower and upper salinity ranges, and their attendant delivery of ecosystem services, will be most affected by accelerated sealevel rise, unless geomorphic conditions (ie gradual increase in elevation) enable tidal freshwater marshes to migrate inland, or vertical accretion of salt marshes to increase, to compensate for accelerated sea-level rise."[119]

Policy

1 In the Georgia Code, the "Shore Protection Act" (§ 12-5-231) focuses mainly on the issue of erosion, identifying that the main problem is that "Removal of sand from [offshore] bars and shoals can interrupt natural sand flows and can have unintended, undesirable, and irreparable effects on the entire sand-sharing system, particularly when the historical patterns of sand and water flows are not considered and accommodated." The Act addresses the threat by authorizing regulation of development of offshore sandbars and shoals.[120]

Under Chapter 7 "Control of Soil Erosion and Sedimentation," the state Code recognizes that "oil erosion and sediment deposition… are occurring as a result of widespread failure to apply proper soil erosion and sedimentation control practices in land clearing, soil movement, and construction activities", and similarly addresses this by regulation of the offending activities. (§ 12-7-2)[121] The regulations[122] carrying out these laws are set by the Environmental Protection Department of the Georgia Department of Natural Resources.

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. Georgia has used beach nourishment successfully to preserve the small resort island of Sea Island.[123] The beach was nourished in 1990, and two groins were constructed; after eight years, sand dunes and vegetation were thriving on the beach, and the threat to beachfront homes from coastal hazards had greatly diminished.

[119] C. Craft et al, "Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services," Frontiers in Ecology and the Environment 7(2) (2009): 73-78. http://www.esajournals.org/doi/abs/10.1890/070219

[120] The Georgia Code, "Title 12: Conservation and Natural Resources, Chapter 5: Water Resources, Article 4: Coastal Waters, Beaches, and Sand Dunes, Part 2: Shore Protection." Accessible through http://www.lexis-nexis.com/hottopics/gacode/blanklogin.asp

[121] The Georgia Code, "Title 12: Conservation and Natural Resources, Chapter 7: Control of Soil Erosion and Sedimentation."

[122] Georgia Department of Natural Resources Rules and Regulations, "Chapter 391-3: Environmental Protection, Chapter 391-3-7, Erosion and Sediment Control, 391-3-7-.05 Buffer Variance Procedures and Criteria," Rules and Regulations by Georgia Secretary of State (January 9, 2005). http://rules.sos.state.ga.us/docs/391/3/7/05.pdf

[123] Department of Land and Natural Resources Land Division Coastal Lands Program, "Hawaii Coastal Erosion Management Plan; II. Managing Coastal Erosion; B. New Tools for Erosion Management; 3. Regulatory Tools; f. Setback Programs, 4. Georgia Beach Nourishment Program" (2000): 27. http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/coemap.pdf

Hawai'i

Research

1 In 2000, the Hawai'i Department of Land and Natural Resources (DLNR) described a proposal for an 'Integrated Shoreline Policy,' noting that despite the establishment of the Coastal Zone Management Program in the late 1970's, "coastal communities in Hawaii continue to face serious erosion hazards, seawalls continue to be built, and beaches continue to vanish with the continued development of the coastal zone."[124]

The proposal describes some problems resulting from a lack of coordination among different jurisdictions. One major challenge is "the legal bifurcation of administrative responsibilities between state and county governments at the shoreline… The State is responsible for lands seawards of the shoreline… [but] the County is generally responsible for areas landward of the shore, including coastal dunes that share sand with the beach… Thus, long-range planning, or even short term siting decisions by County authorities may not adequately consider and evaluate factors that lie outside of (seaward) their legal jurisdiction, such as the effects of sea-level rise, waves and currents, and other factors in coastal erosion including shoreline hardening."[125]

2 Included in the document for the "Hawaii Coastal Erosion Management Plan is a survey of setback programs of other states.[126] And in an appendix, the document discusses global sea level rise including the risk of future sea level rise caused by human-induced global warming. Local factors come from the comparative youth of the islands of Hawai'i, which are still adjusting to achieve equilibrium with the underlying layers of earth. The islands of Hawai'i, Maui, and Haleakala are sinking in a process of lithospheric flexure. A flextural bulge in the crust surrounds this subsiding area, and the island of Oahu is passing over this bulge; with the result that Oahu is rising, but not fast enough to outpace global sea level rise.[127]

3 * The University of Hawaii's Mapping Research Group[128] has used map data first to model sea level rise scenarios, and then to create images, 3-D models, and animations for the scenarios. This media is available on the Research Group's website.[129]

4 Rising sea level might manifest itself in Hawai'i not as shoreline inundation, but as a rising water table. Thus sea level rise might unexpectedly be beneficial for wetlands, as the rising water table would restore the wetlands of the 19th century, as well as converting other tracts of land to wetlands.[130]

Policy

1 In 2000, following the proposal for an 'Integrated Shoreline Policy,' the Department of Land and Natural Resources adopted the "Hawaii Coastal Erosion Management Plan." The Plan is a comprehensive assessment whose purpose is to "outline socioeconomic and technical mechanisms for conserving and restoring Hawaii's beaches in a framework of mitigating erosion impacts and reducing exposure to coastal hazards for future generations." Its recommendations include:
– considering erosion at the zoning and

[124] State of Hawaii Department of Land and Natural Resources, "Proposed 1st Elements of a Comprehensive Coastal Lands Policy – Integrated Shoreline Policy" (2000): 1. http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/DLNR-Shoreline-Policy11-15.pdf
[125] Ibid., 5-6.
[126] Department of Land and Natural Resources Land Division Coastal Lands Program, "Hawaii Coastal Erosion Management Plan" (2000): 26-28. http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/coemap.pdf
[127] Ibid., 80-81.
[128] Hawaii Mapping Research Group, University of Hawaii (April 2009). http://www.soest.hawaii.edu/hmrg/index.php,
[129] Hawaii Mapping Research Group, "Flooding Oahu - A look at sealevel rise in Hawaii," University of Hawaii (April 2009). http://www.soest.hawaii.edu/hmrg/FloodingOahu/index.php,
[130] C. Fletcher, "Sea Level Rise Website: The Blue Line," University of Hawaii Coastal Geology Group (2008). http://www.soest.hawaii.edu/coasts/sealevel/

subdivision stages of land development;
– developing a manual to provide direction for development, restoration and redevelopment of the coastline;
– implementing a pilot project of beach and dune restoration;
– funding coastal land acquisition programs; and
– integrating hazard mitigation and coastal conservation.[131]

2 The Center for Island Climate Adaptation and Policy at the Hawai'i Sea Grant produced a report analyzing current and proposed legislation. It includes a discussion about shoreline setbacks, including a summary of all setback requirements in the state. It draws attention to the importance of proper standards, pointing out how under the existing State Coastal Zone Management Law, shoreline setbacks are to be not less than 20 ft and not more than 40 ft, yet in some jurisdictions a structure within 20 ft of a shoreline is treated as an emergency situation.

The report further notes that states such as California, Connecticut, Mississippi, Louisiana, and Texas have no shoreline setback, and the damage from recent hurricanes may be partially attributable to this. Other coastal states, the report notes, have arbitrary or unclear setbacks.

The report then presents the Hawai'ian Island of Kaua'i as an exemplar of non-arbitrary planning, and as a model for the state as a whole to follow: "In 2008, Kaua'i passed the most scientifically based shoreline setback in the country, which was based on an annual erosion rate times a planning period of 70 years plus a buffer of 40 feet. The annual erosion rate is determined by guidelines laid out in the Hawaii Coastal Hazard Mitigation Guidebook or data from the University of Hawai'i. The 70-year period is based on engineering study to determine the life expectancy of coastal structures considering building materials, maintenance, water damage, habitability and other factors."[132]

3 The Department of Land and Natural Resources maintains a list of administrative rules, along with citations of authorizing legislation, on its website.[133]

4 In 2006, the DLNR produced a "3-Year Plan for Beach Restoration Studies and Projects," describing the creation of the Hawai'i Beach Management Program (HBMP). [134] The HBMP will "identify and evaluate management options for the coastal regions of Hawaii, assess its current condition and relationship to the upland area, and identify a complete set of development and planning options appropriate for the beach system. The HBMP shall approach planning, development, and future options from a comprehensive, integrated regional planning perspective that assesses each coastal region like an individual sediment system and coastal environment…

"The HBMP will provide a single, comprehensive document and implementation tools that all management agencies will reference for any land use applications for that coastal region, and will help guide the Department on the allocation of resources towards beach restoration and preservation. This will eliminate the *ad hoc* process that is currently in place, and remove both the interagency and developer/agency conflicts that arise from an absence of a unified plan. It is envisioned that the HBMP will be completed in approximately two years [from 2007]."

[131] Department of Land and Natural Resources Land Division Coastal Lands Program, "Hawaii Coastal Erosion Management Plan" (2000): 6-9. http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/coemap.pdf

[132] D. Hwang and M. Burkett, "Shoreline Impacts, Setback Policy & Sea Level Rise," University of Hawai'i Sea Grant Center for Island Climate Adaptation and Policy (April 2009): 6. http://www.soest.hawaii.edu/SEAGRANT/communication/pdf/GG-10-01.pdf

[133] State of Hawai'i Department of Land and Natural Resources, "Administrative Rules" (2009). http://hawaii.gov/dlnr/occl/documents-forms/rules

[134] State of Hawai'i Department of Land and Natural Resources, "Report to the Twenty-Fourth Legislature Regular Session of 2007: 3-Year Plan for Beach Restoration Studies and Projects" (November 2006). http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/BeachReport.pdf

5 * The Department of Land and Natural Resources' "Report to the Twenty-Third Legislature Regular Session of 2006" deals with the issue of "induced vegetation." Both the legislative and the DLNR's definition of shoreline rely partially on vegetation as a reference point.[135] "Induced vegetation" is where property owners induce vegetation through artificial means in order to define the shoreline more seaward and consequently be able to build closer to the sea. Besides problems in determining on what grounds such induced vegetation can be considered illegal, it can be extremely difficult to determine if vegetation is induced or natural, compounded with more than a decade of inadequate funding that has made enforcement impossible. [136] While induced vegetation's *ad hoc* nature likely renders it ineffective for shoreline protection, it is still interesting to note how the problems of using vegetation to define shorelines has had the side effect of being an incentive for property owners to plant vegetation.

Actions

1 The 2000 "Hawaii Coastal Erosion Management Program," which includes sea level rise from human-induced global warming as a factor contributing to erosion, summarizes actions taken up until that point. Most actions listed here are studies undertaken of erosion management efforts. While only the recommendations of the studies are listed, consistent themes for these recommendations are establishing larger setbacks (usually in the range of 80 ft), enforcing those setbacks and other regulations, removing illegal shoreline structures, and further mapping the coastline. These suggest that the main failures of existing efforts lay in existing setback requirements being far too narrow, and difficulty in enforcement (especially from lack of available funds).[137]

2 * Based off a brochure from the North Carolina Sea Grant College Program, the University of Hawai'i Sea Grant has produced an educational handbook, "Purchasing Coastal Real Estate,"[138] seeking to inform potential buyers and builders of the hazards of owning coastal property before such purchases are made. Diagrams explain both natural processes and how shoreline hardening interferes with them. It recommends as the primary response to "Do nothing. Allow the erosion to take place without interfering with the natural coastal processes."[139] The second recommended option is managed retreat, followed by beach replenishment, then placement of geotextile bags, and then shoreline armoring but only as a last resort. The guide further warns potential buyers that obtaining permits for shoreline protection structures "can be a considerable challenge," and that they might be prohibited from rebuilding after a coastal storm. [140] For new construction, it gives setback recommendations and structure design recommendations such as pilings.[141]

3 The department of Land and Natural Resources' Office of Conservation and Coastal Lands maintains a list of recent, approved/active, and pending beach nourishment projects.[142]

[135] State of Hawaii Department of Land and Natural Resources, "Report to the Twenty-Third Legislature Regular Session of 2006: Requesting a Review and Analysis of the Issues Surrounding the Shoreline Certification Process for the Purpose of Establishing Shoreline Setbacks" (December 2005): 6. http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/SCR051-12-7-05-FINAL.pdf

[136] Ibid., 8-9.

[137] Department of Land and Natural Resources Land Division Coastal Lands Program, "Hawaii Coastal Erosion Management Plan" (2000): 67-75. http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/coemap.pdf

[138] D. Eversole and Z. Norcross-Nu'u, "Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawai'i: A Practical Guide of Common Questions and Answers," University of Hawai'i Sea Grant College Program (August 2006). http://www.soest.hawaii.edu/SEAGRANT/communication/pdf/Purchasing%20Coastal%20Real%20Estate.pdf

[139] Ibid., 12.

[140] Ibid., 14, 18.

[141] Ibid., 15, 17.

[142] Department of Land and Natural Resources, "Beach Nourishment Projects" (2009). http://hawaii.gov/dlnr/occl/projects/beach-nourishment

Louisiana

Research

1 Since the 1930s, over 1,875 square miles (1.2 million acres) of land in coastal Louisiana has converted to open water, and every year an additional 24 square miles (15,300 acres) are lost. A 2003 study estimates that the state will lose an additional 513 square miles (328,000 acres) by 2050.

In addition to the massive human impact on marshland, hurricanes Rita and Katrina destroyed 200 square miles of marsh.

According to the US Department of Commerce, Louisiana provides 26% (by weight) of the commercial fish landings in the lower 48 states. And according to the LA Department of Wildlife and Fisheries, more than five million migratory waterfowl spend the winter in Louisiana's marshes.[143]

2 While Louisiana suffers extensive local sea level rise from both subsidence and eustatic rise, several projections show that relative sea level rise is within the wetlands' abilities to cope, especially if actions are taken to re-establish natural land-building processes.[144]

3 Hurricane protection structures placed across estuarine basins have altered patterns of marsh flooding. The structures prevent water from moving inland, which reduces high water levels, but also reduces the frequency with which new sediment and nutrients spread across the marsh. Hurricane protection also holds water in; for example, during Hurricane Rita, the structures in Chenier Plain were overtopped with salt water and the wetlands were inundated with salt water.[145]

Policy

1 In the wake of the devastating hurricanes Rita and Katrina of 2005, in November of 2005 the Louisiana legislature passed Act 8 to create the Coastal Protection and Restoration Authority (CPRA). The CPRA's mandate was charged with coordinating efforts of local, state and federal agencies, and integrating the previously discrete areas of activity of flood control and wetland restoration.

Eighteen months later, in April 2007, the CPRA produced the state's coastal master plan entitled "Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast." The process of producing the report included six workshops with groups such as agency partners, science advisors and NGOs to provide input to the Master Plan process, over 50 stakeholder workshops and meetings, 9 public meetings for the Preliminary Draft Master Plan, and 3 public hearings and 1 public meeting for the Draft Master Plan. Appendices of the plan contain more than 2,000 pages of received public comments and notes.

The Plan recognizes that "Coastal Louisiana will be among the first places in North America to feel the effects of global warming. Its low-lying coast will be directly impacted by rising sea level and more frequent hurricanes. Longer dry periods and more intense storms linked to global climate change would further stress some of the more highly managed wetland areas of coastal Louisiana. Larger storms will drive more salt water into fresh systems that are unable to flush it back out because of the lack of drainage, rainfall, and fresh water input from rivers. And the longer salt water remains in the wetland system, the harder it will be for the vegetation to recover

[143] Coastal Protection and Restoration Authority, "Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast" (April 2007): 12, Executive Summary 4. http://www.lacpra.org/masterplanfinal

[144] Ibid., 26.

[145] Ibid., 28.

after a storm surge."[146] The plan is focused towards preparation for a 100-year storm or greater.

The plan consists of several major areas. Restoring sustainability to the Mississippi River Delta (the 'Mississippi River Delta Management Plan') involves reconnecting the Mississippi River to wetlands through controlled diversions, in order to restore flows of water to bring sediments and nutrients to the ecosystem. The majority of the river's sediment and fresh water will be used to nourish existing wetlands as well as create new delta lobes, although not in large areas of open water. Dredge material will be used to restore marshes through a process of "pulsing," where dredging is turned on and off in coordination with seasonal changes in the availability of sediment. The plan recognizes that wetlands "built via pipeline" do not always function like wetlands built through natural processes, for which the plan recommends additional research including inventories of sediment and pilot projects.[147]

Barrier shorelines and ridge habitats will be restored. Shorelines will be stabilized by rock structures or by establishing living reefs. The plan calls for the immediate closure of the Mississippi River Gulf Outlet (a deep-draft maritime traffic route from the Gulf of Mexico to the Port of New Orleans opened in 1965 despite concerns even at the time from citizens and scientists about potential harm to the ecosystem[148]) to deep draft navigation, and for the construction of a closure dam to restore the integrity of the Bayou LaLoutre ridge. Appropriate economic mitigation plans will be needed after the channel is closed.

While levees are part of the plan, the Plan recognizes that they can no longer be the traditional earthen levee embankments. The plan recommends seeking innovative technology that minimizes disruptions to tidal regimes and hydrology, and keeps basin systems functional by integrating landward diversions and drainage structures. This must be combined with ensuring that strict land use controls are enforced.[149]

For restoring sustainability to the Atchafalaya River Delta, the only region of coastal Louisiana that is building land naturally, this natural process will be encouraged by building new channels to distribute fresh water from the Atchafalaya River.

The Chenier Plain in southwest Louisiana has its own set of unique land loss challenges, and people use it differently from the Delta Plain. In particular, navigation channels and canals have caused salt water to penetrate inland, impinging on freshwater lakes and destroying marshes. For the Chenier Plain, the Plan suggests managing drainage, maintaining the integrity of freshwater resources by shoring up bands of selected navigation channels, raising and armoring sections of highway, and placing saltwater barriers at deep draft shipping channels to manage salinity levels.

The plan also includes a series of measures relating to hurricane protection. For these measures, the plan stresses that hurricane protection structures must be built around the ecosystem; water, sediments and nutrients must be delivered to wetlands, and impediments to water flow must be minimized. Protection and restoration actions should work together to make sure that flood water is not trapped within the system. Non-structural solutions must also be utilized, which includes flood insurance, elevating and retrofitting structures, and planning evacuation routes.[150]

Actions

1. While not specifically focused on habitat protection from sea level rise, the Master Plan incorporates sea level rise into its integrated framework.

2. Implementing the Master Plan faces many challenges: funding, materials and resources

[146] Ibid., 26.
[147] Ibid., 30-31.
[148] Ibid., 55.
[149] Ibid., 29.
[150] Ibid., Executive Summary 13.

are limited; laws, policies and other administrative procedures need to be updated; some concepts require further planning before they can be carried out, and some projects will take years to plan and construct.

For carrying out the plan, outlined in the Master Plan is that each year an "Annual Plan: Ecosystem Restoration and Hurricane Protection" will be published in the spring before the state's legislative session begins. This report will identify actions will be undertaken in that fiscal year as well as a report card of progress made and forecasts of project priorities for up to three years. [151] The Annual Plans of 2008, 2009 and 2010 are posted online on the CPRA's website.[152]

The 2010 plan adopts a new format and provides many more details than the previous two plans, reflecting the progress that has been made towards carrying out various projects. Appendix A, "Ongoing Protection and Restoration Project Summaries," gives a table summary of hundreds of individual projects, including both pending projects and projects completed between 1986 and 2008. Also listed are the costs of engineering, design, landrights, construction, operation, maintenance, and monitoring.[153]

Appendix D contains a list of constructed barrier shoreline restoration projects, from 1996 onwards. One project, new cut dune and marsh restoration in 2007 at the eastern Isles Dernieres, was undertaken after the publication of the Master Plan.

Projects that have been funded and are in the process of construction include dedicated dredging and deposition of dredged material to create dune and marsh habitat, creation of tidal creeks and ponds, vegetation planting, and construction of breakwater and groins, across a number of sites mostly concentrated in the barrier islands off southwest Louisiana (under the 'toe' of the 'boot').

3 Cameron Parish has three major lakes, each used for both commercial fishing and commercial transport activities. The three suffer from varying amounts of saltwater intrusion and shoreline erosion. To address this, the local coastal program developed a policy to plug all new canals opening into the lakes using spoil material or rip-rap at least 75 feet from lake banks. This is in addition to monitoring lake conditions, and regulation of dredging (especially discouraging dredging through the coral reefs located in the area).[154]

[151] Ibid., 93.
[152] Coastal Protection and Restoration Authority of Louisiana, "Fiscal Year 2008 Annual Plan" (April 2007); "Fiscal Year 2009 Annual Plan" (March 2008); "Fiscal Year 2010 Annual Plan" (April 2009). http://www.lacpra.org/assets/docs/FY2010%20Annual%20Plannew.pdf, http://www.lacpra.org/assets/docs/FY09_Annual_Plan%2003-26-2008-1.pdf, http://www.lacpra.org/assets/docs/FY08%20Annual%20Plan%20--FINAL--%20(2).pdf,
[153] Ibid.

[154] Cameron Parish Local Coastal Program, "Goals, Objectives and Policies for Cameron Parish Environmental Management Units" (June 2004). http://dnr.louisiana.gov/crm/coastmgt/interagencyaff/lcp/parish/cam_emu.asp

Maine

Research

1 In 1995, the University of Maine, Maine State Planning Office, and Maine Geological Survey, under an EPA grant, produced a report entitled "Anticipatory Planning For Sea-Level Rise Along The Coast Of Maine." This document recognizes projections of an accelerated rate of sea level rise from global climate change associated with the greenhouse effect.[155] The report uses IPCC reports to decide to plan on shoreline changes resulting from a sea level rise of 0.5 m, 1.0 m, or 2.0 m (1.6 ft, 3.3 ft, and 6.6 ft respectively) over the next 100 years, even though the 2.0 m scenario is cited as very unlikely to be realized by 2100. The logic given for such planning is that opportunities to avoid adverse impacts by acting now may be lost if action is delayed; and that this is good practice whether climate change occurs or not.

The report seeks to:
– first, identify sea level trends focusing on change in shoreline position, accelerated erosion/inundation of dunes and beaches, inundation of wetlands and lowlands, and loss of natural coastal protection systems;
– second, assess vulnerability under a number of different scenarios;
– third, take a "no regrets" strategy where actions taken to address sea level rise will prove harmless or beneficial even if sea level rise does not accelerate;
– fourth, continue to participate in national and international efforts to reduce emissions; and
– fifth, recognize the State's responsibility over mitigation of the impacts of accelerated sea level rise.

The findings determine that sand dune systems, wetlands, and eroding buffs along the coast face significant threats from erosion even without accelerated sea-level rise. The projections for shoreline retreats under the three scenarios are 3-35 m, 8-50 m, and 17-100 m for salt marshes; 15-45 m for bluffs under all three scenarios; and 10-150 m, 100-300 m, and 200-600 m for beaches. It notes that the loss of wetlands from this shoreline change depends on whether conditions allow a wetland to migrate inland.

The report then lists policy response options, but notes that it is not a formal plan, only preliminary recommendations. It found overall that the most cost-effective strategy was one of retreat, rather than attempting to protect development and maintain the existing shoreline position. It applied a cost/benefit analysis to four possible courses of action:
(1) if the state were to adopt a combination of beach nourishment, maintenance of existing bulkheads and construction of new bulkheads along wetlands to prevent inland migration (and protect human development), the report estimates that the cost would exceed the benefits by 1.1:1 under a 0 cm rise scenario, and by 1.6:1 for a 200 cm rise scenario.
(2) if the state were to add initial buy-outs and abandonment of vulnerable structures ("compensated setback" strategy) to a strategy of beach nourishment and bulkhead maintenance, the cost/benefit ratio would be 1:1.16 (benefits would exceed costs) if there were no rise in sea level. But under a 50 cm rise scenario, the ratios would be 1.1:1, and under a 200 cm rise scenario, 1.8:1.
(3) if the state were to use regulation to prohibit all new development in the areas expected to change, and require existing development to be removed (rolling easements), the cost-benefit ratios become 1:1.4 for a 50 cm rise, 1:1.1 for a 100 cm rise, and 1:1.2 for a 200 cm rise—a greater benefit than cost under all scenarios.
(4) if the state were to apply rolling easements to existing as well as new development (new development would be allowed, but subject to the same removal requirements if and when

[155] Environmental Protection Agency and Maine State Planning Office, "Anticipatory Planning for Sea-Level Rise Along The Coast of Maine" (September 1995): Executive Summary 1. Typed Executive Summary available at www.epa.gov/climatechange/effects/downloads/maine_0.pdf and at http://www.maine.gov/spo/coastal/docs/SeaLevelRise_ExecSummary.pdf. Full scan of the 1995 report at http://www.maine.gov/spo/coastal/docs/SeaLevelRise.pdf.

inundated by the sea), the ratios of cost to benefit would be 1:1.7 for a 50 cm rise, 1:1.3 for a 100 cm rise, and 1:1.5 for a 200 cm rise. Thus, under this analysis, the fourth option provides the greatest benefit.

The report notes that policies in place for Maine's sand dune systems already form an appropriate base for adaptation strategies, and it recommends these rules should be retained and enforced. Overall, the state should seek to "protect and strengthen the ability of natural systems to adjust to changes in shoreline position" and "prevent new development which is likely to interfere with the ability of natural systems to adjust to changes in shoreline position." It offers some concrete steps to achieve these goals, mainly relating to land-use planning.[156]

In addition to this, Appendix B provides a selected review of other state initiatives addressing sea level rise or coastal erosion.

2 A study presented in 2001 used foramineral and chronological analysis of salt marsh peat sequences to produce high-resolution sea-level records for three locations along the coast of Maine and Nova Scotia.[157] The studies showed that the sea level of Maine rose 30-50 cm since 1750 AD, and of Nova Scotia as much as 60 cm. The results matched with available tide-gauge records available from 1912 onwards.[158] The authors of the study note that the level of rise is unprecedented in the past millennium, and ask whether it is due to natural events or human interference. According to lead author Roland Gehrels, from the University of Plymouth in the UK, "There seems to be a two-stepped rise. First, sea level rose at the end of the 18th century as a result of natural climatic warming. In the 19th century, sea level didn't rise much at all. But at the beginning of the 20th century, sea level took off again, in tandem with global and hemispheric temperature rise. But sea level is rising faster now than during times when there was only 'natural' warming. This is a strong indication that current sea-level rise is not just the result of 'natural' warming but is, at least in part, caused by human-induced climate change."[159]

3 * A publication by the Maine Sea Grant analyzes cultural changes as the main reason for the devaluation of salt marshes: "Before European settlement, Native Americans depended on Maine's salt marshes as bountiful hunting, fin- and shellfishing grounds. Early settlers also relied on salt marshes for hay and pasture for their livestock, altering the marshes with dikes, berms and ditches in an effort to grow more hay. During the industrialization and urbanization of the 19th century, the public's perception of salt marshes was transformed from seeing them as valuable resources to thinking they were dank, soggy barriers to development and sources of disease. As a result, salt marshes were:
– filled for the disposal of human garbage and waste
– diked, ditched and drained for conversion to agricultural land
– restricted or blocked from the tide by railroad and highway embankments
– dredged for navigation
– filled with dredge materials
– ditched with the intention of eliminating temporary, standing water on the marsh
– damaged or destroyed by residential and commercial development, especially after World War II when population and recreation in the coastal zone began increasing dramatically."[160] See Maine-Research-5 below

[156] Ibid., Executive Summary 11.
[157] NASA Earth Observatory News, "New Evidence for Sea-Level Rise along the Coasts of Maine and Nova Scotia" (November 2001). http://earthobservatory.nasa.gov/Newsroom/view.php?id=22001
[158] There has been an 8 in (20 cm) rise since 1912, according to tide gauges in Portland, at an average rate of 0.07 in/ yr (1.9 mm/yr). G.I. Jacobson et al, "Maine's Climate Future: An Initial Assessment," Orono, ME: University of Maine (April 2009): 3, 21. http://www.climatechange.umaine.edu/mainesclimatefuture/Maines_Climate_Future.pdf
[159] "New Evidence for Sea-Level Rise along the Coasts of Maine and Nova Scotia."
[160] M. Dionne et al, "Main's Salt Marshes: Their Functions, Values and Restoration. A Resource Guide," Maine Sea Grant (2003): 8. http://www.seagrant.umaine.edu/files/pdf-global/03marshbook.pdf. Emphasis of terms found in the publication's glossary, such as the bolding and italicizing of 'dikes,' is omitted.

for how values can be identified as human-dimension uncertainties.

4 A 2005 summary of Maine's historical sea-level changes from 14,000 years ago notes that "Coastal erosion is often considered unpredictable, and an implacable foe of homeowners. Coastal erosion is in fact decidedly predictable, all we are lacking is information on precisely when the events will occur. Similarly, erosion is only a problem when we try to fix property lines or build structures in an inherently unstable environment, when the long-term change in many locations is dominated by landward movement of the shoreline."[161]

On the issue of future trends, the summary reads, "Global climate models provide predictions of warming and precipitation changes under future scenarios of increased carbon dioxide in the atmosphere… Depending on the rate of input of carbon dioxide, predicted sea levels range from a low of 0.5 m (1.6 ft) to a high of 3.5 m (11.5 ft!) above present by the year 2100. Most scientists now accept the lower to middle-lower range predictions, but notice that this is still more than double the historic trend shown by tide gauges. Remember that the tide gauges, in turn, show far more rapid rates of rise than those of the past 1000-2000 years." The article also notes that colleagues of the authors at the University of Maine are involved with national efforts at climate modeling.

5 * A study[162] by Susanne Moser looks at human-dimension uncertainties in policy responses to sea-level rise in Maine, North Carolina and South Carolina. The study seeks to provide background for incorporating human-dimension uncertainties into policy planning.

These three states were chosen because they had begun to address sea level rise in coastal policy as far back as the 1980s, and because there existed published reviews from the 1980s and 1990s about the coastal programs of these states and their responses to the threats of global climate change and sea level rise.

Moser, who conduced the study on the basis of face-to-face or phone interviews with key informants from coastal management, academic institutions or NGOs, found that the words "uncertainty" and "ignorance" undermined trust and seemed to individuals to be challenges to their authority. This became a finding in itself, revealing that human resistance, itself a human-dimension uncertainty, was an obstacle to incorporating consideration of human-dimension uncertainties. In order to proceed, Moser learned to allow the interviewee to first establish his or her authority, and then turn the interview into a collaborative discussion of challenges.

Other results include:
(1) Social scientists perceive engineering and physical knowledge as more solid than knowledge on the human dimensions, a perception vehemently countered by physical scientists by itemizes lists of knowledge gaps in their fields.
(2) The largest uncertainties came from vulnerability and societal responses to global climate change. I.e., the biggest uncertainty in climate change adaptation and mitigation was the amount of human initiative in responding. Interviewees thought that such unknowns were least rigorously studied.
(3) Impacts of and responses to slow-onset and slowly progressing changes are under-studied. Episodic and short term events such as coastal storms are better studied and better understood than long-term gradual processes like sea level rise. Moser notes that the study of human responses to "creeping hazards" is not well understood, but offers the partial explanation that slow hazards are relatively unattractive as objects of study. For example, the research on sea level rise impacts that

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[161] J. Kelley et al, "Maine's History of Sea-Level Changes," Maine Geological Survey (October 2005). http://www.maine.gov/doc/nrimc/mgs/explore/marine/facts/sealevel.htm

[162] S. Moser, "Impact assessments and policy responses to sea-level rise in three US states: An exploration of human-dimension uncertainties," *Global Environmental Change* 15 (2005): 353–369. http://www.isse.ucar.edu/moser/pdf/GEC_Moser_final.pdf

does exist is "frequently justified by the potential of SLR to aggravate short-term hazards or by the dramatic impacts when viewed cumulatively over time."
(4) Interviewees agreed that unpredictable random variation in and between physical, ecological and social dimensions makes understanding and generalization difficult.
(5) Impact assessments tend to be static and ignore things like the nature and level of human response, including variables such as "the workings of markets, inefficiencies in implementation of policies, timing, delay in decisions, 'non-rational' actor behavior, changes in demographic structures and distributions, societal learning, institutional changes, and changes in people's perception and valuation of coastal resources and environmental change". Moser notes that these points of critique have been made before, but they remain understudied.
(6) Research so far has largely neglected social surprises, in contrast to the recognized importance and scientific devotion to investigation of potential geophysical surprises such as major system shifts or break-downs such as the shut-down of thermohaline circulation or the collapse of the West-Antarctic ice shield. Possible social surprises include "an end of federal disaster assistance, the collapse of the insurance industry, major shifts in the public trust vs. private property rights debate, or unexpected technological breakthroughs."
(7) Assumptions and biases not only determine findings, but reinforce areas of ignorance. For example, "impact assessments are always premised on convenient, if realistically indefensible, assumptions and unspoken biases in impact assessments" such as assumptions that economic and demographic growth rates will be constant, or that human values will remain unchanged. It is rarely explicitly acknowledged that these assumptions, and the uncertainties they omit considering, can affect the validity and usefulness of impact assessments. A related bias is only pursuing areas of study for which it is possible to find data and information, or expressible in convenient metrics such as dollars. This data and method-based approach does not necessarily provide solutions, and it reinforces ignorance and lack of awareness of less convenient or inaccessible aspects of the challenges of climate change. Moser suggests that "researchers may try to avoid some of the pitfalls of this 'lamp posting' practice by making a conscious effort to tackle and communicate less obvious knowledge gaps."
(8) An "internal logic of values, interest, and preferences among researchers (and not necessarily the need for better understanding) drives the research agenda." This means that the research agenda is often determined by personal leanings including choice of region, assumptions about relative current or future importance of particular coastal industries, choice of scale (impacts attention given to distributional effects), and determinations of what structures, environmental resources and processes are most critical to the functioning of society. Researchers also tend to focus on near-term, first-order, easily discernable and measurable impacts over complex interactions, stochastic events, and events whose causality is difficult to trace. Researchers also "exhibited or commented on a bias towards studying negative impacts as opposed to potentially positive ones." Interviewees also emphasized human impacts over ecological impacts, even though they thought that ecological impacts were ultimately more serious.
(9) "Preventing the erosion/loss of the knowledge base may be as or more important (but less attractive) than developing new knowledge." This applies to loss of institutional memory (such as from personal turnover), barriers to information exchange, and a problem related to both of these, which is the good chance that for any given locale or from similar locales, "at least some of the needed information and relevant research exists, albeit in basements, on dusty shelves, or simply forgotten, unknown, or inaccessible."[163]

[163] Note: While Moser's study often is obviously critical, it is not always so. For example, research attention and ability is finite, and so there must be some standard by which priorities are determined. In this case, Moser points out how these priorities are determined (i.e., threats of big impacts are prioritized over threats of small impacts). Unlike other cases, she does not provide any critique about why such values by which priorities are based are bad, and indeed it is doubtful that some other alternative is desirable. So the overall critical tone

On pages 358-359, Moser provides a summary list of "uncertainties in the human factors that co-determine the impacts of sea level rise," grouped into categories including 'human wants,' 'expectations about "How the World Works",' 'valuation of scientific knowledge and progress,' 'attitudes towards uncertainty,' and 'valuation of impacted systems/of impacts.'

Other conclusions from the interviews are that:
(1) Case studies show that short-term acute hazard mitigation is not a substitute for long-term planning for sea level rise, but that the short-term is the usual approach. Storm hazard mitigation is insufficient to address the coastline changes of sea level rise.
(2) "Severe losses of shoreline development can only be avoided or postponed through rules that recognize a changing shoreline."
(3) The question of whether to harden the shoreline or not remains contentious and a probably site of future conflict.

For Maine specifically, see Maine-Policy-1 below.

6 An EPA study, "Anticipatory Planning For Sea-Level Rise Along The Coast Of Maine," estimates the impact in the Camp Ellis area of wetlands under three scenarios of projected sea level rise. A 0.5 m rise would result in the loss of >1 acre; a 1.0 m rise, the loss of 21 acres; and a 2.0 meter rise, the loss of 57 acres. Most of the wetlands in question are tidally influenced freshwater wetlands, classified as having low, moderate or indeterminable value for habitat. The study notes that wetland reaction was beyond the scope of the study, but that wetlands would probably undergo slow conversion to salt marsh or, under the 2.0 m rise scenario, be inundated.[164]

7 * "Impacts of Future Sea Level Rise on the Coastal Floodplain," a 2006 report prepared by the Maine Geological Survey for the Maine Coastal Program and Maine State Planning Office, is a demonstration project to model a static 2-ft rise in sea level for part of the Rachel Carson National Wildlife Refuge. The area chosen was the portion of the refuge covered by NOAA LIDAR data gathered in 2004. The study looks at a 2 ft rise because Maine's official policy is to plan for a 2 ft rise over the next 100 years, a figure based on tide-gauge data and IPCC projections. The Maine Geological Society also simulated a state 1 ft and 3 ft rise for the study area, and looked at the possible impacts on marsh habitat.

The study incorporated differences in marsh areas and corresponding difference in water levels, using aerial interpretations of marsh vegetation with corresponding elevation data. The study classified the area between open water and mean high water as low marsh, and the area between mean high water and highest annual tide as high marsh.

The study made several assumptions: that marshes would be able to keep up with sea level rise, which assumes sedimentation rates would keep up with sea level rise; that marsh migration would not be impeded by existing developed property; and that sea level rise would be static. The current conditions of the study area were 48% upland above highest annual tide, 24% high marsh, 14% low marsh, and 14% open water. With a 1 ft level rise, these proportions become 44% upland, 12% high marsh, 27% low marsh, and 17% open water. With a 2 ft rise, the proportions are 40% upland, 9% high marsh, 33% low marsh, and 19% open water. And under a 3 ft rise, the proportions are 36% upland, 8% high marsh, 34% low marsh, and 22% open

of the paper should not be taken as a negative judgment about every mentioned observation. I would also add that ultimately, prioritizing ecological impacts in the long terms might still be prioritizing human impacts. Ecological devastation will have a human impact so long as human remain biologically reliant upon environmental resources. And it makes sense to put the presumption on the side of environmental preservation as long as we suspect that the extent of our biological (and perhaps aesthetic) reliance on environmental resources is much more extensive than the amount of reliance we currently understand.

[164] Environmental Protection Agency and Maine State Planning Office, "Anticipatory Planning for Sea-Level Rise Along The Coast of Maine" (September 1995): Chapter 3 page 10. http://www.maine.gov/spo/coastal/docs/SeaLevelRise.pdf

water.[165]

These results indicate that that high marsh would be unable to migrate up the steeper upland slopes, and would be squeezed out by migrating low marsh. The currently existing high marsh seems to be near its maximum area. Extrapolating these results beyond the assumptions, the study notes that increasing open water areas would alter channel morphology and increase erosion, taking sediment away from the marsh system and increasing the proportion of open water. Taking into consideration the human development that would limit wetland migration, the loss of high marsh may be even greater than projected.

The study makes the recommendations, "communities should evaluate existing developed and open space areas in order designate natural areas to allow for the natural transgression of marsh surfaces," and "upland areas identified as being vulnerable to marsh transgression could be targeted as prime areas for restoration, conservation and/or land-use planning." Other recommendations include expanding such studies to other highly-developed and resource-valuable areas of the Maine coastline, that communities should evaluate natural resources to determine best management practices, and that future studies should try to incorporate non-static responses of marshes and topography to sea level rise.[166]

8 A continuation of the "Impacts of Future Sea Level Rise on the Coastal Floodplain" study was announced for completion in June 2007. This extension planned to expand the geographic scope to include all large coastal and sand dune systems and adjacent back barrier salt marshes covered by LIDAR data.[167]

9 "Maine's Climate Future: An Initial Assessment" is a report from the University of Maine, revised in April 2009. Chapter III contains a discussion of the effect of climate change on the coast of Maine, including the effects of sea level rise. The report notes that 50% of the coastline is composed of bedrock, generally not affected by rising seas. The remaining coastline is bluffs, sand beaches, and vegetated wetlands. Out of the proportion of the coastline that is comprised of bluffs, 17% are unstable, and another 17% are armored with seawalls.

Aside from high salt marsh environments reverting to low salt marsh (for which they cite the study discussed in Maine.Research.6), the freshwater bogs and marshes inland of salt marshes will die as they are inundated with salt water, changing much of the shoreline. More frequent flooding of tidal mudflats may lead to millions of shorebirds being unable to feed on their migrations.[168]

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[165] We are naturally curious, how does this compare to the 1995 study (Maine-Research-6)? Because the two studies look at different things, meters retreat of salt marsh shoreline versus percentage of a given area that is salt marsh, we can only make a very loose comparison.

In the 2006 study, open water increased from 14% under current scenarios to 17% under a 1 ft rise, and 19% under a 2 ft rise. The 1995 study uses a scenario of a rise of 0.5 m, which is about 1.6 ft, so we can estimate that a 1.5 ft rise under the 2006 study would have an open water percentage of 18%. The current proportion of salt marsh is 14% high marsh + 24% low marsh = 38%. Taking a rough estimate from a glace on a GIS program of choice, a Maine salt marsh will extend 1 mi inland from open water, so 38% would correspond to 1 mi. Also, taking the figure that Maine has 30 square miles of salt marsh ("Maine's Climate Future: An Initial Assessment" p 31), and a figure on page Summary-5 of the 1995 report that salt marshes are 20% of Maine's coastline, a coastline which the NOAA estimates at 228 statue miles, we get (0.02)(228 mi) = 45.6 mi of coast is salt marsh, and so salt marshes extent (30 mi^2 / 45.6 mi) = 0.66 mi inland on average. Thus we can see that our estimate of 1 mi is at least in the right order of magnitude.

Then, open water increasing from 14% to 18% would be an increase of 4% of the total area studied, and (4/38)% of 1 mi = 0.1 mi =161 m (or, using 38% corresponding to 0.66 mi, (4/38)% of 0.66 mi = 0.16 mi = 257 m).

This is a significant difference, so we may say that the new data's prediction of a 161 m retreat from a 1.5 ft (0.46 m) rise suggests a much more drastic salt marsh shoreline retreat than 1995 study's prediction of a 3-35 m retreat from a 0.5 m rise. The 1995 study's high end estimate of a maximum of 100 m retreat under a 2 m rise is closer to current data's prediction of the distance of retreat from a mere 0.46 m rise.

Again, this is more a rough attempt to satisfy curiosity than a useable comparison, as no comparison here of data from different sources is strictly appropriate.

[166] P. Slovinsky and S. Dickson, "Impacts of Future Sea Level Rise on the Coastal Floodplain," Maine Geological Survey (July 2006): 1-7. http://www.maine.gov/doc/nrimc/mgs/explore/marine/sea-level/mgs-open-file-06-14.pdf

[167] P. Slovinsky, "Simulating Sea Level Rise in Maine Abstract," Maine Geological Survey (June 2007). http://www.aswm.org/member/wetlandnews/february/simulating_sea_level_rise_in_maine.pdf

[168] G.I. Jacobson et al, "Maine's Climate Future: An Initial Assessment," Orono, ME: University of Maine (April 2009): 21-22.

Policy

1 In August 1991, Buzzards Bay completed an "Action Plan: Planning For A Shifting Shoreline." Buzzards Bay shores are threatened by sea level, erosion, natural shifts of barrier materials, storms, and other natural phenomena, and "These natural processes now appear to have been altered by a variety of environmental changes, including some prompted by human activities. In particular, atmospheric concentrations of carbon dioxide, methane, and other gases released during the combustion of fossil fuels such as coal and gasoline are increasing. The concentration of chlorofluorocarbons released because of wide-spread use in modern industrial society is also increasing. Because these atmospheric gases absorb and trap heat like the glass panels of a greenhouse, this phenomenon is known as the 'greenhouse effect.' "

The report cites a 1987 study for an estimate of a relative sea level rise at 0.8 ft, and cites a 1989 study that projects upland loss in acres through 2100. (109-110) The document is partially an attempt to depart from assumptions of a static sea level and shoreline. The third of three given goals is to "Plan for the loss of buffering wetlands and shifting sand formations." The Department of Environmental Protection, the Plan states, will amend wetland regulations by 1991. The Coastal Zone Management Office will, beginning 1991, provide technical assistance to planning boards, conservation commissions and other relevant entities, for mapping as well as developing bylaws, regulations, guidelines and policies.

Other actions recommended by the Plan include Buzzards Bay communities increasing setback requirements for septic systems and coastal construction, and regulate construction activities more stringently for areas predicted to be subject to sea level rise, erosion or flooding.[169]

2 * In Maine, the coastal program was codified into law in 1978, the year of a major blizzard. The program originally focused on hazard area development, but did incorporate sea level rise from natural post-glacial rise. "In the late 1980s, however, accelerated SLR due to global warming—found entry into ME's coastal laws (sand dune rules, SDRs) and became a pioneering example in nationwide coastal policy-making."

The policy was based on a prohibition of new hardening structures, allowing repair and maintenance of existing structures only if not doing so posed "unreasonable" flooding hazards, restriction of building in high-hazard flood zones, and the [then[170]] strictest retreat policy in the nation. The retreat policy prohibited rebuilding a structure damaged more than 50% in a storm unless the owner could clearly and convincingly demonstrate that the site would be stable from a 3 ft sea level rise over 100 years.

Several legal challenges based on property rights takings and minor revisions somewhat weakened the rules, but the policy remained mostly intact. Moser writes, "Not only does ME continue to be the only state in the US that uses the prospects of future SLR as a basis for its rules; it is also the only law that makes in its text reference to uncertainty. An explanation added at the end of the rules states… 'theories have been developed which predict an accelerated rise in sea level, but the amount which will occur remains uncertain'… [These policies were not] a reflection of ME's unmatched concern for future global climate, but [an] opportunistic response to several key events and trends in the mid-1980s, including a proposed dam project at the upper end of the Bay of Fundy, a building boom in

http://www.climatechange.umaine.edu/mainesclimatefuture/Maines_Climate_Future.pdf

[169] Buzzards Bay Comprehensive Conservation and Management Plan, "Action Plan: Planning For A Shifting Shoreline" (August 1991): 109-113. http://www.buzzardsbay.org/ccmpold/ccmp-ap-shift.pdf

[170] The rule was revised to this form in 1993; I assume that there are now stricter rules, since the prohibition on rebuilding structures damaged 50% or more is now common and in federal guidelines as well.

southern ME causing residents to want to avoid heavy development common along coastlines and the associated influx of 'out of staters' and tireless efforts of state geologists to raise public awareness of coastal hazards, the rise of climate change on the national agenda, and continuous pressure from advocacy groups. Notably, no coastal disaster, but contingent pressures combined with expertise and policy entrepreneurship led to this policy change."[171]

3 Under the authority of the Comprehensive Planning and Land Use Regulation Act, MRSA Title 30-A, §4312.3.F; §4326.1.C; §4326.3-A.D. (2001), a "Comprehensive Planning" manual for Maine communities released by the Maine State Planning Office release in 2005 devotes its fifth chapter to protecting "Habitats and Other Critical Natural Resources."[172] Its main comments relating to habitat protection are about how to conduct inventory and analysis, and then how to follow the applicable policies for balancing development with natural preservation. There is also encouragement and suggestions for going beyond minimum state mandates in such protection.

Chapter 6 is "Hazard Mitigation," and includes a recognition that "the vast majority of Maine beaches are moving inland, and many are under pressure for development. A safe location today may become hazardous in 25 years or less. This issue may be aggravated by expected sea level rise associated with trends in global warming. Even though there is no conclusive agreement on how fast sea level may be rising, it is a good idea to plan in case it happens."[173]

Sea level rise and habitat protection are not explicitly put together. The chapter on hazard mitigation includes a mention that wetlands and floodplains can retain large amounts of water and offset flooding, and that stormwater-eroded soils can fill in channels and lakes, reducing their ability to carry or store water. The focus is on maintaining the ability of natural resources to reduce the severity of hazard damage, and that it might be appropriate for hazard mitigation committees to coordinate with conservation efforts.

A comment about how to protect the water-carrying ability of channels and lakes could apply to environmental protection as well: the effect of sediment blocking off passages of water can be mitigated by preventatively planting vegetation to minimize erosion or by capturing sediment before it enters the water.[174]

4 Full details of applicable laws are available on the website of the Department of Environmental Protection's Bureau of Land and Water Quality.[175]

5 In September 2001, the Maine State Planning Office produced the "Maine State Wetlands Conservation Plan."[176] Identifying a systematic problem, the report notes the that the primary means of protecting wetlands has been regulation of land use for wetland areas, but government regulation of privately held wetlands unavoidably clashes with the United States' history of strong private property rights. It proceeds to give a summary of the history of wetland protection in Maine.

The goals the report sets out are:
(1) provide full protection to Maine's priority wetland systems;
(2) increase and improve knowledge of Maine's wetlands for use at all levels of protection;
(3) improve applicable laws and regulations

[171] S. Moser, "Impact assessments and policy responses to sea-level rise in three US states: An exploration of human-dimension uncertainties," *Global Environmental Change* 15 (2005): 353–369. http://www.isse.ucar.edu/moser/pdf/GEC_Moser_final.pdf
[172] E. Richert and S. Most, "Comprehensive Planning: A Manual for Maine Communities," Maine State Planning Office (2005): 45. http://www.maine.gov/spo/landuse/docs/compplanning/2005manual_highres.pdf
[173] Ibid., 65.
[174] Ibid., 72.
[175] Maine Department of Environmental Protection Bureau of Land & Water Quality, "Natural Resources Protection Act ("NRPA Page")" (2005). http://www.maine.gov/dep/blwq/docstand/nrpapage.htm
[176] Maine State Planning Office, "Maine State Wetlands Conservation Plan" (September 2001). http://www.maine.gov/spo/coastal/docs/wetlands/wetlandconsvplan.pdf

while streamlining the regulatory process;
(4) promote appreciation, stewardship and voluntary protection by private landowners, towns and non-governmental entities;
(5) improve interagency coordination; and
(6) participate in state, regional and national forums to exchange information and develop new approaches.[177] Although ostensibly a plan, many of the institutional suggested actions had already been completed or were ongoing; see Maine-Actions-1 below.

6 In July 2006, the Maine State Planning Office published a report serving as a strategic planning document. The programmatic objectives for wetlands are:
(1) protect and preserve existing levels of wetlands as measured by acreage and functions from direct, indirect and cumulative adverse impacts by developing or improving regulatory programs;
(2) increase acreage and associated functions of restored wetlands;
(3) use non-regulatory and innovative techniques for protection, restoration and acquisitions of coastal wetlands; and
(4) develop and improve wetland creation programs.[178]

A revised Erosion Hazard Area, on which setback rules in the Coastal Sand Dune Rules are based, now includes areas of dune systems that may become wetlands after a combination of short- and long-term erosion and sea level rise. Any area that will become coastal wetlands with two feet of sea level rise, and areas subject to future flooding after 2 feet of sea level rise, are defined as an Erosion Hazard Area.[179] Because the regulatory definition requires spatial and topographic analysis, the report lays out plans for continuing on previous successful efforts using GIS information to define areas likely to be converted to wetlands under a 2-ft sea level rise scenario.[180]

[177] Ibid., 12-16.
[178] Maine State Planning Office, "Maine Costal Plan: Final Assessment and Strategy under Section 309 of the Coastal Zone Management Act" (July 2006): 69. http://www.maine.gov/spo/coastal/docs/coastalplans/mcp309plan_2006.pdf
[179] Ibid., 29, 42.
[180] Ibid., 78.

Actions

1 In the September 2001 "Maine State Wetlands Conservation Plan" of the Maine State Planning Office, alongside a list of goals given are also recommendations, actions associated with those recommendations and the status (completed, ongoing, unscheduled, or failed) of these actions.

Completed actions include conducting a wetland characterization project, comparing the Army Corps of Engineers Highway Method and the New Hampshire Method, making a wildlife habitat predictor computer model with the US Geological Survey, developing a comprehensive digital statewide inventory of 95% of all wetlands one acre and larger, digitizing and linking remaining NWI quadrangles, changing the Natural Resources Protection Act, revising the state's wetland regulations and rules, establishing model requirements with federal agencies in advance of a permit process for cranberry permits, and formalizing the State Wetland Interagency Team (WIT).

Ongoing actions include exploring a compensation fund towards wetland protection objectives, assessing current methods of data collection and disseminating information, developing a computerized wetland permit tracking system, assessing cumulative effects on the state's wetland resources, developing protocols for wetland biomonitoring to determine natural variability and assess the effects of human activities, securing adequate resources for understanding and combating invasive plant species threatening wetland resources, coordinating state wetland programs through WIT, continuing active participation in the national and New England Biological Assessment of Wetlands Working Groups, and continuing to work with the New England Interstate Water Pollution Control Commission on wetland issues. [181]

[181] Maine State Planning Office, "Maine State Wetlands Conservation Plan" (September 2001): 32-40.

2 A public-education pamphlet for mailing, published in 2002, describes the accomplishments of the Maine Coastal Program in 2000 and 2001. Listed actions taken to protect and restore coastal habitats include removing a dam, whose removal would improve water quality and fisheries habitat in an estuary; securing a grant and matching funds that will partially be used to support a coordinator to develop and carry out a coastal habitat restoration plan; identifying priorities in wetland restoration; and assisting Southern Maine towns and regional planners to restore important sand beaches vulnerable to erosion.[182]

3 A public-education pamphlet published in 2004 describes the accomplishments of the Maine Coastal Program in 2002 and 2003. Actions taken to protect and restore coastal habitats listed include hosting an international conference on managing stormwater in cold climates; launching the Maine Healthy Beaches Initiative; supporting a "Beginning with Habitat" program—which uses a landscape approach to assess wildlife and plant conservation needs and opportunities—with staff, funds, and by giving presentations introducing the project in over 60 towns; and 6 coastal habitat conservation projects that will restore 50 acres of salt marsh, 35 miles of riverine habitat for anadromous fish and 40 acres of tidal mudflats.[183]

4 In the Maine State Planning Office's July 2006 report, wetlands were downgraded to an area of "Medium" priority for enhancement, down from being classified as an area of "High" priority in the previous 2001 assessment. The document reports that the change in priority is due to the large amount of work done on coastal wetlands in the previous five years; new policies and programs have come into place or are about to become operational.

The actions taken were:
(1) creating inventories of potential restoration sites in three areas along southern and midcoast sections of the Maine coastline, made available online and to share with active community groups in each region;
(2) Coastal Zone Management staff completing a review of the Natural Resources Protection Act relating to impacts from floats on subtidal habitats, determining that for permitting purposes, seasonal ramps and floats are accessory structures necessary for dock operations. Concern about the increasing number of docks led the Department of Environmental Protection to develop a stand alone dock permit, removing docks from the permit-by-rule process;
(3) based on insights from a June 2005 two-day NOAA dock workshop focusing on New England, CZM staff revised the dock construction handbook. The revisions were being finalized at the time of the report and were expected to be published in the summer of 2006.[184]

Two tables provide summaries of the amount of licensed impacts to coastal wetlands (from fill or alteration) since 2001, as well as the amount of wetland mitigation (restoration, creation, enhancement, preservation). Coastal habitat restored from 2002-2005 includes: 83 acres of salt marsh reintroduced to tidal flow, and 100 acres of intertidal and subtidal mudflats restored, 1000 feet of river channel realignment, and 1200 linear feet and 2 acres of native riparian river bank cover.[185] In addition, Maine partners with Massachusetts and New Hampshire in a Habitat Restoration grant program through NOAA/National Marine Fisheries.[186]

Since the last assessment, the report identifies 'significant changes' in the regulatory program, wetland protection policies and

http://www.maine.gov/spo/coastal/docs/wetlands/wetlandconsvplan.pdf

[182] State Planning Office Maine Coastal Program, "Maine Coastal Program: Accomplishments—2000 and 2001" (March 2002). http://www.maine.gov/spo/coastal/docs/mcp_accomplishments/mcp_accomp_00-01.pdf

[183] State Planning Office Maine Coastal Program, "Maine Coastal Program: Accomplishments 2002-2003" (May 2004). http://www.maine.gov/spo/coastal/docs/mcp_accomplishments/mcp_accomp_02-03.pdf

[184] Maine State Planning Office, "Maine Costal Plan: Final Assessment and Strategy under Section 309 of the Coastal Zone Management Act" (July 2006): 5-6. http://www.maine.gov/spo/coastal/docs/coastalplans/mcp309plan_2006.pdf

[185] Ibid., 71, 75.

[186] Ibid., 74.

standards, assessment methodologies of health, function and extent, impact analysis, restoration and enhancement programs, mitigation banking, mapping/GIS/tracking systems, and acquisition programs, and 'no change' in special area management plans, education/outreach, wetlands creation programs, and publicly funded infrastructure restrictions.[187]

Problems identified include the state lacking a coordinated approach to tracking development and cumulative impacts in the coastal zone, the lack of a non-federal source of match funding for habitat restoration activities, and although habitat restoration has increased significantly in the past five years, the state lacks a cohesive monitoring network to measure the effectiveness of restoration activities, and the increase in wetland functions.[188]

[187] Ibid., 73.
[188] Ibid., 76.

Maryland

Research

1 A 1914 study by the Maryland Geological Survey provides a historical example of a dramatic observed relative sea level rise. This study found that Sharps Island, one of the smallest islands in the Chesapeake Bay, decreased in size from 438 to 53 acres from 1848 to 1910. The island no longer exists.[189] A lighthouse built on Sharps Island is now surrounded by water 3-4 m deep.[190]

2 An October 1985 study by the EPA's Office of Policy Planning and Evaluation, entitled "Potential Impacts of Sea Level Rise on the Beach at Ocean City, Maryland" studies the impacts of sea level rise on "a typical Atlantic Coast resort." It notes that increases in atmospheric carbon dioxide are expected to cause global warming that would raise the sea level a few feet in the next century.[191]

The study notes that most of the land in Maryland low enough to be inundated consists of wetlands such as salt marshes along the Chesapeake bay and various coastal estuaries such as ones near Ocean City. Salt marshes could keep pace with current rates of sea level rise, but would not keep pace with increased levels. The study also notes that development could prevent landward migration of marshes and cause these ecosystems to be lost, and that delay by

[189] Z. Pfahl Johnson, "A Sea Level Rise Response Strategy for the State of Maryland," Maryland Department of Natural Resources Coastal Zone Management Division (October 2000): 12. http://www.ecy.wa.gov/climatechange/PAWGdocs/ci/071007CIsealevelstrategy.pdf
[190] US Geological Survey, "Fact Sheet 102-98 - The Chesapeake Bay: Geologic Product of Rising Sea Level" (October 1998). http://pubs.usgs.gov/fs/fs102-98/
[191] J. Titus et al, "Potential Impacts of Sea Level Rise on the Beach at Ocean City, Maryland," Environmental Protection Agency Office of Policy, Planning and Evaluation (October 1985): *i*. http://www.epa.gov/climatechange/effects/downloads/ocean_city.pdf

decision makers could make large-scale loss of coastal wetlands impossible to avoid.[192] And in some locations along the shores of coastal estuaries, homeowners would have to build levees and bulkheads to prevents marshes from taking over their properties[193]

3 A 1992 report from the University of Maryland, entitled "Future Sea Level Rise Impacts: Maryland's Atlantic Coastal Bays" calculated historical shoreline erosion rates and projected future shoreline positions for several sea level rise scenarios for the years 2020, 2050, and 2100. The study notes that "some government officials, scientists and the general public are unaware of or have largely ignored these warnings [of global warming], the evidence for global change and its impacts is mounting."[194]

The study predicts a total sea level rise of 0.4-0.5 ft for 2020, 0.8-1.5 ft for 2050, and 1.4-4.4 ft for 2100 (with the variance representing different scenarios). In studying historical shoreline changes using historical maps, the study notes that marshy shorelines seem to erode quicker than other shorelines, and that overall there was a great deal of marsh erosion as early as the 1850's.[195] The study incorporates estimates of the possibility of wetland migration; it finds that steep shores between the 1 and 3 ft elevation contours for the wetlands would prevent migration or formation of new wetlands as the sea level rises.[196] Based on these contours and projects of sea level rise, the study estimates that of the 1500 acres of wetlands in the study area in 1989, 1.5 ft of sea level rise would submerge and erode this area completely, and under all scenarios by 2100 all existing wetlands would be destroyed.[197]

The study cites previous documentation (from 1986) from the Blackwater Wildlife Refuge in Maryland showing that the rapid enlargement and coalescence of interior ponds was a major mechanism of marsh loss, and that this was a likely mechanism for the future as well.[198]

The study also gives a brief description of possible options, recommending retreat as the best option but noting the political untenability of this position will probably make it impossible to implement. The study then recommends measures such as restrictions on future development, setbacks, and providing subsidies and incentives as appropriate. Protection is an option, but the study emphasizes that it will always be a temporarily solution.[199]

4 During the 1999 legislative session, the Maryland General Assembly passed a resolution requesting that the Governor establish a Shore Erosion Task Force. The Task Force was created in August 1999, and issued its report in January 2000. Although focused on erosion, the Task Force recognizes sea level rise as a significant factor contributing to shoreline erosion, and that accelerating sea level rise from global warming will intensify shore erosion rates.[200]

It recommended "Environmentally sensitive areas need to be identified and used, together with shoreline and sea level rise impact maps, to prioritize individual and regional projects.[201] The Task Force has four objectives: "(1) identify shore erosion needs by county, (2) clarify local, State, and federal roles, (3) establish five and ten year shore erosion control plans, and (4) review contributing factors to shore erosion."

The report makes nine recommendations: (1) establish an immediate response capacity, including emergency assistance and interim financial assistance for structural control measures, as well as creating a predictive

[192] Ibid., 10.
[193] Ibid., 4.
[194] C. Volonté and S. Leatherman, "Future Sea Level Rise Impacts: Maryland's Atlantic Coastal Bays," Maryland Department of Natural Resources Coastal and Watershed Resources Division (November 1992): 2. http://czic.csc.noaa.gov/czic/GB459.4.V65_1992/5209.pdf
[195] Ibid., 21-23, 82.
[196] Ibid., 82.
[197] Ibid., 75.
[198] Ibid., 82.
[199] Ibid., 88-92.
[200] State of Maryland Shore Erosion Task Force, "Final Report," Maryland Department of Natural Resources (January 2000): 17. http://www.dnr.state.md.us/ccws/sec/download/shoreerosion.pdf
[201] Ibid., 51.

model for sea level rise impacts;
(2) establish regional shore erosion control strategies to study shore erosion, sea level rise and environmental sensitivity and thereby identify priority areas;
(3) develop project review and implementation criteria for regional shore erosion control strategies;
(4) improve coordination among various entities to encourage cooperative management and implementation;
(5) conduct technical evaluations of new products and methods, determine minimum engineering needs, and review industry practices;
(6) utilize available dredged materials;
(7) conduct public outreach;
(8) fill information and data needs to support the Control Plan; and
(9) identify funding needs, potential resources, and develop a financial strategy.[202]

5 In October 2000, the Maryland Department of Natural Resources' Coastal Zone Management Division published "A Sea Level Rise Response Strategy for the State of Maryland," although it was the work of NOAA Coastal Management Fellow and not necessarily official Department policy. The report consists of a review of technology, data and research; an assessment of Maryland's vulnerability based on the range and magnitude of impact; and an assessment of Maryland's' existing response capabilities.

The average rate of sea level rise on Maryland's coast has been 3-4 mm/yr, about twice the global average probably due to substantial land subsidence.[203]

The report mentions sea level rise research by the University of Maryland. This research analyzes marsh response to sea level rise, with particularly notable studies in the Blackwater Wildlife Refuge determining whether marshes can accrete at rates high enough to keep pace with sea level rise. Research has also looked at variables relating to the interaction between sea level rise and ground water withdrawal, glacial isostatic readjustment, nutria for marsh vegetation, and prescribed marsh burning. One result from this research is that approximately 3,460 acres of marshes in the Blackwater Wildlife Refuge were converted to open water between 1938 and 1989.[204]

6 A piece of legislation from the Maryland state legislature notes that lands associated with the Chesapeake Bay and Atlantic coast designated "Critical Areas" (and thereby under the authority of the Critical Areas Commission) comprise approximately 11% of Maryland's land mass.[205]

7 * In 2000, the University of Maryland published a study entitled, "The Health and Long Term Stability of Natural and Restored Marshes in Chesapeake Bay." Using satellite imagery, the researchers tracked signs of marsh decline, including "reduced productivity, canopy thinning, channel enlargement, rotten spots and salt pans as well as ultimate conversion to mudflat and open water."

The study offers analysis of restoration attempts: "Past attempts at restoring Blackwater marshes have not been successful due in part to the combination of excessive grazing by muskrats and nutria as well as anthropogenic influences (reduced diel tidal amplitude because of road building, increasing salinity because of canals, and possibly large-scale burning). Ultimately, restoration efforts depend on the maintenance of groundwater pressure and/or on supplementation of the system with sediment from other sources to keep them abreast of rising sea level. Restoration efforts will depend not only on controlling groundwater withdrawals, but possibly in revitalizing existing marshes by promoting rhizosphere oxygenation. Where

[202] Ibid., 13.
[203] Z. Pfahl Johnson, "A Sea Level Rise Response Strategy for the State of Maryland," Maryland Department of Natural Resources Coastal Zone Management Division (October 2000): 1. http://www.ecy.wa.gov/climatechange/PAWGdocs/ci/071007CIsealevelstrategy.pdf

[204] Ibid., 3.
[205] Maryland Code, "Chapter 119 (House Bill 1253): Chesapeake and Atlantic Coastal Bays Critical Area Protection Program – Administrative and Enforcement Provisions" (April 2008): 3. http://mlis.state.md.us/2008rs/chapters_noln/Ch_119_hb1253E.pdf

these strategies are not practical, more innovative approaches may be necessary such as the use of highly productive species (e.g., *Phragmites australis*) that appear to be more efficient in promoting sedimentation and long term accretion than other marsh species."[206]

8 As reported in a study published in 2002, researchers at the University of Maryland developed a spectral mixing model based on (historical) Landstat Thematic Mapper imagery to generate a marsh surface condition index (MSCI). This method was developed because of inadequacies of satellite and aerial photography. The MSCI emulates the progressive degradation of marsh substrates that accompanies the marsh loss cycle.

Based on 1993 Thermatic Mapper Imagery, the study found that out of the 115,000 hectares (284,000 acres) of marsh of the Chesapeake Bay, 50% of the upper and middle bay and 52% of the lower bay was slightly to moderately degraded, and 19% of the upper and middle bay and 20% of the lower bay was severely to completely degraded.[207]

9 The US Geological Survey has developed an inundation model for the Blackwater National Wildlife Refuge and surrounding areas. Different sea level rise scenarios produced similar results: areas of intertidal marsh as well as critical high marsh remain constant until 2050, after which the low-lying land surface is overtopped by rising sea level and converted to open water.[208]

10 A 2005 article entitled "Eutrophication of Chesapeake Bay: historical trends and ecological interactions" notes that sea level rise contributes to erosion, which means less nitrogen and phosphorous uptake and more resuspension, which is a step in a degradation cycle.[209]

11 A National Wildlife Fund study[210] applied version 5.0 of the 'Sea Level Affecting Marshes Model' (SLAMM)[211] to the entire Chesapeake Bay region and Delaware Bay. For the Chesapeake Bay, the model measured:
– inundation, using changes in elevation to project changes in the salt boundary;
– erosion, based on proximity of marsh to estuarine water or open ocean and rates based on site-specific data;
– overwash, assuming barrier islands under 500 meters wide will undergo overwash; and
– saturation, looking at the ability of coastal swamps and fresh marshes to migrate upland.

Several scenarios are used, based on different projections of sea level rise and whether or not developed land is protected. The results vary by site, but overall suggest that the largest impacts will be felt by coastal barrier islands and beaches. From 69 cm of sea level rise by 2100, the area of brackish marshes declines by 83%. Tidal marshes decline by 36%, ocean beaches by 69%, and estuarine beaches by 58%, and tidal swamp by 57%.[212]

12 * "Maryland Eastern Shore RC&D Council, Inc. has been working on living shoreline projects for over 20 years (1987-2006) and has completed 258 projects. RC&D wanted to document the success of these projects so as to expand the knowledge base for the concept of living shorelines techniques as a viable erosion control alternative to conventional bulkheads and ripraps. A pilot study of 35 projects (marsh sills, groins, and edging) in

[206] J. C. Stevenson et al, "The Health and Long Term Stability of Natural and Restored Marshes in Chesapeake Bay," *Concepts and Controversies in Tidal Marsh Ecology*, Springer Netherlands (2000). Abstract available at http://www.springerlink.com/content/q78136040j058p75/
[207] M. Kearney et al, "Landstat Imagery Shows Decline of Coastal Marshes in Chesapeake and Delaware Bays," *Eos* Transactions of the American Geophysical Union 83 (April 16, 2002): 173, 178. http://ian.umces.edu/pdfs/stevenson_6.pdf
[208] C. Larsen et al, "The Blackwater NWR Inundation Model. Rising Sea Level on a Low-lying Coast: Land Use Planning for Wetlands." U.S. Geological Survey (August 2004). http://pubs.usgs.gov/of/2004/1302/
[209] W. Kemp et al. "Eutrophication of Chesapeake Bay: historical trends and ecological interactions," Marine Ecology Progress Series 303 (2005): 21. http://www.int-res.com/articles/feature/m303p001.pdf
[210] P. Glick et al, "Sea-Level Rise and Coastal Habitats in the Chesapeake Bay Region," National Wildlife Federation (May 2008). Summary at http://www.nwf.org/sealevelrise/pdfs/NWF_ChesapeakeReportFINAL.pdf, technical report at http://www.nwf.org/sealevelrise/pdfs/FullSeaLevelRiseandCoastalHabitats_ChesapeakeRegion.pdf.
[211] Warren Pinnacle Consulting, "SLAMM Homepage." http://warrenpinnacle.com/prof/SLAMM/
[212] "Sea-Level Rise and Coastal Habitats in the Chesapeake Bay Region" pp. 15, 18.

Talbot County was conducted as a part of the effort. Parameters included slope of the bank (steep or flat as compared to as-build), bank condition (undercut/slumping), marsh erosion, structure type (sills/groins/edging), structure condition (displacement, sinking, or no change), and the presence/absence of plant species (other than the ones that were planted initially) were studied to assess the success of all projects. The study also involved the development of a Geographical Information System (GIS) database that could aid in decision-making for future projects. A Global Positioning System (GPS) unit was used in the field to collect and input data related to location and other parameters. A laser level was used to calculate the change in slope along the marsh fringes, and a camera was used to record the current status of the projects for comparative analysis. After careful analysis of the data, it was found that 83% of banks inspected were stable (no undercut or slumping), and 74% of the marshes exhibited minimal erosion or no erosion. The stone structures in 71% of the projects were in excellent condition. Overall, 32 out of the 35 projects studied were ranked good or improved from initial conditions. Therefore, the pilot study results indicate that living shorelines have been used successfully for erosion control purposes. Further studies are needed to confirm the findings with additional data and analysis needed to determine impacts of fetch, energy of the system, and the role of design type to expand knowledge of living shoreline project success. Plans are in place to inspect the remaining projects in other counties."[213]

"The living shoreline projects that RC&D completed in the past 20 years have yielded the following benefits:
1. Stabilization of 117,208 linear feet of shorelines.
2. Reduction of sediment inputs (49,877 tons y^{-1}), presumably due to decreased wave action, delivered to waterways.
3. Creation of 2,376,570 ft^2 and preservation of 200,309 ft^2 of tidal wetland habitat.
4. Loading reductions of approximately 41,835 pounds of nitrogen and 27,508 pounds of phosphorus per year, respectively.
Thus, living shorelines approach is an effective shoreline erosion control strategy that has additional environmental benefits in its routine use."[214]

Policy

1 The Shore Erosion Control Program was authorized in 1967, and from 1970 to the 1990s the Department of Natural Resources provided interest free loans for building structural erosion controls like bulkheads, concrete walls, stone revetments, jetties and breakwaters. From 1992 to 1996, budgetary constraints led the Department to phase out the program in favor of matching grants for non-structural projects, which were combinations of sediment, biodegradable protective material and plants.[215]

2 On April 20, 2007, Governor O'Malley signed an Executive Order establishing the Maryland Commission on Climate Change, consisting of sixteen state agency heads and six General Assembly members. The Order "emphasized Maryland's particular vulnerability to climate change impacts of sea level rise, increased storm intensity, extreme droughts and heat waves, and increased wind and rainfall events. It recognized that human activities such as coastal development, burning of fossil fuels, and increasing greenhouse gas (GHG) emissions are contributing to the causes and consequences of climate change. While noting Maryland's recent climate initiatives, the

[213] B. Subramanian, "Evaluation of Marsh Sills, Groins and Edging Projects on Maryland's Eastern Shore: A Pilot Study of Talbot County," in panel discussion "Current Understanding of the Effectiveness of Nonstructural and Marsh Sill Approaches." S. Erdle, J. Davis, and K. Sellner, eds., "Management, Policy, Science and Engineering of Nonstructural Erosion Control in the Chesapeake Bay: Proceedings of the 2006 Living Shoreline Summit," CRC Publication No. 08-164, Gloucester Point, VA (2008): 38-39. http://web.vims.edu/cbnerr/pdfs/2006LivingShorelineProceedings/2006_LS_Full_Proceedings.pdf

[214] B. Subramanian et al, "Living Shorelines Projects in Maryland in the Past 20 Years," Ibid., 49, 52.

[215] State of Maryland Shore Erosion Task Force, "Final Report," Maryland Department of Natural Resources (January 2000): 7. http://www.dnr.state.md.us/ccws/sec/download/shoreerosion.pdf

Order emphasized that continued leadership by example by Maryland State and local governments is imperative." The commission was tasked with developing a Climate Action Plan,[216] which it completed in August 2008.[217]

3 Chapter 5 of the Climate Action Plan is entitled, "Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change Phase I: Sea-level rise and coastal storms." It provides several priority policy recommendations:
(1) Identify and direct protection and restoration actions towards high priority protection areas. The report notes that the Department of Natural Resources (DNR) and the Maryland Department of the Environment (MDE) are currently addressing this and by September 2009 expect to have a comprehensive plan to evaluate and integrate models and identify data gaps. Additional targets for this plan include developing a general permit that streamlines rebuilding and placement of clean sandy fill, plants and temporary biodegradable structure, standardize design and construction methods.
(2) "Develop appropriate regulations financial incentives, and educational, outreach and enforcement approaches to retain and expand forests and wetlands in areas suitable for long-term survival." Within two years, the DNR and MDE will complete a two-phase plan, with Phase 1 entailing targeting high-priority areas and Phase 2 entailing identification of new needed policies, programs, regulations and incentives.
(3) Promote and support sustainable shoreline and buffer area management. The report adds that passage of the 2008 Living Shorelines Protection Act (which was among suggested "Early Actions" in an Interim Report presented by the Maryland Commission on Climate Change to the 2008 session of the General Assembly[218]) was a huge step in this direction. DNR and MDE are working together for regulatory implementation of the Act, and were scheduled to present a final implementation plan at the Spring 2009 meeting of the Maryland Commission on Climate Change.[219]

4 In April 2008, the Maryland state legislature passed the Living Shoreline Protection Act of 2008. The preamble of this Act begins with, "WHEREAS, The State of Maryland and its people, property, natural resources and public investments will be significantly impacted by climate change and sea level rise… 'Living shorelines' are the preferred method of shore protection… It is the public policy of the State to protect natural habitat and that shoreline protection practices, where necessary, consist of nonstructural 'living shoreline' erosion control measures wherever technologically and ecologically appropriate."

The Act requires that improvements to protect a person's property against erosion be nonstructural and preserve the natural environment, allowing for exceptions determined by the Department of Natural Resources.[220]

5 Revisions to the Maryland State Code Chapter 119 were also passed in April 2008 as the "Living Shoreline Protection Act." The preamble states, "Particularly in light of the ongoing, accelerating decline of the State's water quality resources and the loss of valuable shoreline areas due to erosion and global warming, it is the view of the General Assembly that significant improvements are in order at this time…" The preamble continues to state that experience has shown that the general authority to adopt regulations is fundamental to ordinary business operations of all other State agencies, but a March 1987 opinion of the Attorney General rendered the Critical Area Commission's ability to do this

[216] Maryland Commission on Climate Change (MCCC), "Climate Action Plan" (August 2008). http://www.mde.state.md.us/air/climatechange/index.asp
[217] MCCC, "Climate Action Plan Executive Summary" p 3. http://www.mde.state.md.us/assets/document/Air/ClimateChange/Executive_Summary.pdf
[218] MCCC, "Climate Action Plan Chapter 5: Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change. Phase I: Sea-level rise and coastal storms," p 32. http://www.mde.state.md.us/assets/document/Air/ClimateChange/Chapter5.pdf
[219] Ibid., 20-24.
[220] Maryland Code, "Chapter 304 (House Bill 973): Water Management Administration – Living Shoreline Protection Act of 2008" (April 2008): 1-2. http://mlis.state.md.us/2008rs/chapters_noln/Ch_304_hb0973E.pdf

unclear. The revisions clearly give the Critical Area Commission regulatory and enforcement powers.[221]

Actions

1 The Preamble to April 2008 revisions to Chapter 119 of the Maryland State Code contains a summary description of actions taken since the 1984 founding of the Chesapeake Bay Critical Area Commission. It states that, at the time of the bill, "local Critical Area programs are operative in Baltimore City, 16 counties, and 47 municipalities, and Critical Area issues directly impact at least several State department… the Critical Area Program has effectively influenced thousands of land use decisions, addressed and minimized the adverse impacts of growth associated with hundreds of requests for growth allocation, and represented a comprehensive effort between the State and local governments to enforce a variety of water quality and habitat protection standards…"[222]

2 Since 1998, from September through March, 2 million yards of material dredged from the Baltimore shipping channel has been used by the Army Corps of Engineers to rebuild Poplar Island. From 10 acres in 1990, the Island is now 1,140 acres. The project manager estimates that the project will finish not before 2020, at a total cost of $400 million, of which 75% comes from the federal government and the other 25% from the state. Marsh habitat has begun to repopulate the island.[223]

3 In the Climate Ready Estuaries' January 2009 "Synthesis of Adaptation Options for Coastal Areas," the Department of Natural Resources' Maryland Shore Erosion Control Program is given as an exemplar of maintaining shorelines utilizing "soft" measures. The specific climate stressor addressed by these actions was sea level rise. The report writes, "The Shore Erosion Control program has created over 300 marsh fringe sites along the Chesapeake Bay. The marshes have been created as 'living shoreline' in order to control erosion and reduce land lost to sea level rise. These non-structural shoreline stabilization methods create a vegetative buffer for the land, improve water quality, and provide habitat to many species. The marshes were created with sand fill and stabilized through the planting of marsh grasses and the use of soils, stones, gravels, and biodegradable protective materials. Individual property owners who wish to construct these types of erosion control measures can also receive financial assistance to do so through the Shore Erosion Control program."[224]

[221] Maryland Code, "Chapter 119 (House Bill 1253): Chesapeake and Atlantic Coastal Bays Critical Area Protection Program – Administrative and Enforcement Provisions" (April 2008): 3-4. http://mlis.state.md.us/2008rs/chapters_noln/Ch_119_hb1253E.pdf

[222] Ibid.

[223] K. Burton, "In a Benchmark Restoration Effort in Chesapeake Bay, the Island That Almost Vanished is Slowly Reappearing," U.S. Fish and Wildlife Service Office of Public Affairs. http://www.outdoorcentral.com/mc/pr/05/07/06a1a.asp

[224] Environmental Protection Agency, "Synthesis of Adaptation Options for Coastal Areas." U.S. Environmental Protection Agency Climate Ready Estuaries Program (January 2009): 12. http://www.epa.gov/cre/downloads/CRE_Synthesis_1.09.pdf

Massachusetts

Research

1 A three-year collaborative project entitled "Climate's Long-Term Impacts on Metro Boston (CLIMB)" by Tufts University, Boston University, and the Metropolitan Area Planning Council (MAPC) studied (among other topics) sea level rise in Massachusetts. The project found that, based on Boston Tide gauge data, sea level rose 0.87 feet from 1921 to 1999. The project projected that by the end of the 21st century, relative sea levels in Boston will rise from two to three feet.[225]

2 Numerous studies undertaken since the 1990s examine coastal habitat conditions. One mentions consideration of the effects of global climate change on wetlands through increased air temperature, shifts in precipitation, increased frequency of storms, droughts and floods, increased atmospheric carbon dioxide, and sea level rise, and lists sea level rise as a major cause of wetland loss and degradation.[226] Another study notes that the marsh plain may not be keeping pace with sea level rise, and high marsh may be converted to low marsh.[227]

3 Applied Science Associates created projections of a 15 inch rise in Boston over 100 years. In 2006, the Boston Globe posted a slideshow of map images showing the ASA projections of potential flooding.[228]

4 In February 2006, the Massachusetts Office of Coastal Zone Management, the US Fish and Wildlife Service, and the University of Massachusetts completed a cooperative report looking at long-term estuarine marsh trends in Boston Harbor, Cape Cod, Nantucket, Martha's Vineyard, and the Elizabeth Islands. The project relied on interpretations of historical maps spanning from 1893 to 1995. Overall, estuarine marshes gained 5,176 acres and lost 10,464 acres, resulting in a net loss of 5,288 acres.

Half of this net loss was in the third quarter of the 20th century. From 1952 to 1971, marshes gained 815 acres and lost a net of 2,539 acres. Losses were from unchecked filling, diking and draining of marshes, especially in the post-War population boom where there was high demand for real estate and development. From 1971 to 1995, the rate of loss slowed, with a loss of 1,255 acres, a gain of 797 acres, for a net loss of only 458 acres. This corresponds with adoption of wetland regulatory protection programs.[229] The study does not mention sea level rise.

5 As sea level rises, the area around the Crane Beach, an important barrier beach in Massachusetts's 250,000 acre Great Marsh system, will flood and likely convert to open water.[230]

6 A report published in April 2007 summarized a project undertaken in the summer of 2006 to study marsh dieback. Staff from the Massachusetts Bays National Estuary Program (MBNEP) and the Massachusetts Office of Coastal Zone Management (CZM) surveyed 25 coastal sites (mainly on Cape Cod) for

[225] "Climate's Long-term Impacts on Metro Boston," Tufts Institute of the Environment (2008). http://environment.tufts.edu/?pid=41; P. Phippen and A. Donovan, "Sea Level Rise and Shrinking Salt Marsh," CZScience: 1. http://www.mass.gov/czm/coastlines/2008/pdf/ef/czscience.pdf, http://www.mass.gov/czm/coastlines/2008/pdf/ef/czscience.pdf

[226] B. Carlisle et al, "Wetland Ecological Integrity: An Assessment Approach," Massachusetts Coastal Zone Management (March 1998): 1:4, 1:5. http://www.mass.gov/czm/ma_czm_wetlandassess_waquoitreport1998.pdf

[227] B. Carlisle et al, "Cape Cod Salt Marsh Assessment Project; Final Grant Report, Volume 2: Response of selected salt marsh indicators to tide restriction 2000-2003," Massachusetts Office of Coastal Zone Management (August 2004): 35. http://www.mass.gov/czm/capecodreport_volume2.pdf

[228] D. Butler and E. Medina, "Interactive Graphic: Boston in 100 years," The Boston Globe (2006). http://www.boston.com/news/multimedia/interactive_bostonflood/

[229] B. Carlisle et al. "100 Years of Estuarine Marsh Trends in Massachusetts (1893 to 1995): Boston Harbor, Cape Cod, Nantucket, Martha's Vineyard, and the Elizabeth Islands." Massachusetts Office of Coastal Zone Management, U.S. Fish and Wildlife Service, and University of Massachusetts (2005): 3. http://www.mass.gov/czm/ma_estuarine_trends_1.pdf

[230] "Sea Level Rise and Shrinking Salt Marsh" p 2.

where there were anecdotal reports of marsh dieback.

But existing vegetation seemed generally healthy, with very little recently dead or dying vegetation. Great Island sites appear to be nearly completely isolated from (local) anthropogenic stressors; a cited draft report suggests that what dying vegetation and unvegetated marsh there is on the Great Island is due to changing sea and marsh elevations. The report cites a 2006 poster presentation of a study suggesting New England marshes are less susceptible to effects from sea level rise because of the landscape is rebounding from the last ice age.[231]

Policy

1 A 1994 document, "Guidelines for Barrier Beach Management in Massachusetts" (still referred to as a primary resource on the current CZM site[232]), mentions sea level rise as one of the threats facing the beach.[233] It cites as its goal the fulfillment of the three parts of the Massachusetts Wetland Protection Act, which are storm damage protection, flood control, and protection of wildlife habitat including rare species.

Its discussion of erosion control methods constantly integrates environmental impacts or contextualizes discussion in terms of it. For example, when discussing "Geomorphic Needs for Maximum Shoreline Property Protection on Barrier Beaches," the manual includes a disclaimer that "This opinion is based solely on shoreline property protection interests. It is recognized that multiple interests, such as rare species protection, for barrier beach use must be balanced in any initiative."[234]

For different erosion control and restoration techniques, environmental impacts are assessed. Snow fences can be appropriate, but can also create steep dune faces that prevent plover nesting, and wire from damaged fences can post a threat to coastal wildlife. Christmas trees may become unearthed and become a solid waste nuisance. Beach nourishment is often a preferred alternative to hard structures, and can improve the quality and availability of plover and tern habitats. But the significant habitat alterations could also be detrimental if dredged material is not a suitable nesting substrate, or if the timing of the deposition disturbs nesting birds. Vegetative plantings can be an effective method, but care must be taken not to destroy rare species habitat by improper planting in overwash fans and low relief foredune areas.

For vegetative plantings, it provides specific guidelines, summarizing the native plant species for pioneer zones, primary dunes, secondary dunes, secondary dune salt marsh border, and salt marsh, and the best plant to use for stabilizing each. Then, the manual gives directions for area and depth of planting, amount of vegetation, location relative to Mean Low Water and Mean High Water, time of year of planting, amount of fertilization, and salinity.

Appendix I gives the Department of Environmental Protection's recommended or required management measures. For beach and dune restoration, regulations include a prohibition removal of existing sediment for restoration, and a requirement for siltation fencing where dune reconstruction occurs close to salt marsh.[235]

2 The "Comprehensive Conservation and Management Plan for the Massachusetts Bays," created in 1995, notes that "Although

[231] J. Smith and M. Carullo, "Survey of Potential Marsh Dieback Sites in Coastal Massachusetts," Massachusetts Bays National Estuary Program and Massachusetts Office of Coastal Zone Management (April 2007): 5, 9, 16, 21. http://www.mass.gov/czm/docs/pdf/marsh_dieback.pdf

[232] "Barrier Beach Management in Massachusetts," Massachusetts Office of Coastal Zone Management. http://www.mass.gov/czm/hazards/beach/barrierbeach.htm

[233] Massachusetts Barrier Beach Task Force, "Guidelines for Barrier Beach Management in Massachusetts" (February 1994): 97. http://www.mass.gov/czm/hazards/pdf/barrier_beach_guidelines.pdf

[234] Ibid., 101.

[235] Ibid., 218-219.

Massachusetts is considered to have one of country's the [sic] most effective wetlands protection programs, the state has not been able to completely stem wetlands loss… Moreover, the Wetlands Protection Program relies heavily on replicated wetlands to mitigate "unavoidable" losses. The success rate of these replication projects seems to have been less than adequate, according to some state and local conservation officials."[236]

To remedy this, it lays out an action plan. According to the Plan, municipalities should adopt bylaws and management plans for wetlands, riverfronts, open spaces, and barrier beaches, as well as hiring full-time, professionally trained conservation staff. The Department of Environmental Management should develop resource management plans, and acquire and restore undeveloped coastal properties with valuable natural habitats. The Department of Environmental Protection should complete a statewide inventory of mapping coastal and inland wetlands, and provide local Conservation Commissions with this information. And the Executive Office of Environmental Affairs should continue the Wetlands Restoration and Banking Program to restore and protect degraded coastal and inland wetlands.[237]

3 The March 2002 "Massachusetts Coastal Zone Management Plan" gives a complete overview of the Coastal Zone Management Program, including its history, policies and regulatory role, its programs and services, and its interagency relationships.

The first Coastal Hazard Policy point is to preserve, protect, restore and enhance the beneficial functions provided by natural coastal landforms. Natural coastal landforms are identified as, aside from being valuable as habitat and sources of primary productivity, a significant source of protection from coastal storms, flooding, erosion and relative sea level rise.

While mostly geared towards preserving the ability of natural coastal landforms to protect human interests, it notes, "as relative sea level rises the entire complex of coastal wetland resources are likely to be in a state of transition as the entire complex gradually moves landward due to rising sea levels… Activities carried out within these special transitional areas of coastal floodplains may interfere with the natural landward migration of the adjacent coastal resource areas. The result may be adversely reducing the geographic extent and thus the storm damage reduction and flood control capabilities of these important landforms. Therefore, relative sea level rise should be factored into the design life, elevation, and location of buildings and other structures within the coastal floodplain." Recommended implementation consists of non-structural alternatives to coastal engineering and land acquisition of hazard-prone areas.[238]

4 * The Massachusetts Office of Coastal Zone Management developed the "StormSmart Coasts" program to help communities prepare for and protect themselves against coastal storms and flooding.[239]

The program offers numerous guides and other informational resources focused towards informing property owners as well as officials from the Board of Health, Board of Selectmen, Building Department, Conservation Commission, Department of Public Works, Planning Board, and Zoning Board of Appeals.

The provided information relates to hazard identification and mapping, planning, regulations and development standards, mitigation and shore protection, infrastructure, emergency services, and education and outreach, and covers such

[236] Massachusetts Bays Program, "Comprehensive Conservation and Management Plan for the Massachusetts Bays" (1995): V-23. http://www.mass.gov/envir/massbays/pdf/Chapter%20V%20part%201.pdf

[237] Ibid., V-4.

[238] Massachusetts Office of Coastal Zone Management, "Massachusetts Coastal Zone Management Plan" (March 2002): 40-43. http://www.mass.gov/czm/plan/docs/czm_program_plan_02.pdf

[239] StormSmart Coasts, "About StormSmart Coasts," Massachusetts Office of Coastal Zone Management. http://www.mass.gov/czm/stormsmart/other/about_ssc.htm

topics as suggested actions, legal precedents, sources of funding from the federal or state government, and contacts to other resources.[240]

5 The Governorship of Mitt Romney that took office in January 2003 adopted a "no regrets" policy to climate change, where, as Romney writes, "Rather than focusing our energy on the debate over the causes of global warming and the impact of human activity on climate, we have chosen to put our emphasis on actions, not discourse. If climate change is happening, the actions we take will help. If climate change is largely caused by human actions, this will really help. If we learn decades from now that climate change isn't happening, these actions will still help our economy, our quality of life and the quality of our environment."[241]

The primary goals of the Climate Protection Plan are the two related measures of reducing emissions of greenhouse gases and improving energy efficiency, but also addresses sea level rise, stating, "By 2100, a 5-9°F increase in global temperatures is forecast to double the rate of sea-level rise from 11 inches over the last century to 22 inches in this century."[242] While not specifically integrating habitat conservation with sea level rise, the Plan calls for the Massachusetts Coastal Zone Management Office to promote coastal planning programs that integrate responses to climate change in programs that help preserve wetlands.[243]

6 "In a landmark 2005 ruling, the highest court in Massachusetts decisively affirmed the authority of municipalities to regulate or even prevent residential or other high-risk development in flood prone areas without financial compensation to the property owners, so long as the regulation does not render the land entirely valueless."

When the town of Chatham refused to allow construction of a new home in a flood zone, partially also because the construction would have violated a local wetlands bylaw, the owner sued the Selectmen, Zoning Board and Conservation Commission (which a court combined into one suit) on the grounds that the land-use regulations constituted an unconstitutional taking.

The decision was appealed twice, but in all three decisions, courts found that there was a significant public interest in prohibiting the construction, and so long as the property was not completely devalued, even a substantial reduction (from $192,000 to $23,000 in this case) did not constitute a taking. In particular, a decision was cited where the Supreme Court ruled that no compensation was due for a regulation that reduced the value of a parcel from $3,150,000 to $200,000 (a reduction of 99.37%, whereas in Chatham the reduction was by 88.02%).

Massachusetts Storm Smart notes that Chatham won the case because (1) zoning bylaws had clear goals of protecting people and property; (2) the bylaws still permit many uses aside from construction of new homes; (3) the law was fair and applied fairly based on identifiable, mapped areas; (4) the town's emergency management experts testified that evacuation in case of a storm or flood would put rescue workers at risk; and not least, (5) the town was willing to legally defend its position.[244]

7 * The Massachusetts Association of Conservation Commissions produces a set of model bylaws on 'Wetland Law, Science and Policy,' last updated in 2006. These model bylaws are intended to provide expertise and

[240] StormSmart Coasts, "StormSmart Coasts – Home Page," Massachusetts Office of Coastal Zone Management. http://www.mass.gov/czm/stormsmart/index.htm
[241] The Commonwealth of Massachusetts, "Massachusetts Climate Protection Plan" (Spring 2004): 3. http://www.newamerica.net/files/MAClimateProtPlan0504.pdf
[242] Ibid., 6.
[243] Ibid., 46.
[244] StormSmart Coasts, "Case Study - A Cape Cod Community Prevents New Residences in Floodplains: Lessons learned from Chatham's legally successful conservancy districts," Massachusetts Office of Coastal Zone Management (April 2008): 1-3. http://www.mass.gov/czm/stormsmart/resources/stormsmart_chatham.pdf

experience for communities in the process of establishing bylaws to protect wetlands.[245]

8 The interagency Massachusetts Coastal Hazards Commission, created in February 2006, released its final report entitled "Preparing for the Storm: Recommendations for Management of Risk from Coastal Hazards in Massachusetts" in May 2007. The report recognizes that the shoreline can migrate in response to sea level rise, but that static development conflicts with this. The challenge is to balance development and natural resource protection. In terms of recommendations relating to sea level rise, the report mainly focuses on data-gathering actions, such as supporting US Geological Survey data gathering through LIDAR and other subaerial and submarine data.[246]

9 A January 2009 StormSmart fact sheet, "Landscaping to Protect Your Coastal Property from Storm Damage and Flooding," provides a guide for coastal property landscaping. It notes which permits are necessary for landscaping directly in a coastal resource area or within a 100 ft buffer zone. If the landscaping is in threatened or endangered species habitat, the landscaper must follow the guidelines from the 1994 "Guidelines for Barrier Beach Management in Massachusetts."

The fact sheet discourages hard structures, noting that in most cases they are prohibited, and recommends considering planting a protective cover of native plants. The fact sheet includes a guide for selecting combinations of plants for different areas and conditions. Recommendations include:
– pioneer plants for the wrack line;
– American beachgrass for holding together and building fronting sand dunes, and for shorter-term stabilization while waiting for other slower plants to grow in;
– other native grasses and low-growing shrubs for slopes of banks and bluffs;
– larger shrubs for exposed areas of coastal bank;
– trees only on lower slopes or set back from steep slopes;
– plants like beach heather, lowbush blueberry, bayberry, beach plum, Japanese black pine, pitch pine, and Eastern red cedar for secondary dunes; and
– saltmeadow cordgrass for troughs between dunes.

Other recommendations are to:
– keep lawn areas as small as possible, and plant a buffer area of native trees, shrubs and deep-rooted grasses between the property and shore;
– grade property to direct stormwater towards planted areas and away from the shoreline;
– replace impervious driveways with pervious material, and plant an area around driveways to slow stormwater and trap sediments and pollutants;
– avoid using heavy equipment to install plants;
– prepare soils with a layer of organic material;
– ensure that newly planted vegetation has 1 inch of water per week from April through October, providing temporary irrigation if natural water is not sufficient; and
– where erosion threatens property, use biodegradable erosion fabric on steep slopes while plants to take root.[247] This fact sheet drew from a 2006 UMass Extension guide, itself adopted from another work.[248]

10 The Cape Cod Commission, approved by the voters of Barnstable County in March 1990, is charged with preparing and overseeing a regional land use policy plan, including conservation and preservation of natural

[245] Massachusetts Association of Conservation Commissions, "MACC Non-Zoning Wetlands Protection Bylaw/Ordinance" (2006). http://www.maccweb.org/documents/MACC_Model_Bylaw.doc, http://www.maccweb.org/resources_bylaws.html.
[246] Massachusetts Coastal Hazards Commission, "Preparing for the Storm: Recommendations for Management of Risk from Coastal Hazards in Massachusetts" (May 2007): 1, 8. http://www.mass.gov/czm/chc/recommendations/chc_final_report_2007.pdf, or pdf's by chapter, http://www.mass.gov/czm/chc/recommendations/final_recommendations.htm.
[247] StormSmart Coasts, "Landscaping to Protect Your Coastal Property from Storm Damage and Flooding" (January 2009). http://www.mass.gov/czm/stormsmart/resources/stormsmart_landscaping.pdf.
[248] R. Clark, "Selection and Maintenance of Plant Materials for Coastal Landscapes," UMass Extension (July 2006). http://www.umassgreeninfo.org/fact_sheets/plant_culture/coastal_landscaping.pdf.

habitats. The fourth edition[249] of the "Cape Cod Regional Policy Plan," effective January 2009, discusses sea level rise from global climate change[250] as part of coastal hazard mitigation.

The Commission reports that uncontrolled and unplanned shoreline development has continually and rapidly increased, and that a combination of this development and the projected impacts of relative sea level rise pose risks to public health, safety and welfare, damages to property, and degradation of coastal resources.

The Plan notes that the Massachusetts Wetlands Protection Act provides a 100 ft buffer zone around wetlands, but that the buffer zones serve important functions and yet are not protected by the Act. The Commission cites studies that find that 100 to 300 ft wide buffers are needed to protect surface water bodies from sedimentation and to maintain wildlife habitat, and 300 to 1,000 ft buffers are needed to remove 50 percent to 90 percent of man-made nutrients.

In a 2005 survey of Cape Code residents, 88% supported or strongly supported restrictions on new development in or near wetlands, ponds, floodplains, dunes and critical habitat areas. The Plan thus suggests there is both reason and public will to implement local restrictions on development more strict than state or federal requirements.

One recommended action for towns is to remove development from the floodplain, either outright by purchase from Community Preservation Act funds or other grants, or by removing development rights.[251]

Best management practices for barrier beaches, coastal dunes and their buffers include prohibiting new developments on the features and restricting new development with a setback of 100 ft or 30 times the annual erosion rate, whichever is greater, as well as restricting renovations.

Best development practices for wetlands include prohibiting development in V-Zones, requiring that all new buildings accommodate documented relative sea level rise rates, and prohibiting new development and redevelopment within the 10-year floodplain from impeding landward sea level rise driven migration of salt marshes, coastal dunes, coastal beaches, tidal flats and the coastal floodplain.

For wetland restoration, "Measures to restore altered or degraded inland and coastal wetlands, including nonstructural bank stabilization, revegetation, and restoration of tidal flushing are encouraged; however, such areas should not be used as mitigation for wetland alteration projects (mitigation banking)… Construction of artificial wetlands for stormwater and wastewater management may be permitted in appropriate areas where there will be no adverse impact on natural wetlands, waterways, and groundwater.[252]

Actions

1. The Massachusetts Office of Coastal Zone Management's Wetlands Restoration Project had, as of May 2008, 57 completed projects, 36 active projects, and 721 acres under restoration.[253]

2. A fifth of the state, an area of about a million acres, is protected. Half of this area is owned by the state, an eighth by nonprofit environmental organizations and land trusts, and a sixteenth by the federal government. Aside from outright ownership, protections include restrictions on development and conservation easements.[254]

[249] Cape Cod Commission, "Cape Cod Regional Policy Plan" (January 2009): 10. http://www.capecodcommission.org/RPP/RPP-Effective01-16-09.pdf
[250] Ibid., 71.
[251] Ibid., 48-50.
[252] Ibid., 117-126.
[253] Massachusetts Office of Coastal Zone Management, "Wetlands Restoration Program: Projects Overview" (May 2008). http://www.mass.gov/czm/wrp/projects_pages/projects_overview.htm
[254] The Commonwealth of Massachusetts, "Massachusetts Climate Protection Plan" (Spring 2004): 48.

3 The Office of Coastal Zone Management has made available online a series of detailed technical reports from the Dredged Material Management Plan. These site-specific reports include environmental impact reports, exploring things like alternative disposal sites and suitability of dredged sentiment, drawing on measures such as geotechnical borings and underwater archaeological surveys.[255]

4 Numerous publications relating to wetlands restoration projects are available from the Office of Coastal Zone Management upon request. Some projects have additional resources online. The Buzzards Bay National Estuary Program has posted on its site Google Earth map files of restoration sites, and a chart of how many sites have been restored each year out of the 18 sites restored since 2000.[256] The Executive Office of Environmental Affairs has produced brochures for some years detailing the activities of the Wetland Restoration Program, generally small, local projects that depend on community volunteers.[257] The Program has been active since 1994, and has since restored 339 acres of coastal and freshwater wetlands through support of 27 projects. In an April 2002 progress report, the Program stated a goal to restore 3,000 acres of wetland by 2010.[258] The Program has posted an online interactive plan for restoration projects in the Great Marsh region, including a list of 121 restoration sites,[259] of which 14 have been completed.[260]

http://www.newamerica.net/files/MAClimateProtPlan0504.pdf

[255] Massachusetts Office of Coastal Zone Management, "Publications: Dredged Material Management Plan Technical Reports" (2004). http://www.mass.gov/czm/publicationsdredge.htm

[256] Buzzards Bay National Estuary Program, "The Atlas of Salt Marsh Tidal Restrictions in Buzzards Bay" (May 2009) http://www.buzzardsbay.org/smatlasmain.htm

[257] Wetlands Restoration Program, "Summary of Massachusetts Wetland Restoration Projects Completed in 2001," Executive Office of Environmental Affairs (April 2002). http://www.mass.gov/czm/wrp/downloads/wrp_2001_progress_partb.pdf

[258] Wetlands Restoration Program, "2001 Progress Report," Executive Office of Environmental Affairs (April 2002). http://www.mass.gov/czm/wrp/downloads/wrp_2001_progress_parta.pdf

[259] http://www.mass.gov/czm/wrp/planning_pages/gmplan/list_id.htm

[260] http://www.mass.gov/czm/wrp/planning_pages/gmplan/results.htm

Mississippi

Research

1 * A conference presented in Biloxi, Mississippi on September 27-28, 1990, published its proceedings as "Long Term Implications of Sea Level Change for the Mississippi and Alabama Coastlines" (Also cited above for Alabama-Policy-1). Participants whose papers are included in the proceedings include the Mississippi Secretary of State and a Mississippi State Senator, EPA officials, law academics, an Army Corps engineer, climate scientists, and geologists. One paper, "Responding to Global Warming Along the U.S. Coast"[261] summarizes research, responses or planning processes underway nationwide.

Another paper, "Sea Level Rise: Policy Implications for the Mississippi Coast" notes that a rapid rise of sea level caused by global climate change could outpace the ability of wetlands to keep pace, and that this could be compounded by human development preventing migration. The paper classifies Mississippi as one of several states that have recognized the need to implement policy but have not moved beyond initial discussion stages yet, and recommends that Mississippi could move out of this stage by implementing policies that promote 'sustainable development,' including land use regulations, land acquisition, and nonstructural erosion protection.[262]

"Sea Level Rise in Coastal Alabama and Mississippi" uses the a tide gauge at Biloxi, Mississippi, active intermittently since 1881, to plot annual means and calculate averages. It finds a rise of 0.06 in/yr (1.55 mm/yr).[263]

"Mississippi and Adjacent Coastal Sectors; Geological and Environmental Perspectives" discusses the possible effect of sea level rise on wetlands. The paper states, "A 3-m (10-ft) sea level rise, barring a catastrophic Antarctic ice sheet "meltdown" not expected for many centuries, would eventually shift the heads of the estuarine embayments about 28 km inland in the Pearl River Valley, approximately 22.5 km in the Pascagoula Valley, and about 56 km from the present bayhead in the Mobile River Valley."[264]

2 Two features of the Mississippi Sound, the Mobile Bay and the Pascagoula River drainage basin, are particularly important. "The 480-square-mile Mobile Bay estuary contains a documented 337 species of fish, more species per area than any other region of North America. Of the 74 major river estuaries in North America, the Pascagoula River is the only one in the United States that remains unaffected by channel fragmentation and flow regulation along its entire length. As a result, the Pascagoula River is a vital center of biodiversity and essential fish habitats for numerous threatened and endangered species."[265]

3 At a conference held on March 10 and 11 2009 at Biloxi, Mississippi, professionals expressed a desire for government help in predicting sea level rise. See Alabama-Research-6.

Policy

1 In the Mississippi Code of 1972, Title 49, "Conservation and Ecology," Chapter 49, "Coastal Wetlands Protection," Section § 49-27-3 states, "It is declared to be the public policy of this state to favor the preservation of the natural state of the coastal wetlands and their ecosystems and to prevent the despoliation and destruction of them, except

[261] "Long Term Implications of Sea Level Change for the Mississippi and Alabama Coastlines: Proceedings of a Conference Presented in Biloxi, Mississippi" (September 1990): 6-17. http://www.masgc.org/pdf/masgp/90-015.pdf
[262] Ibid., 19-20.
[263] Ibid., 35-36, 39, 43.
[264] Ibid., 65.
[265] Mississippi-Alabama Sea Grant Consortium, "Strategic Plan: Plotting a Course for 2006-2010" (October 2006): 10. http://www.masgc.org/pdf/masgp/06-016.pdf

where a specific alteration of specific coastal wetlands would serve a higher public interest in compliance with the public purposes of the public trust in which coastal wetlands are held."[266]

2 The Mississippi-Alabama Sea Grant Consortium (MASGC) Strategic Plan: Plotting a Course for 2006-2010 addresses local, regional, and national issues that were identified through an 18-month strategic planning process involving more than 350 internal and external stakeholders. The plan identifies priority issues affecting the estuarine, coastal, and Gulf environments of Alabama and Mississippi. The plan also establishes goals, objectives, and expected outcomes for MASGC-sponsored programs.[267]

The Plan mentions anthropogenic impacts on estuarine ecosystems leading to a decline total habitat acreage, but does not mention climate change, global warming, or sea level rise (neither local nor eustatic). Nonetheless, the stated objectives of the 'Health and Restoration of Coastal Habitats' Priority Theme Area could apply to the impacts of climate change. The MASGC includes the following in 'strategic actions:' determining environmental benefit-cost analysis of restoration strategies, developing and assessing estuarine restoration strategies, developing predictors to link land-use planning to health of coastal watersheds, assessing living resources' responses to environmental stress, and testing and implementing alternatives to hard shoreline control devices like seawalls and bulkheads.[268]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. In restoration efforts, the US Department of Agriculture's Natural Resources Conservation Service (NRCS) has a Mississippi Wetlands Reserve Program. Since 1992, there have been 249 easements encompassing 100,000 acres. The program is popular with landowners, and there is a backlog of applications for a total of 47,000 acres.

Since 1992, the Program has completed restoration on about 68,000 acres of bottomland hardwood forests by using direct-seeding techniques and planting of bare-root seedlings. Hydrology restoration enhancement measures have been completed on 12,000 acres. NRCS estimates that with its partners, it restores 10,000 acres of wildlife habitat in Mississippi annually. [269]

[266] Mississippi Code of 1972, "Title 49: Conservation and Ecology, Chapter 49: Coastal Wetlands Protection." http://michie.com/mississippi/lpExt.dll?f=templates&eMail=Y&fn=main-h.htm&cp=mscode/eda0/fb4d/fb54

[267] "MASGC Strategic Plan 2006-2010," p ii.

[268] Ibid., 10-11.

[269] Natural Resources Conservation Service, "Mississippi Wetlands Reserve Program," United States Department of Agriculture. http://www.nrcs.usda.gov/programs/wrp/states/ms.html

New Hampshire

Research

1 A September 1991 study by the Rockingham Planning Commission, entitled "Preliminary Study of Coastal Submergence and Sea Level Rise in Selected Areas of New Hampshire," takes a confined study area and looks at places within it that are potentially at risk from projected sea level rise. The study notes that since 1929, relative sea level has risen 0.5 ft (0.17 m), and that "*excluding* [emphasis original] any rise caused by the affects [sic] of global warming", sea level is expected to rise 0.75 feet over the next 100 years.[270] (13-14).

The study found that sea levels 5.3 ft higher than present levels (excluding the effect of possible erosion and storm damage) would submerge 340 acres, or 20% of the defined study area. The study cites the destruction of coastal wetlands as one of the most serious environmental impacts expected from sea level rise. Wetlands would be most threatened if sea level rise outpaces wetland migration and/or if landowners resist wetland migration, towards which the Plan recommends that federal, state and local policy makers devise fair and equitable ways to abandon development in the path of wetland migration. This may include limiting future development in areas where wetlands are likely to migrate, allowing development but prohibiting protection measures such as bulkheads and seawalls, and disallowing or greatly discouraging reconstruction of structures damaged from sea level rise.[271]

2 Map data from the 1990s shows New Hampshire has nearly 290,000 acres of wetland, covering about 5% of the state's area. However, due to the limitations of photographic interpretation methods used, the actual extent is likely somewhere between 290,000 and 576,000 acres, representing 5-10% of the state's land area.[272]

3 Relative sea level in New Hampshire rose at an average rate of 2.0-2.7 mm/yr in the last century, a rate of about a foot a century.[273]

4 New Hampshire lost approximately 700 acres in a five-year period from 2001 to 2005. During this time, compensatory mitigation created or restored 168 acres. Also during this period, conservation easements were placed on land totaling 9,213 acres.[274]

Policy

1 In the New Hampshire Statues, Title L "Water Management and Protection," Chapter 482-A "Fill and Dredge in Wetlands," wetlands are protected from "despoliation and unregulated alteration."[275] In the Chapter 483-B "Comprehensive Shoreline Protection Act" statement of purpose, standards include protecting wildlife habitats, protecting wetlands, and land use

[270] "Preliminary Study of Coastal Submergence and Sea Level Rise in Selected Areas of New Hampshire," (Exeter, New Hampshire: Rockingham Planning Commission, 1991): 13-14.
[271] Ibid., 31-32.

[272] R. Tiner, "New Hampshire Wetlands and Waters: Results of the National Wetlands Inventory," U.S. Fish & Wildlife Service (August 2007): 10, 19. http://library.fws.gov/wetlands/NH07.pdf
[273] New Hampshire Climate Change Policy Task Force, "The New Hampshire Climate Action Plan: A Plan for New Hampshire's Energy, Environmental and Economic Development Future," NH Department of Environmental Services (March 2009): 30-31. http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/nhcap_final.pdf
[274] New Hampshire Office of Energy and Planning, "New Hampshire Outdoors 2008-2013: Statewide Comprehensive Outdoor Recreation Plan, Appendix F: SCORP Wetlands Priority Conservation Plan Update" (December 2007): F-3. http://www.nh.gov/oep/programs/recreation/SCORP_2008-2013/documents/AppendixFAdobe.pdf
[275] State of New Hampshire Revised Statutes, "Title L: Water Management And Protection, Chapter 482-A: Fill And Dredge In Wetlands" (October 2008). http://www.gencourt.state.nh.us/rsa/html/L/482-A/482-A-mrg.htm

controls.[276] The Department of Environmental Services has certified administrative rules relating to wetlands posted on its website.[277]

2 In March 2009, the New Hampshire Climate Change Policy Task Force issued "The New Hampshire Climate Action Plan: A Plan for New Hampshire's Energy, Environmental and Economic Development Future." The main recommendation of the Task Force is to achieve a long-term reduction in greenhouse gas emissions of 80 percent below 1990 levels by 2050, [278] but it also includes a discussion of protecting coastal areas from sea level rise.

Towards this, it proposes several actions:
– analyzing the environmental consequences of shore protection;
– promoting shore protection techniques that protect habitat;
– identifying land use measures to ensure that wetlands migrate inland as sea level rises in some areas;
– engaging state and local governments in defining responses to sea-level rise; and
– educating decision-makers about the importance of changing zoning regulations.[279]

Details are given in Appendix 4.9, "Plan for How to Address Existing and Potential Climate Change Impacts." 'Action 4' is to "Strengthen Protection of New Hampshire's Natural Systems." This will take place by encouraging growth in or near already-developed areas, possibly at higher densities. In implementation, the policy should prioritize places to project along criteria of where habitats will shift inland, northward, and upwards. The Plan also recommends adapting existing or creating new statewide monitoring programs for habitats, minimizing habitat fragmentation, and possibly establishing a Green Infrastructure Assessment to identify hubs and corridor networks of ecological value to determine where to focus conservation and restoration.

Implementation will require legislation to change environmental and zoning regulations, and resources from the federal or state government or from regional programs. The Plan notes that some LIDAR data is available for the coastal area, but it lacks scale and geographic scope. The Plan recommends filling gaps by incorporating data associated with a recently completed flood assessment report, GRANIT data from places with a Land Conservation Plan, and NH Geological Survey maps. The timeframe for implementation given is 1-4 years.

In examining obstacles, it notes that there are no technical barriers, but there are economic obstacles, and legislating and social obstacles as people may feel climate change action is premature, and as landowners and developers possibly resist additional restrictions on land use. [280]

Actions

1 Currently none directly addressing sea-level rise, although the 2009 Climate Action Plan provides plans for future actions.

2 The US Department of Agriculture's Natural Resources Conservation Service published a study in 1994 identifying 700 acres of salt

[276] State of New Hampshire Revised Statutes, "Title L: Water Management And Protection, Chapter 483-B: Comprehensive Shoreland Protection Act" (October 2008). http://www.gencourt.state.nh.us/rsa/html/L/483-B/483-B-mrg.htm

[277] New Hampshire Department of Environmental Services, "Certified Administrative Rules." http://des.nh.gov/organization/commissioner/legal/rules/index.htm#wetlands, http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wt100-800.pdf

[278] New Hampshire Climate Change Policy Task Force, "The New Hampshire Climate Action Plan: A Plan for New Hampshire's Energy, Environmental and Economic Development Future," New Hampshire Department of Environmental Services (March 2009): 1. http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/nhcap_final.pdf

[279] Ibid., 30-31.

[280] New Hampshire Climate Change Policy Task Force, "New Hampshire Climate Action Plan: A Plan for New Hampshire's Energy, Environmental and Economic Development Future. Appendix 4.7: Protect Natural Resources (Land, Water and Wildlife) To Maintain the Amount of Carbon Fixed or Sequestered," New Hampshire Department of Environmental Services (March 2009): 12-14. http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/032509_nhccptf_appendix_4.7.pdf

marsh it was practical to restore.[281] As of March 2003, approximately 600 acres had been restored.[282] Also posted online is a draft of a marsh restoration guide related to this project.[283]

3 The Stream and Wetland Restoration Institute of the University of New Hampshire has undertaken numerous stream and wetland restoration projects. These are detailed on their website[284] with final reports or with project descriptions, site design plans, and before and after photos. The site also includes a guide for creating and replacing stream crossings.[285]

4 An April 2008 report from the New Hampshire Department of Environmental Services Wetlands Program entitled "2003-2007 Status and Trends Report" summarizes permits issued, mitigation actions (required for projects impacting more than 10,000 square feet of wetlands), complaints received, and enforcement actions taken.[286]

[281] USDA Natural Resources Conservation Service, "Evaluation of Restorable Salt Marshes in New Hampshire" (October 1994, October 2001). http://www.nh.nrcs.usda.gov/technical/Publications/EREvalRestorSaltMarshNH.pdf

[282] New Hampshire Natural Resources Conservation Service, "Salt Marsh Restoration in New Hampshire," United States Department of Agriculture. http://www.nh.nrcs.usda.gov/technical/Ecosystem_Restoration/salt_marsh_NH.html

[283] A. Ammann, "Ecosystem Restoration Planning Guide: Saline Tidal Wetlands [DRAFT 03/31/00]," USDA Natural Resources Conservation Service (March 2000). http://www.nh.nrcs.usda.gov/technical/Publications/ERSalt_marsh_restor_guide.pdf

[284] Stream and Wetland Restoration Institute, "Stream and Wetland Restoration," University of New Hampshire (June 2009). http://www.unh.edu/erg/stream_restoration/

[285] "New Hampshire Stream Crossing Guidelines," University of New Hampshire (May 2009). http://www.unh.edu/erg/stream_restoration/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

[286] Wetlands Bureau, "State of New Hampshire Department of Environmental Services Wetlands Program: 2003-2007 Status and Trends Report," New Hampshire Department of Environmental Services (April 2008). http://des.nh.gov/organization/divisions/water/wetlands/documents/2003-2007nh_wetland_status_trends.pdf

New Jersey

Research

1 A 1988 publication, *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*, contains a chapter detailing a case study in New Jersey, using the same method as a case study done in Charleston, South Carolina (see South Carolina-Research-1). "The major difference between the responses of the New Jersey and Charleston coastal areas to accelerated sea level rise would be under the low scenario. In the case of Charleston, the more productive *S. alterniflora* low marsh would suffer significant net loss, whereas New Jersey would possibly gain slightly by a transformation from high marsh to low marsh. This difference is, of course, related to the significant difference in present distribution of high and low marsh for each area. Low marsh, which at present dominates in Charleston, would most likely become tidal flats; high marsh, which at present dominates the New Jersey study area wetlands, would become low marsh and actually promote the tall growth form of *S. alterniflora*.

"Under the high scenario for both areas, 70-80 percent of existing wetlands would become submerged or transformed into tidal flats. There are significant potential impacts to highlands suggesting that shore-protection measures would be considered in both study areas to protect existing developed land at marginal elevations above the marsh transition zone. The critical highland elevations in Charleston are between 2.0 m and 3.0 m (6.5 ft and 10 ft), compared to between 1.5 and 2.6 m (5.0 ft and 8.5 ft) in New Jersey. This difference, of course, is attributable to the lower tidal range in New Jersey."[287]

[287] T. Kana et al, "Chapter 3: New Jersey Case Study," *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*, ed. J. Titus. Washington, D.C.: U.S. Environmental Protection Agency (1988): 78-79.

"New Jersey's wetlands have been able to keep pace with the recent historical rise in sea level of thirty centimeters (one foot) per century. However, a one- to one-and-one-half-meter (three- to five-foot) rise would almost certainly be beyond the wetlands' ability to keep pace with the sea. We estimate that a ninety-centimeter (three-foot) rise in relative sea level would result in a conversion of 90 percent of the study area's marsh from high marsh to low marsh. A large majority of the area's tidal flats could be expected to convert to open water. Although such changes would represent a substantial transformation, the predominance of high marsh in some sense provides a buffer against the impact of sea level rise. Many would view the conversion of high marsh to low marsh as acceptable.

"The impact of a one and-one-half-meter (five-foot) rise in sea level would be more severe. Such a rise would result in an 85 percent reduction of marsh and substantial reductions in the area of transition wetlands and tidal flats. The loss of marsh could be even greater if development just above today's marsh precludes the formation of new marsh as sea level rises.

"This study did not examine options for increasing the proportion of coastal wetlands that survive an accelerating sea level rise. The institutional pressures to consider this issue may not be great until wetland loss from sea level rise accelerates. Nevertheless, our long-run efforts to protect coastal wetlands may be more successful if some thought is given to long-term measures while the issue is still far enough in the future for planning to be feasible."[288]

The chapter's lead author, in a 2007 conference presentation, argues that this 1988 study is still relevant. [289]

2 Between the 1780's and 1980's, New Jersey lost 39% of its original 6,000 km² (1.5 million acres) of wetlands (coastal and interior) to human reclamation,[290] and the New Jersey Department of Environmental Protection (NJDEP) estimates that New Jersey lost 20% of its wetlands in the 20 years between 1950 and 1970. The state legislature passed the Wetland Act of 1970 and the Freshwater Wetlands Protection Act in 1987, but the programs was not fully operative until 1995. During that time, the state lost 1,755 acres. From 1995 to 2002, the state lost approximately 150 acres per year. [291] In 1995, coastal wetlands covered approximately 811 km² (200,000 acres).[292]

3 Historically, New Jersey has relied heavily on shoreline armoring; stabilization structures are found on more than 165 km of the 204 km Atlantic coastline. In the second half of the 20th century, beach nourishment and dune construction and stabilization became the preferred methods. At current rates of erosion alone, the state will need approximately $5 billion over the next 50 years to sustain its beach nourishment.[293] See also Delaware-Research-3 for a mention of New Jersey beaches becoming completely submerged at high tide because of shoreline armoring.

4 As of 2002, New Jersey has over 300,000 acres of tidal wetlands, used by 1.5 million shorebirds and with higher concentrations of

http://www.epa.gov/climatechange/effects/downloads/toc-wet_chap2.pdf

[288] Ibid., 81.

[289] T. Kana, "Sea Level Rise Impacts on Beaches and Wetlands – Problems you may not know," 2007 North Carolina Beach, Inlet & Waterway Association Annual Conference 'Everything You Always Wanted to Know About Sea Level Rise, But Were Afraid to Ask' (November 2007): 2. http://www.coastalplanning.net/projects/NCBIWA/pps2007/2%20Tim%20Kana.pps

[290] M. Cooper et al, "Future Sea Level Rise and the New Jersey Coast: Assessing Potential Impacts and Opportunities," Science, Technology and Environmental Policy Program, Woodrow Wilson School of Public and International Affairs, Princeton University (June 2005): 17. http://www.princeton.edu/~cmi/news/Future%20of%20Sea%20Level%20Rise%20and%20the%20New%20Jersey%20Coast.pdf

[291] S. Balzano et al, "Creating Indicators of Wetland Status (Quantity and Quality): Freshwater Wetland Mitigation in New Jersey," New Jersey Department of Environmental Protection (March 2002): *i-ii*. http://www.state.nj.us/dep/dsr/wetlands/final.pdf

[292] "Future Sea Level Rise and the New Jersey Coast" p 17.

[293] Gaul and Wood 2002, cited in "Future Sea Level Rise and the New Jersey Coast" p 23.

use by certain birds than any other wetland system.[294]

5 As determined by photo-interpretation of 1995/1997 aerial photography, in 1995, there were 208,847 acres of tidal wetlands, 108,035 acres of freshwater wetlands, and 8121 acres of restored or created wetlands. In 2000, there were 208,770 acres of tidal wetland and 107,261 acres of freshwater wetland, representing a small decrease.

6 The 2002 study previously cited in Maryland.Research.7 also looked at the North Shore of the Delaware Bay, which is in New Jersey. Non-degraded wetland were 27,095 hectares (66,953 acres), slightly to moderately degraded wetlands were 30,660 hectares (75,763 acres), and severe to completely degraded wetlands were 13,547 hectares (33,457 acres), respectively 38%, 43% and 19% of the total 176,173 acres.[295]

7 * A June 2005 report from Princeton University, entitled "Future Sea Level Rise and the New Jersey Coast: Assessing Potential Impacts and Opportunities" assesses possible impacts based on sea level rise projections. The report estimates, based on IPCC projections and local tide gauge data, that 70% of future sea level rise on the New Jersey Coast will be due to the effects of climate change rather than local factors. It also notes that even if people stabilize the anthropogenic greenhouse gas emissions that are exacerbating global warming, it will have little effect on slowing sea level rise for at least 50 years.[296]

The study looked at two scenarios for 2100, one scenario at the median and the other at the high end of sea level rise projections: respectively, 0.61 m (50% probability) and 1.22 m (1% probability). The maps used belonged to the New Jersey Department of Environmental Protection's Bureau of Geographic Information Systems, which the DEP had gotten from the US Geological Survey. The study did not consider land subsidence, erosion, accretion or other possible natural adaptations.[297]

The study notes that coastal inundation and beach erosion are distinct processes, though they are related and both contribute to shoreline retreat. Inundation drowns land areas, whereas erosion redistributes sediment from onshore to offshore areas. They are related in that rising sea levels allow larger waves to reach the coast and this intensifies beach erosion.[298] The study considers mainly inundation, but also makes estimates about total shoreline retreat.

The study uses the 1962 Bruun model that estimates the rate of shoreline retreat as 50 to 100 times greater than the rate of sea level rise, along with a 2004 study that estimated shoreline change as 36.6 m per 0.3 m of sea level rise on sandy beaches, to estimate that sea level changes of 0.61 m and 1.22 m would result in shoreline changes between 73 m and 146 m.[299]

The study estimates that "a 0.61 m rise in sea level could permanently inundate approximately 15% of the saline marshes in New Jersey, while a 1.22 m rise in sea level could inundate about 30%. These estimates assume a fixed position for all wetlands and do not account for the ability of wetland complexes to adapt through vertical accretion. The increase in flooding associated with sea level rise will also affect wetland habitats. In total, approximately 906 km² of wetlands lie within the current 100-year flood level of 2.90 m. This area includes virtually all 772 km² of New Jersey's saline marshes and 95% of

[294] Coastal Management Program, "Fact Sheet 2: What is the New Jersey Coast?" New Jersey Department of Environmental Protection (March 2002). http://www.state.nj.us/dep/cmp/fact2.pdf

[295] M. Kearney et al, "Landstat Imagery Shows Decline of Coastal Marshes in Chesapeake and Delaware Bays," *Eos* Transactions of the American Geophysical Union 83 (April 16, 2002): 178. http://ian.umces.edu/pdfs/stevenson_6.pdf

[296] "Future Sea Level Rise and the New Jersey Coast" p 25.

[297] Ibid., 5.

[298] Frequently quoted is a 2004 study by Zhang et al, which looks at the connection between sea level rise and coastal erosion over the Atlantic coast. The study finds a multiplicative association between the two—specifically, the rate of erosion is about two orders of magnitude greater than the rate of sea level rise. Zhang et al, "Global Warming and Coastal Erosion." *Climatic Change* 64 (2004): 41–58. http://www.springerlink.com/content/w072202jr03xh214/BodyRef/PDF/10584_2004_Article_5149871.pdf

[299] "Future Sea Level Rise and the New Jersey Coast" pp 51-52.

freshwater marshes."[300]

Also included is a discussion of a case study of Cape May Point, New Jersey, an area of 1.5 km² composed of approximately 40% freshwater and saline marsh, 40% wooded wetland, and 20% forest. The study estimates that, not taking into account shoreline displacement, wetland accretion or human alteration, a 0.61 m rise would inundate 20% of the study area, and a rise of 1.22 m would inundate 45% of the study area. Comparing this to historical shoreline retreat (from combined sea level rise and erosion) using analysis of digitized historical maps, the rate since 1879 has been around 4 mm/yr, and comparing this to records of sea level rise, this corresponds to about a one meter retreat for each millimeter of sea level rise (an order of magnitude greater than predicted by the Bruun model). At this rate, a 0.61 m rise would erode 610 m of the central beach, or 70% of the study area, and a 1.22 m rise would displace the entire study area and adjoining lands.

These projections are far more than the estimates made using sea level rise alone; however, Cape May Point has had rates of shoreline displacement greater than the statewide average. The study emphasizes that shoreline displacement is highly variable and dependent on local conditions. [301]

The study recommends gradual withdrawal as the optimum strategy for preserving natural ecosystems.

8 A 2005 report from Princeton University entitled "Future Sea Level Rise and the New Jersey Coast: Assessing Potential Impacts and Opportunities" presents an assessment of expected impacts of increased rates of sea level rise caused by global warming. The abstract reads, "We project future sea level rise based on historical measurements and global scenarios, and apply them to digital elevation models to illustrate the extent to which the New Jersey coast is vulnerable. We estimate that 1 to 3% of New Jersey's land area will be affected by inundation and 6.5 to over 9% by episodic coastal flooding over the next century. We also characterize potential impacts on the socioeconomic and natural systems of the New Jersey coast focusing on Cape May Point for illustrative purposes. We then suggest a range of potential adaptation and mitigation opportunities for managing coastal areas in response to sea level rise. Our findings suggest that where possible a gradual withdrawal of development from some areas of the New Jersey coast may be the optimum management strategy for protecting natural ecosystems."[302]

9 A January 2007 report published by the Woodrow Wilson School of Public and International Affairs at Princeton University, entitled "The Garden State in the Greenhouse: Climate Change Mitigation and Coastal Adaptation Strategies for New Jersey," makes a series of policy recommendations for New Jersey. Its main recommendations relate to reducing greenhouse gas emissions. With respect to sea level rise impacts on natural habitats, the report recommends "[preserving] land strategically to protect natural resources from the impacts of climate change through partnerships among NJDEP [New Jersey Department of Environmental Protection], NJOSG [New Jersey Office of Smart Growth] and non-profit conservation organizations and municipalities. Preservation could be achieved through acquisition, regulation and NJOSG's planning process."[303] The report gives "Conservation Resources Inc."[304] as an

[300] Ibid., 18.
[301] Ibid., 20-21.

[302] M. Cooper et al, "Future Sea Level Rise and the New Jersey Coast: Assessing Potential Impacts and Opportunities," Woodrow Wilson School of Public and International Affairs, Princeton University (November 2005): 2. http://www.princeton.edu/~cmi/news/Future%20of%20Sea%20Level%20Rise%20and%20the%20New%20Jersey%20Coast.pdf
[303] J. Colón et al, "The Garden State in the Greenhouse: Climate Change Mitigation and Coastal Adaptation Strategies for New Jersey," Woodrow Wilson School of Public and International Affairs, Princeton University (January 2007): 16, 35. http://www.princeton.edu/~mauzeral/teaching/wws591a_report.pdf, and mirror at http://www.wws.princeton.edu/research/PWReports/F06/wws591a.pdf.
[304] Conservation Resources Inc. New Jersey, "Welcome" (2009). http://conservationresourcesinc.org/index.htm

example of a land conservation organization in New Jersey.

10 A 2007 study from Rutgers University "undertook a geographic information system-based approach to identify vulnerable development and where this development is constricting the natural dynamics of coastline migration. This study was part of a broader assessment of New Jersey's coastal environmental resources conducted by the Walton Center for Remote Sensing & Spatial Analysis (CRSSA) of Rutgers University and the American Littoral Society. The objective of the New Jersey Coastal Assessment was to compile and synthesize a diversity of mapped information to provide a fuller picture of New Jersey's coastal resources and habitats to assist in land and conservation planning."

The study found, "New Jersey's coastal zone is heavily impacted by development with a high degree of developed land uses in close proximity to the tidal waters and thereby vulnerable to future sea level rise:
- The majority of near-shore coastal zone (<500 m from tidal water) is in some form of human dominated land use: 42% urban, transitional or mining; and, 14% in agriculture.

"To model the potential hazard posed by future sea level rise and storm surge, we mapped the predicted inundation zone for a 100-year tidal surge, which also equates very closely to a 30-yr storm under a 2100 sea level rise scenario:
- Approximately 16% of the predicted 100-yr tidal surge inundation zone is in developed land uses including all of New Jersey's barrier island communities, as well as significant sections of the Barnegat, Delaware and Raritan Bays.

"Near shore development and other infrastructure such as shoreline armoring limits the future flexibility in adapting to predicted sea level rise and coastal storm surges.
- 17% of New Jersey's shoreline is altered due to bulkheading or rip-rap or other coastal protection structures;
- 60% of New Jersey's Atlantic shore beaches and dunes are in close proximity (< 100 m) to developed land uses; and,
- 29% of tidal marsh retreat area is presently limited by development and roads."

"If we are to sustain functioning coastal ecosystems, then we need to maintain our beaches, tidal flats and bars, seagrass beds and tidal wetlands. To ensure vitality of these coastal habitats for the long term then we need to plan for and design flexible adaptation strategies that recognize the dynamic nature of our coastlines. Sea level rise and associated problems of shoreline erosion and storm surges have been primarily addressed through 'hard' structural approaches to protect existing developed infrastructure. We suggest that future adaptation to sea level rise is not just an engineering issue but rather primarily a **land use** issue.

"New development should be minimized in beach, dune and coastal wetland retreat zones to provide for future shoreline retreat and minimize the need for future investment in structural protection (USEPA, 1988). Present state regulations limit development in proscribed buffer zones adjacent to coastal wetlands and waters to limit the impact associated with runoff, sedimentation, and non-point source pollution. As such these presently regulated buffer zones serve the dual purpose of also serving as coastal 'retreat' zones. These buffer zones should to be 'rolling' to reflect changes as sea levels rise and the water/wetland boundary retreats landward (Titus, 1988). Where existing beach or bayfront development is threatened by shoreline erosion, 'soft' approaches such as dune protection/stabilization or salt marsh restoration should be used rather than shoreline armoring.

"New Jersey is presently engaged in an expensive experiment involving beach nourishment as a buffer against sea level rise and shoreline erosion. The efficacy of beach nourishment as a viable policy option/approach for the long term (i.e., the next 100 years) remains to be proven. Alternatively, a policy of 'strategic adjustment'

where developed properties in high hazard erosion and storm inundation zones are acquired and removed should receive careful consideration (Psuty and Ofiara, 2002). Such a Coastal Blue Acres program would mirror the approach that New Jersey has successfully used in removing vulnerable development in river floodplains. Future work is needed to identify 'high hazard conflict' zones where 'strategic adjustment' may serve as the preferred policy option/approach."[305]

11 A report from Princeton University published in 2008, "The potential impacts of sea level rise on the coastal region of New Jersey," presents an assessment of potential sea level rise impacts on the New Jersey Coast. The abstract reads, "We produce two projections of sea level rise for the New Jersey coast over the next century and apply them to a digital elevation model to illustrate the extent to which coastal areas are susceptible to permanent inundation and episodic flooding due to storm events. We estimate future coastline displacement and its consequences based on direct inundation only, which provides a lower bound on total coastline displacement. The objective of this study is to illustrate methodologies that may prove useful to policy makers despite the large uncertainties inherent in analysis of local impacts of climate and sea level change. Our findings suggest that approximately 1% to 3% of the land area of New Jersey would be permanently inundated over the next century and coastal storms would temporarily flood low-lying areas up to 20 times more frequently. Thus, absent human adaptation, by 2100 New Jersey would experience substantial land loss and alteration of the coastal zone, causing widespread impacts on coastal development and ecosystems. Given the results, we identify future research needs and suggest that an important next step would be for policy makers to explore potential adaptation strategies."[306]

Policy

1 The Wetlands Act of 1970 and the Freshwater Wetland Protection Act instituted permit requirements for any activity that would impact wetlands. Laws and Regulations are available on the NJDEP website.[307]

2 In June 2006, the New Jersey Coastal Management Program, a program of the Coastal Management Office of the New Jersey Department of Environmental Protection (NJDEP), published the latest "Assessment and Enhancement Strategy," covering FY 2006-2010. Sea level rise is characterized as a "High Risk" coastal hazard; however, specific to wetlands, it is classified as a threat of "Medium" significance.[308]

The report uses forecasts of a sea level rise between 0.31 m and 1.10 m by 2100, noting that the median value, 0.71 m, is more than twice the rise of the past century. Wetlands, in responding to sea level rise, can either be lost to inundation, can accrete vertically, or can migrate inland. Given the projected levels, organic plant matter is not likely to accumulate enough to allow vertical accretion, meaning that wetlands will either migrate inland or be inundated. Development that prevents inland migration will diminish wetland extent or cause wetlands to be lost to inundation.

Since the last assessment, NJDEP has made several moderate changes, some of which relate to natural resources. New rules specify

[305] R. Lathrop and A. Love, "Vulnerability of New Jersey's Coastal Habitats to Sea Level Rise," Grant F. Walton Center for Remote Sensing & Spatial Analysis, Rutgers University (January 2007): 2, 13-14. http://www.crssa.rutgers.edu/projects/coastal/sealevel/report/Vulnerability_of_New_Jersey_coastal_habitats_v4.pdf

[306] M. Cooper et al, "The potential impacts of sea level rise on the coastal region of New Jersey, USA," Climate Change 90 (2008): 475-492. http://www.springerlink.com/content/k847813473430 6j2/

[307] Land Use Regulation Program, "Laws & Regulations," New Jersey Department of Environmental Protection (August 2009). http://www.nj.gov/dep/landuse/njsa_njac.html

[308] Coastal Management Office, "New Jersey Coastal Management Program: Assessment And Enhancement Strategy FY 2006 - 2010," New Jersey Department Of Environmental Protection (June 2006): 9, 74. http://www.state.nj.us/dep/cmp/309_combined_strat_7_06.pdf

that alternatives to hard shoreline protection structures are preferred methods of shoreline stabilization. NJDEP's Division of Land Use Regulation has put effort towards ensuring that alternative stabilization techniques such as bioengineering are discounted before it issues permits for hard protection structures. In June 2003, NJDEP co-sponsored a workshop about stabilizing eroding shorelines, including alternative shoreline stabilization methods. NJDEP adopted two changes to CZM rules for beach and dune protection: increasing required minimum dune design volume for 100-year storm protection from 540 to 1,100 square feet, and instituting new construction standards for geotextile bags or tubes. NJDEP's Bureau of Coastal Land Use Enforcement has substantially increased personnel and resources dedicated to monitoring compliance.[309]

Under future goals, the report states, "The values of coastal wetlands are widely recognized. These values may be measured in terms of their ecology and their fundamental contribution to economically important estuarine and marine resources. Coastal wetlands are also valuable for their ameliorative effects on the forces of coastal erosion.

During the 2006-2010 Section 309 Assessment and Strategy interval, the NJCMP proposes to carefully examine the potential effects of sea level rise on tidal wetlands and determine the most appropriate measures that can be taken to accommodate the perpetuation of these important coastal features. This examination will focus on the physical factors that influence the future disposition of these wetlands. The goal of this endeavor is to identify and clearly define the geomorphological, biological, and hydrological factors that are conducive to the landward migration of coastal wetlands, the development of coastal wetlands along open water areas, and the transformation of freshwater wetlands to tidal wetlands."[310]

For future plans, the report notes, "Currently, the CZM rules do not contain a specific methodology for establishing 300-foot buffers adjacent to coastal wetlands for the purpose of accommodating horizontal wetlands migration in response to sea level rise. In addition, the CZM rules do not contain provisions for establishing buffers adjacent to open waters. During the 2006-2010 Section 309 Assessment and Strategy interval, the NJCMP proposes to define the parameters that are conducive to wetlands migration and development in response to sea level rise." Towards this, NJDEP plans to prepare a policy guidance document or revise current rules as necessary. In this 2006 report, developing this methodology was planned to be completed in 2007-2008. In implementation, NJDEP expects that incorporating clarifying protocols will be relatively easy, but anticipates significant opposition to developing a new rule that addresses buffers to open water.[311]

3 The Division of Land Use Regulation released revised Flood Hazard Control Rules in November 2007. As explained on the Division's website: "In order to minimize the impacts of development on flooding, a 0% net-fill requirement (which was previously implemented only in the Highlands Preservation Area and Central Passaic Basin) will now apply to all non-tidal flood hazard areas of the State. The new rules also expand the preservation of near-stream vegetation (previously protected within 25 or 50 feet of streams) by implementing new riparian zones that are 50, 150 or 300 feet in width along each side of surface waters throughout the State. The riparian zone width depends on the environmental resources being protected, with the most protective 300-ft riparian zone applicable to waters designated as Category One and certain upstream tributaries."[312]

4 "The Partnership for the Delaware Estuary (formerly, The Delaware Estuary Program) is

[309] Ibid., 11-13.
[310] Ibid., 19.
[311] Ibid., 19-20, 25-26.
[312] Land Use Regulation Program Notices & Announcements, "11/5/2007: Flood Hazard Area Control Act Rules Adopted," New Jersey Department of Environmental Protection (November 2007). http://www.nj.gov/dep/landuse/announce.html#110507

intending to propose a demonstration project in New Jersey, to rebuild and stabilize an eroded marsh edge with an intertidal, mussel-dominated community in a brackish region of the Delaware Estuary. One of the goals of the project relates directly to the response of tidal marshes to sea level rise. An expected outcome of the project is that dense beds of marsh mussels (*Geukensia demissa*) will significantly contribute to vertical marsh accretion by filtering suspended matter and depositing it on the marsh surface, facilitating overall plant productivity, and stabilizing the marsh surface. The NJCMP will closely monitor the results of the project for its implications regarding the advisability of instituting similar projects in New Jersey's coastal area."[313]

Actions

1 Currently none directly addressing sea-level rise. However, in southern New Jersey, in collaboration with local industries, NJDEP has preserved approximately 11 km² (2,700 acres) of wetlands and an additional 11 km² of upland areas in the wetland migration path. The Green Acres Program has used state funding to acquire more than 81 km² of land including almost 1 km² (247 acres) of beachfront, dune, and wetlands along Delaware Bay. [314]

2 New Jersey requires compensatory mitigation for activities that disrupt or destroy wetlands. In 2002, Environmental Consultants, Inc. reviewed 90 mitigation sites and concluded that, on average, only 0.78 acres of wetland were created for every 1 acre of required construction, and on average the wetland quality was 0.51 out of an index of 1 (i.e., wetlands were half what they should have been).[315] One reason for the failure is unsuitable hydrological conditions, suggesting inadequate understanding or inaccurate description. In response, the NJDEP's Division of Land Use Regulation identified the need to better study hydrologic conditions for proposed mitigation sites.[316]

3 NJDEP, in conjunction with the Army Corps and local sponsors, continue to conduct beach re-nourishment. Current appropriates from the State's real estate transfer tax are $25 million annually, including funds contributed as a matching share to federal funding of large projects. The program has restored significant stretches of eroding oceanfront beaches. The projects also include construction, restoration and enhancement of dunes and selective notching of existing groins.

Oceanfront communities have approved of beach nourishment efforts, but some residents complain about the loss of ocean views or direct beach access (and consequent reduction in property value) from the accompanying dunes. The problem is more acute where beach nourishment and dune construction occurs on private property, and the NJDEP has encountered resistance. In a recent case, the New Jersey Superior Court awarded damages to an Ocean City beachfront resident. The primary basis for the decision was due to the dune coming across the plaintiff's property, but the decision also stated in its decision that the dune project completely obstructed ocean view and eliminated direct access to the beach.[317]

4 The New Jersey Coastal Green Acres Land Acquisition Program is highlighted as a program fulfilling the goal to "preserve coastal land/development (including infrastructure)" in the 2009 Climate Ready Estuaries Synthesis of Adaptation Options for Coastal Areas.[318]

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[313] Ibid., 20, 25.
[314] Cited as 'NJDEP 2001a' in "Future Sea Level Rise and the New Jersey Coast" p 24.
[315] S. Balzano et al, "Creating Indicators of Wetland Status (Quantity and Quality): Freshwater Wetland Mitigation in New Jersey," New Jersey Department of Environmental Protection (March 2002). http://www.state.nj.us/dep/dsr/wetlands/final.pdf
[316] Coastal Management Office, "New Jersey Coastal Management Program: Assessment And Enhancement Strategy FY 2006 - 2010," New Jersey Department Of Environmental Protection (June 2006): 82-83. http://www.state.nj.us/dep/cmp/309_combined_strat_7_06.pdf
[317] Ibid., 15-16.
[318] Environmental Protection Agency, "Synthesis of Adaptation Options for Coastal Areas." U.S. Environmental Protection Agency Climate Ready Estuaries Program (January 2009): 10.

The program takes into account the impacts of climate change, and acquires coastal lands damaged or prone to damages by storms to provide a buffer as well as space for recreation and conservation. Program funds were used to acquire 18.5 acres in Cape May County, providing critical undeveloped, upland and wetlands habitat;[319] other "Green Acres Success Stories" are described on the Green Acres website.[320]

New York

Research

1 From 1924 to 1974, Jamaica Bay lost 780 acres of tidal wetlands to direct filling and another 510 acres due to unknown reasons. From 1974 to 1994, the Bay lost 526 acres for unknown reasons. From 1994 to 1999, the Bay lost 220 acres. Sea level rise was one of several possible factors contributing to the losses.

Including losses from known causes, wetland loss on salt marsh island complexes went from 1,821.08 acres in 1974 to 1,050.5 acres in 1994, a loss of 770.58 acres or -42.3%. These losses were detailed across 19 wetland complexes within the Bay. [321]

2 In 1999, approximately 50% of the Long Island Sound shoreline was armored with erosion control structures, most without functional relationships to coastal waters.[322]

3 The "New York City Wetlands: Regulatory Gaps and Other Threats" report (see New York-Research-4 below) cites a 2001 study from Columbia University's Earth Institute[323] and studies by the New York State Department of Environmental Conservation[324] about wetlands in Long

http://www.epa.gov/cre/downloads/CRE_Synthesis_1.09.pdf The report refers to the "New Jersey Coastal *Blue* Acres Land Acquisition Program [emphasis mine]". This appears to be a mistake.

[319] Green Acres Program, "Green Acres Success Stories: Higbee Beach Wildlife Management Area," New Jersey Department of Environmental Protection (October 2007). http://www.state.nj.us/dep/greenacres/success_images/higbee.html

[320] Green Acres Program, "Green Acres Success Stories," New Jersey Department of Environmental Protection (October 2007). http://www.state.nj.us/dep/greenacres/intro.htm

[321] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Volume II – The Plan, Chapter 4 (Category 2, Restoration Ecology: Objectives, Current Programs, and Potential Management Strategies)" (October 2007): 90-91. http://www.nyc.gov/html/dep/pdf/jamaica_bay/vol-2-chapter-4.pdf

[322] Division of Coastal Resources and Waterfront Revitalization, "Long Island Sound Coastal Management Program," New York State Department of State (January 1999): 75. http://nyswaterfronts.com/downloads/pdfs/lis_cmp/Combined_Chapters.pdf

[323] E. Hartig et al, "Wetlands, in Climate Change and a Global City: The Potential Consequences of Climate Variability and Change—Metro East Coast," New York: Columbia Earth Institute (2001): 67-68.

[324] "Tidal Wetlands," New York State Department of Environmental Conservation (2009). http://www.dec.ny.gov/lands/4940.html

Island retreating inland where there is sufficient open space. Two examples are give: Shinnecock Bay gained 161 acres of tidal wetland from 1974 to 1995, more than making up for the loss of 21 acres of tidal wetlands (including the destruction of 6 of 13 tidal wetlands islands), and Moriches Bay gained 100 acres of tidal wetlands from 1974 to 1988 from inland migration, again more than making up for a loss of 2.5 acres. However, in urban areas there have not been sufficient protections for upland areas. The "Regulatory Gaps and Other Threats" report comments, "Federal law has no transition area. While State law requires a 150-foot transition area in New York City, and 300 feet elsewhere, in practice permitted fill activity has been allowed up to 35 feet from the tidal wetland boundary. Even where some inland migration is possible, or wetlands will otherwise tolerate sea level rise, other aspects of climate change will pose a threat."[325]

4 In March 2008, Scenic Hudson published the "Audit and Action Agenda for New York State Coastal Management Program," analyzing the state's 25 year-old shoreline program. The report praises the national leadership of New York's Coastal Management Program (CMP), but says that the effectiveness of the program is hampered by the lack of a centralized repository for information on coastal conditions. There is also a lack of authority, coordination and cooperation among state agencies, leading to insufficient resources and authority to respond to threats to critical natural resources. The report notes that the CMP has so far been effective in guiding economic progress and environmental protection, but is insufficiently equipped to deal with a rapidly rising residential population.[326]

The rising residential usage is the greatest concern, but the report mentions sea level rise, saying that the threats of climate change should add to the urgency of wise coastal management. The CMP can add climate change to its assessments of risk by including climate-change scenarios in flood and erosion control policies. Even if planning leads to excess capacity, strategies such as preserving wetlands might benefit the region in the long run if growth continues.[327]

5 "PlaNYC" is a project started by Mayor Bloomberg in 2006, aiming to achieve sweeping changes in New York's urban environment and be a model city for the future. One of the three things PlaNYC is created to address is the impacts of global warming, including rising sea levels.

In January 2009, PlaNYC released a report entitled "New York City Wetlands: Regulatory Gaps and Other Threats." Written by an interagency group, the report fulfills an initiative in PlaNYC's water quality chapter to address existing gaps in wetland protections and exploring option to fill those gaps.

The paper notes, "New York City has only 1% of its historic freshwater wetlands and 10% of its historic tidal wetlands. These remaining wetlands are concentrated in Brooklyn (principally tidal wetlands around Jamaica Bay), Queens (principally tidal), and Staten Island (both tidal and freshwater). Although occupying relatively small land areas compared to their historic range, these wetlands continue to provide important benefits to the city."[328] The Hudson-Raritan Estuary, which includes New York City, has 14 square miles of coastal wetlands, down from the original 86 to 100 square miles.

Of these remaining wetlands, the City owns

[325] Mayor's Office of Long-Term Planning and Sustainability, "New York City Wetlands: Regulatory Gaps and Other Threats," PlaNYC (January 2009): 26-27. http://www.nyc.gov/html/planyc2030/downloads/pdf/nyc_wetlands_january_2009.pdf

[326] J. Hubschman, "Hudson River Coast at Risk on the Eve of the 400th: Audit and Action Agenda for New York State Coastal Management Program, Final Report," Scenic Hudson (March 2008): 5, 7-8. http://www.scenichudson.org/whatwedo/resourcecenter/coastalprogram. The '400' refers to 2009 being the 400 anniversary of Henry Hudson's 1609 exploration of the now eponymous river. See http://www.dec.ny.gov/lands/4923.html for a brief discussion the river's name.

[327] Ibid., 25.

[328] Mayor's Office of Long-Term Planning and Sustainability, "New York City Wetlands: Regulatory Gaps and Other Threats," PlaNYC (January 2009): 4. http://www.nyc.gov/html/planyc2030/downloads/pdf/nyc_wetlands_january_2009.pdf

and manages thousands of acres, the National Park Service controls tracts of wetland around Jamaica Bay and Staten Island, and federal and New York State regulations protect other wetlands within the city from threats related to land use development.

The paper's findings include the following results:
– Freshwater wetlands that are unmapped, or that are smaller than 12.4 acres (5 hectares) are not protected by State law and are outside the scope of federal protection. Most freshwater wetlands remaining in the City are less than this size.
– Tidal wetlands of all size are protected under the Tidal Wetlands Act of 1973. However, for upland buffer areas protected by State laws, the protections do not apply to unmapped areas and areas smaller than 12.4 acres.
– The paper recommends that detailing mapping of small wetlands is a critical step; most applicable regulatory maps are over 30 years old, during which time there has been extensive development. For example, the paper cites a 2005 study that suggests there are no longer any remaining unmapped wetlands in Staten Island. Mapping using satellite imagery and aerial photography was scheduled for April and August 2009, when leaf and vegetation cover would be optimal.
– Development of the New York City shoreline has meant that "many tidal wetlands that would normally migrate inland in response to sea level rise are prevented from migrating. The mapping effort and related climate change adaptation planning that will be completed in 2009 will help identify areas where natural expansion is likely and possible."[329]
– Remaining threats to tidal and freshwater wetlands are not from a lack of regulatory protection, but a lack of state and federal enforcement of permit and mitigation requirements, existing degraded conditions, and the effects of climate change. These problems require resources, which will come from seeking "new and creative funding mechanisms."[330]
– While extensive State and federal regulatory practices apply to open waters, the City lacks a comprehensive management policy for submerged lands. This will be more important as sea levels rise in response to climate change.
– While waiting for mapping data collection, the City will continue to address sea level rise and other threats by several measures, including transferring the most important unmanaged City-owned wetlands to Parks Department as recommended by the Wetlands Transfer Task Force, implementing the comprehensive Jamaica Bay Watershed Protection Plan to restore tidal marshes, exploring mitigation banking and other mechanisms for improved restoration and maintenance of wetlands, developing accurate information about potential inland migration areas for tidal wetlands, and completing a comprehensive plan for the adaptation of wetlands to sea level rise and other effects of climate change through the Climate Change Adaptation Task Force.[331]

6 The New York City Panel on Climate Change, convened by Mayor Bloomberg in August 2008 to help accomplish the goals outlined in "PlaNYC," released the report "Climate Risk Information" in February 2009. Using an IPCC-based approach, the Panel uses global climate models to predict sea level rises of 2.5 inches by the 2020s, 7-12 inches by the 2050s, and 12-23 inches by the 2080s. Impacts will include inundation of low-lying areas and wetlands. Current rates range between 0.86 and 1.5 inches per decade, and the average rate from tide gauge measurements since 1900 is 1.2 inches per decade.[332] Appendix C discusses how the Panel adapted IPCC results and methods.

7 In 2009, the Nature Conservatory released "Rising Waters: Helping Hudson River Communities Adapt to Climate Change,

[329] Ibid., 3.

[330] Ibid.
[331] Ibid., 3-7, 33-34.
[332] R. Horton and M. O'Grady, "Climate Risk Information," New York City Panel on Climate Change (February 2009): 3-4, 9.
http://www.nyc.gov/html/planyc2030/downloads/pdf/nyc_climate_change_report.pdf

Scenario Planning 2010 – 2030 Final Report." The "Rising Waters" Project, spearheaded by the Nature Conservatory, discusses ways to prepare for climate change impacts to the Hudson River Estuary Watershed (HREW). Partners include a state agency, an academic institution, and community and non-governmental groups. In addition, over 160 stakeholders participated in five public workshops and smaller meetings. The project uses scenario planning methodologies first developed at Royal Dutch Shell. Bio Economic Research Associates facilitated and managed the scenario planning process.[333]

The estuary is 5,300 square miles, over 153 miles of river. The major land uses are forest cover (62%) and agriculture (17%). It supports more than 200 types of fish, 19 kinds of rare birds and 140 rare plants, as well as 4 million people with 1 million more expected within the next 10 years.[334]

The Project considers four colorfully-named scenarios: "Procrastination Blues," "Stagflation Rules, "Nature Be Dammed," and "Give Rivers Room." "Procrastination Blues" is defined as little preparation, and preparation not in concert with natural systems; "Stagflation Rules" is defined by little preparation, but preparation in concert with natural systems; "Nature Be Dammed" is a great deal of preparation, not in concert with natural systems; and "Give Rivers Room" is a great deal of preparation, in concert with natural systems.[335]

These scenarios are defined by the major uncertainties of how much will be done to prepare, and what the nature of the preparations will be. The project examines the interaction between these major uncertainties and predetermined elements (global climate change impacts, fragmented government responsibilities, aging infrastructure), driving forces (land use decisions, oil prices, the 'greening' of the economy, tensions between private rights and social responsibilities), and prime movers (local governments, media, real estate developers, railroads, religious and educational institutions).[336]

Here the Project adopts an unusual approach (which is presumably the 'scenario planning methodology' borrowed from Royal Dutch Shell). It considers another driving force of extreme weather events, and allows this "vary freely" across scenarios.[337] For example, the "Procrastination Blues" scenario assumes major flood events in Spring 2015 and Fall 2016, and an extreme heat wave in Summer 2016, while "Stagflation Blues" has major floods in Fall 2011, Summer 2012, Spring 2013, Spring 2015, and Summer 2015, a moderate heat wave in Summer 2012, and an extreme heat wave in Summer 2014.[338] Each scenario then becomes not a systematic permutation over finite variables, but an idiosyncratic narrative of a specific possible future. The Final Report does not discuss whether stakeholders reacted positively to this unusual approach or not.

The Project participants reached a consensus on several recommendations (which are more mundane than the scenario methodology). These recommendations include integrating climate-change considerations over a 20 year horizon into land use planning, considering increasing setbacks to at least 75 ft from riverbanks and 300 feet from streamsides, "identify[ing] and promot[ing] sustainable methods for shoreline erosion control… while enabling vital natural communities to migrate landward as sea level rises," removing incentives for non-sustainable shoreline management methods, sharing best practices when shoreline construction is necessary, beginning an intensive program to restore streams and revegetate banks, and developing long-term acquisition and easement plans.[339]

In the Appendix, the Final Report includes

[333] S. Aldrich et al, "Rising Waters: Helping Hudson River Communities Adapt to Climate Change, Scenario Planning 2010 – 2030 Final Report," The Nature Conservatory Eastern NY Chapter (2009): 3-5. http://www.nature.org/wherewework/northamerica/states/newyork/files/rw_062409.pdf

[334] Ibid., 4.

[335] Ibid., 40.

[336] Ibid., 36-37.

[337] Ibid., 35.

[338] Ibid., 6.

[339] Ibid., 12-14.

the results of participant responses to 80 proposed policy options in the form of radar graphs. Participants were asked to rate, for each option, its performance, barriers, durability, environmental effects, transformative potential, equity, costs, and benefits. Some examples of these eighty policies are: requiring greater building elevation, counting residential improvements cumulatively, changing the definition of "substantial improvement," increasing setbacks, requiring municipal staff to receive floodplain management training, preparing for tidal wetland migration, moving or demolishing all structures in the floodplain, creating a $50 million state fund to purchase floodplain lands, or a $50 million dollar fund to restore riparian corridors, extending "Rising Waters" scenarios, building hard erosion control structures, beginning an intensive program to restore streams and revegetate banks, and requiring corridors for wildlife to migrate through developed areas.[340]

Policy

1 Section 6 of the August 1982 "State of New York Costal Management Program and Final Environmental Impact Statement" is 'State Coastal Policies.' Changes to incorporate routine program changes were approved in 1983 and 2001. The latest compilation of the policies was made in 2004, listing 44 policies. Each policy "either promotes the beneficial use of coastal resources, prevents their impairment, or deals with major activities that substantially affect numerous resources" or some combination thereof.[341]

Relevant policies are:
– Policy 7, "Significant coastal fish and wildlife habitats will be protected, preserved, and where practical, restored so as to maintain their viability as habitats." This policy generally prohibits draining wetlands and ponds, filling wetlands or shallow areas, clear cutting, dredging or excavation, dredge spoil disposal, physical alteration of shore areas through channelization or construction of shore structure, and introducing, storing or disposing of pollutants.[342] Related policies are Policies 13, 14 and 16, which detail with the circumstances under which erosion control structures are permitted. Structures must control erosion for at least thirty years (Policy 13), cannot cause erosion or flooding elsewhere (Policy 14), and must provide benefits that outweigh the adverse effects on natural protective features (Policy 16).[343] Dredging and disposal are regulated by policies 7, 15, 19, 20, 24, 26, 35 and 44, as well as the Environmental Conservation Law articles 15, 24, 25 and 34.[344]
– Policy 12, "Activities or development in the coastal area will be undertaken so as to minimize damage to natural resources and property from flooding and erosion by protecting natural protective features including beaches, dunes, barrier islands and bluffs." This policy seeks to minimize adverse actions such as excavation of coastal features, improperly designed structures, and inadequate site planning.[345]
– Policy 17, "Non-structural measures to minimize damage to natural resources and property from flooding and erosion shall be used whenever possible." The policy specifies non-structural measures as including setbacks (as defined by Section 34-108 of the Coastal Erosion Hazard Areas Act), planting vegetation on dunes and bluffs, installing sand fencing on dunes, reshaping bluffs, and installing drainage systems.[346]
– Policy 44, "Preserve and protect tidal and freshwater wetlands and preserve the benefits derived from these areas."[347] Similar to the manner in which the policy is cited with regards to dredging[348], this policy could be used to establish protection measures not explicitly provided for elsewhere.

[340] "Rising Waters Final Report" Appendix, pp 105-124. http://www.nature.org/wherewework/northamerica/states/newyork/files/rw_062409_app.pdf
[341] Coastal Management Program, "State Coastal Policies," New York State Department of State (2004): 1. http://nyswaterfronts.com/downloads/pdfs/State_Coastal_Policies.pdf
[342] Ibid., 15-16.
[343] Ibid., 21-22.
[344] Ibid., 45.
[345] Ibid., 20-21.
[346] Ibid., 22.
[347] Ibid., 48-49.
[348] Ibid., 45.

2 In 1999, New York State created the Long Island Sound Coastal Management Program to replace the Coastal Management Program as the agency responsible for managing the shorelines of the Long Island Sound. Towards the Long Island Sound Coastal Management Program's goals relating to 'The Natural Coast,' the Program lists objectives such as preventing fragmentation of natural ecological communities, managing development to protect estuarine life, and maintaining the benefits of natural shoreline functions. Recommendations include achieving a net gain in the quality and quantity of tidal wetlands, promoting use of indigenous plants, and developing an ecosystem monitoring program.[349]

In its description of policies for 'The Natural Coast,' the Program notes that relative sea level rise is a significant factor in erosion and flooding and that "sea level rise should be considered when projects involving substantial investments of public expenditures are designed." Based on 100-year tide gauge records showing a rise between 0.04 in/yr to 0.1 in/yr, and assuming a 1:30 ratio of horizontal to vertical sea level rise, it anticipates a one to three inches of horizontal movement per year.[350]

A central tenant of the 'Natural Coast' aspect of the program is "respecting the dynamics of shoreline change." However, this is not connected to sea level rise.[351]

3 The New York City Waterfront Revitalization Program (WRP) is the City's main coastal zone management program. The program was revised in 2002, and described in the Department of City Planning's report, "The New Waterfront Revitalization Program." Policy 4 is to "Protect and restore the quality and function of ecological systems within the New York City coastal area." One technique is to designate three 'Special Natural Waterfront Areas' (SNWAs): Northwestern Staten Island Harbor Herons Area, Jamaica Bay, and East River Long Island Sound area, including a major part of Flushing Bay. The areas contain wetlands, habitats and buffer areas. Other areas are 'Recognized Ecological Complexes,' including waterfront areas in the south shore of Staten Island and Riverdale in the Bronx. Within these designations, policy is to avoid ecologically damaging activities, minimize and mitigate physical loss or degradation when avoidance is not possible, avoid fragmenting natural ecological communities and maintain corridors, restore ecological complexes where practical, and protect indigenous plants. The policy protects tidal and freshwater wetlands from draining, filling, and excavation, seeks to maintain vegetative buffers of indigenous plants between wetlands and nearby development, and seeks to restore wetland wherever practical. [352]

4 * In 2005, Mayor Bloomberg signed Local Law 71, putting into motion the Jamaica Bay Watershed Protection Plan. This requires the New York City Department of Environmental Protection to assess the feasibility of a variety of protection measures, in order to restore and maintain the water quality and ecological integrity of Jamaica Bay. Local Law 71 also established a 7-member Jamaica Bay Watershed Protection Plan Advisory Committee.[353]

Recommendation 31 of the Jamaica Bay Watershed Protection Plan Action Committee in the 2006 "Jamaica Bay Watershed Protection Plan Interim Report" is to expand the buffer zone on tidal wetlands in Jamaica Bay from 150 ft to 300 ft. The reason given is that as "sea level rise continues to due local subsidence and global warming, landward migration of wetlands is inevitable and needs

[349] Division of Coastal Resources and Waterfront Revitalization, "Long Island Sound Coastal Management Program," New York State Department of State (January 1999): 1, 23-26. http://nyswaterfronts.com/downloads/pdfs/lis_cmp/Combined_Chapters.pdf
[350] Ibid., 76-77.
[351] Ibid., 26.
[352] New York City Department of City Planning, "The New Waterfront Revitalization Program" (September 2002): 16-17. http://www.nyc.gov/html/dcp/pdf/wrp/wrp_full.pdf
[353] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Volume I – Regional Profile" (October 2007): 4-5. http://www.nyc.gov/html/dep/pdf/jamaica_bay/vol-1-complete.pdf

to be accommodated through expanded buffer zones."[354]

The 2007 final draft of the "Jamaica Bay Watershed Protection Plan" recognizes the threat of marsh loss and sea level rise in Jamaica Bay, and lists a Blue Ribbon Panel convened by the National Parks Service in 2001, which recommended pilot projects to rebuild recently submerged marshes and to reduce erosion of existing marshes. [355]

The Plan lays out a program for restoring salt marsh complexes. It lists one of most challenging obstacles as securing vast amounts of appropriate substrate material for rebuilding marsh elevation. To restore the marshes of five selected islands to 1951 areas at a minimum depth of 2 ft would require 1.5 million cubic yards, but dredged sand from Rockaway Inlet amounts to only 250,000 cubic yards every 2 to 3 years. Furthermore, a recent pilot project cost $500,000 per acre to restore, meaning the total cost would amount to $235 million. Thus, the Plan recommends a more attractive option as combining restoration with alternative wetland perimeter protection measures. Protection measures would reduce wave velocities and induce sediment accretion.

Management Strategy 2a2 is to use information from a pilot program undertaken at Elders Point, existing literature and other salt marsh island restorations to find technologies of "non-hardened" wave attenuators to protect salt marsh islands from wind and water erosion. The Plan writes: "Recently restored salt marsh islands are extremely vulnerable to the damaging effects of wind and wave energies due to their limited vegetative cover and the limited benefits of sediment anchoring from an under developed root system. These areas are also vulnerable to erosive forces from ice flows during the winter months. The use of geotextile fabrics, temporary floating breakwater systems or other biodegradable materials may be effectively used to armor the vulnerable windward fringe of these marshes, allowing sufficient protection while *Spartina alterniflora* (Smooth Cordgrass) becomes fully established. Used in combination with other salt marsh island restoration efforts, these treatments may help to reduce the rate of loss of existing marsh islands and increase the protective benefits of previous restoration efforts. These systems have the potential to increase the capture of marsh building sediments and may allow the outward expansion of the wetland system.

"The use of wave and wind energy reducing devices for the protection of tidal vegetation has been limited. However, using the wave energy protective methods [to be] utilized for the Elders Point restoration as a measure of their relative success over the long term will help inform future protective measures in salt marsh island restoration efforts. An analysis of existing research in alternative wave attenuating/shoreline protection technologies used in other locations will also provide useful techniques that may be appropriate for use in Jamaica Bay… A pilot project will be developed to test the recommended alternatives on an existing marsh island."

Presumably as examples, the Plan includes two pictures of devices from Elemental Innovations, Inc.: a wave attenuator and a temporary floating wave attenuator. The Plan notes, "Floating breakwaters are typically designed to protect marinas from boat wakes but could possible be modified to work in protecting wetland systems. It is expected that these would only be temporary until the edges of the marshes were stabilized and able to withstand some wave energy impacts. Shoreline areas susceptible to high wave energy typically require structural erosion controls to minimize the impact from wave action. In the case of Jamaica Bay where the salt marsh island are already in a weakened condition, this potentially becomes even more important…"

The pilot study to determine if the installation

[354] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Interim Report" (September 2006): 35. http://www.nyc.gov/html/dep/pdf/jamaica_bay/interimreport.pdf

[355] "Jamaica Bay Watershed Protection Plan Volume I" p 122.

of a wave attenuator around a section of salt marsh island would slow the rate wetland loss and increase the rate of accretion was scheduled for Fall 2008, at a cost of $576,000.[356] An October 2008 progress report of the Jamaica Bay Watershed Protection Plan revised this schedule, listing the design of the project as scheduled for summer 2009. The project is listed as funded.[357]

5 One goal given in a 2007 update of the "Hudson River Estuary Action Agenda 2005—2009" is "By 2007, complete updates to existing conservation measures, including the state's Open Space Conservation Plan and Significant Coastal Fish and Wildlife Habitat designations that benefit a wide range of species, to reflect habitat information gained to date, including projections of shoreline land buffer needs to accommodate wetland migration inland as sea level rises."[358]

6 In 2007, the New York State Legislature passed an act in Chapter 613 of the Laws of New York to create the Sea Level Rise Task Force. It is composed of state agencies, local governments, nonprofit groups, and private citizens, divided into four workgroups: Ecosystems and Natural Habitats, Infrastructure and Community Resilience, Legal, and Public Outreach. The Task Force held its first meeting in June 2008, and its report is due to the legislature by January 1, 2011.

The reason for creating the Task Force is the "series threat [posed by rising sea levels] to coastal communities and natural resources around the globe, altering natural ecosystems and affecting the habitability of cities and towns." The Task Force is examining ways to achieve two objectives: "protect[ing] New York's remaining coastal ecosystems and natural habitats, and increas[ing] coastal community resilience in the face of sea level rise." The Task Force report will cover the five boroughs of New York City, the counties of Westchester, Nassau, and Suffolk, and the tidal waters of the Hudson River.

The 2011 Final Report will include an assessment of anticipated impacts from sea level rise, recommendations to provide more protective standards/enforcement for wetlands protection and shoreline armoring, recommendations for adaptive measures to protect and connect terrestrial and aquatic habitats to allow migration, and recommendations to amend local/state regulations or statues to respond to climate change. All Task Force meetings will be open to the public.[359]

A slide presentation introducing the Natural Resources Working Group is posted online.[360] Also, the Task Force has a listserve for information announcements open to public subscription.[361]

7 In May 2008, the New York City Department of Environmental Protection issued its "Assessment and Action Plan: Report 1" based on the ongoing work of the DEP Climate Change Task Force to compliment the goals of "PlaNYC." As part of its "Action Plan," it lists the goal to "Develop a comprehensive policy for protecting and managing the remaining wetlands in the City," and lists it as the responsibility of the Department of Parks and Recreation with involvement from the DEP's Bureau of Water and Sewer Operations and Bureau of Environmental Planning and Analysis.

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[356] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Volume II – The Plan, Chapter 4 (Category 2, Restoration Ecology: Objectives, Current Programs, and Potential Management Strategies)" (October 2007): 94-97, 100. http://www.nyc.gov/html/dep/pdf/jamaica_bay/vol-2-chapter-4.pdf

[357] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Update" (October 2008): *in*, 18-19. http://www.nyc.gov/html/dep/pdf/jamaica_bay/JBWPP_Update_100108_FINAL.pdf

[358] Hudson River Estuary Program, "Hudson River Estuary Action Agenda 2005—2009: 2007 Update," New York State Department of Environmental Conservation (2007): 12. http://www.dec.ny.gov/docs/remediation_hudson_pdf/actagen07.pdf

[359] New York State Department of Environmental Conservation, "Sea Level Rise Task Force" (2009). http://www.dec.ny.gov/energy/45202.html

[360] "Sea Level Rise Task Force Natural Resources Working Group." http://www.dec.ny.gov/docs/administration_pdf/natresources.pdf

[361] "Sea Level Rise Task Force Info Page" http://lists.dec.state.ny.us/mailman/listinfo/sealevelrisetaskforce

Another part of the Action Plan is to develop agreed-upon estimates of future 100-year sea level rise. However, possible sea level rise impacts on wetlands or other environmental resources is not discussed.[362]

Actions

1 While not done to address sea level rise, by 1999, state and local regulations protected 65 to 75% of Long Island Sound's remaining vegetated wetlands.[363]

2 * As described in the 2007 "Jamaica Bay Watershed Protection Plan,"

"A pilot restoration project was initiated by the NPS [National Parks Service] in 2003 on the two acre Big Egg Marsh. Using an innovative technique knows as 'thin-layer' sediment spraying to raise the salt marsh elevation, the project has been deemed successful as the initial restoration area has been substantially enhanced through additional plant recruitment. Elevation monitoring and data collection by the NPS will continue for at least several more years at this site.

"A larger salt marsh restoration effort (70 acres) that was funded by multiple agencies, including NYCDEP, was completed at Elders Point East in 2006. This restoration will provide additional information on appropriate salt marsh restoration techniques and viability for application to other sites as monitoring data is compiled and analyzed. Additional restoration of Elder's Point West and potentially Yellow Bar, which is also expected to be funded by a multi-agency partnership, is scheduled to begin during the summer of 2008."[364]

3 As of 2007, the Army Corps on Engineers was restoring 60 acres of salt marsh within Elder's Point Marsh as a pilot project, out of a total of 90 acres that the Army Corps identified in a 2005 environmental assessment. The "Jamaica Bay Watershed Protection Plan" explicitly connects the issue of salt marsh loss with sea level rise, and lists this action as a response.[365]

In March and May 2007, the Army Corps studied the efficacy of coir logs used in this project. Coir, the coarse fiber obtained from the tissues surrounding the seed of the coconut palm, is the only natural fiber resistant to saltwater damage. But in studying exposed logs, the Army Corps found that once logs became exposed, they lacked the tensile strength to stay together for long in Jamaica Bay's wind and wave climate. They also suffered from the constant wetting/drying and sun exposure.

In an analysis of this episode in the Jamaica Bay Watershed Protection Plan, the Plan suggests a different interpretation. Citing a 2000 study showing that coir geotextile rolls with coir rope mesh can withstand a shear stress of 0.2 to 0.8 lb/ft^2, and noting that hydrological models of Jamaica Bay seldom calculate stresses in excess of 0.1 lb/ft^2, the Plan suggests that wetting and drying was more to blame for the failure of the logs than the wave and wind velocities.[366]

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[362] Climate Change Task Force, "Assessment and Action Plan: Report 1," New York City Department of Environmental Protection (May 2008): 88, 29. http://home2.nyc.gov/html/dep/pdf/climate/climate_complete.pdf

[363] "Long Island Sound Coastal Management Program" p 20.

[364] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Volume II – The Plan, Chapter 4 (Category 2, Restoration Ecology: Objectives, Current Programs, and Potential Management Strategies)" (October 2007): 87. http://www.nyc.gov/html/dep/pdf/jamaica_bay/vol-2-chapter-4.pdf

[365] New York City Department of Environmental Protection, "Jamaica Bay Watershed Protection Plan Volume I – Regional Profile" (October 2007): 122. http://www.nyc.gov/html/dep/pdf/jamaica_bay/vol-1-complete.pdf

[366] "Jamaica Bay Watershed Protection Plan Volume II, Chapter 4" p 98.

North Carolina

Research

1 The 2003 report "Drowning the North Carolina Coast: Sea-Level Rise and Estuarine Dynamics" presents a detailed and comprehensive geological profile of historical and current sea level rise on the estuaries of the North Carolina coast. The report concludes, "All estuarine shorelines in northeastern North Carolina are eroding in response to the ongoing long-term rise in sea level… the weighted average for the recession of all shoreline types within the highly variable regional setting is –2.7 ft/yr. Erosion, largely driven by storm processes, results in the systematic loss of both uplands and wetlands through time… We do not advocate trying to stop the ongoing and natural process of drowning the North Carolina coastal system — after all, change is the only constant within our coastal system. However, we do advocate learning to live with the evolutionary processes by changing the way shorelines are utilized. And more importantly, the natural upward and landward migration of wetlands in response to slowly rising sea level, must not be hindered. The continued modification of wetlands with drainage networks, highway road dams and bulkheads will lead to a one-way net loss of wetlands. However, if the natural migration processes are recognized and honored with continued rise in sea level, the net expansion of new wetlands along the inner zone should equal the loss of wetlands on the outer shoreline zone. Wetland habitats of the North Carolina coastal system must be allowed to expand into the future, or there will be ever decreasing amounts of this critical coastal habitat."[367]

2 Suzanne Moser provides a summary and historical analysis of North Carolina's coastal program in her 2005 paper (see Maine-Research-5): "NC [North Carolina] was one of the first states in the US to develop and codify its coastal zone management program in the early 1970s. The impetus for the state to establish its coastal program arose out of a general growing environmental consciousness and awareness of development-related local problems, recent experience with damaging storms, growing academic and management concerns and know-how regarding coastal problems, and the federal Coastal Zone Management Act of 1972 that offered financial assistance to put institutions and regulations in place. Bi-partisan support and leadership were instrumental in 1974 for pushing the law through the state legislature without weakening amendments. The rules and regulations put in place over the following 5–10 years with strong academic and public input eventually acquired the reputation of an exemplary program nationwide.

"Key features of NC's coastal management approach include the definition of nine areas of environmental concern to each of which certain regulations and management rules apply (of particular interest here are 'natural hazards areas'); a no-hardening rule along the open oceanfront; a 30- or 60-year setback requirement for open oceanfront development along eroding shorelines; and a requirement that coastal counties and communities write and regularly update comprehensive development plans. The setback requirement varies by size of the development and uses historical erosion rates as the basis for determination of the setback distance. Future acceleration of coastal erosion due to SLR is not considered. Since 1990, however, local governments are required to consider SLR impacts on areas below 5 ft of mean sea level in their development plans. Because planning is a local prerogative not enforced by the state,

[367] S. Riggs and D. Ames, "Drowning the North Carolina Coast: Sea-Level Rise and Estuarine Dynamics," North Carolina Department of Environment and Natural Resources and North Carolina Sea Grant (December 2003): 146-147. http://nsgd.gso.uri.edu/ncu/ncub03002.pdf

interviewees judged this requirement to have 'no teeth' in terms of realizing SLR-conscious development.

"During the late 1980s, leaders of the NC coastal management program and academics (one of whom acquired the nickname 'Mr. Sea-Level Rise') began promoting awareness of potential SLR impacts on the state. Cognizant interviewees could not fully explain how SLR actually entered the local planning guidelines. Interestingly, several policy windows in the late 1980s and 1990s (e.g., program reviews, hurricanes Hugo (1989), Bertha (1996) and Fran (1996), the Year of the Coast in 1994, major coastal conferences, and other coastal governance initiatives in the state in the 1990s) opened and closed without bringing SLR issues to the forefront of policy-makers' and managers' attention. Interviewees suggested that more pressing concerns (e.g., water quality crises, acute recovery from hurricanes, and legal battles over property rights) together with waxing and waning federal support for coastal management, lack of relevant knowledge among state policy-makers, general anti-regulatory sentiments and an adversarial political climate in the state diverted people's attention from the long-term problem."[368]

3 "NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) recently initiated a program entitled 'Ecological Impacts of Sea Level Rise'. This program is intended to evaluate the potential impact of long-term sea level rise on a specific coastal region, 25 to 50 years in the future. An initial goal of the project is to generate a digital elevation model (DEM) for the bathymetry and topography of the North Carolina coastal region, with all elevations tied to a common datum. Present-day sea level trends will be extended into the future, raising the tidal datums and thereby shifting the position of the shoreline."

Some results are that "The stations with the longest data intervals (68 years at Wilmington and 56 years at Southport) have the narrowest confidence intervals. The trends range from 2.04 mm/yr at Southport to 4.27 mm/yr at Duck. The average for all eight North Carolina stations is 2.88 mm/yr. There appears to be a regional gradient with the trends increasing from south to north. This implies that the land is sinking more rapidly along the northern portion of the coastline."[369]

In addition to this study, CSCOR competitively accepted proposals for research projects integrating ecological and hydrodynamical models. The three winning proposals began work in May 2005, with completion scheduled for 2008. The papers are not yet available, but the abstracts are posted on CSCOR's website. The three studies are:
– "Shore-Zone Modification in Response to Sea Level Rise in North Carolina Estuaries," which hypothesizes that "shore-zone dynamics are regulated by inundation and other quantifiable parameters (e.g., fetch)" and planned to "use relevant GIS datasets (e.g., soils) and remotely sensed observations coupled with sediment cores and grab samples collected and analyzed over the last two decades to determine the factors and scales necessary to evaluate shore zone modification. This will provide the foundation for the development of a predictive GIS tool of shore zone/ecosystem modification due to sea level rise."
– "Ecological Effects of Sea-Level Rise on Coastal North Carolina Marshes," "a plan to develop a spatially explicit model of coastal marsh responses to sea-level rise for Pamlico and Core Sounds in North Carolina… The goal is to develop a 2-D landscape model for Pamlico coastal wetlands capable of forecasting changes in plant community composition, sediment accretion, and geomorphology in response to tidal forcing and sea-level rise. Model parameter values will

[368] S. Moser, "Impact assessments and policy responses to sea-level rise in three US states: An exploration of human-dimension uncertainties," *Global Environmental Change* 15 (2005): 360-361. http://www.isse.ucar.edu/moser/pdf/GEC_Moser_final.pdf

[369] C. Zervas, "North Carolina Bathymetry/Topography Sea Level Rise Project: Determination of Sea Level Trends," National Oceanic and Atmospheric Administration Technical Report NOS CO-OPS 041 (May 2004): 1, 5. http://tidesandcurrents.noaa.gov/publications/techrpt41.pdf

be derived where possible from existing data from well-studied sites including Cedar Island, NC, Core Sound, NC, and North Inlet, SC and with a limited set of field experiments where critical data are needed. Existing LIDAR data will establish the baseline topography or digital elevation model (DEM), and existing hyperspectral data will be utilized to map plant community distributions onto the DEM. Long-term measurements of marsh surface elevation from Cedar Island and plant community distributions outside the calibration data set will be used to validate the model."[370]

– "Modeling Estuarine Habitat Response to Rising Water Level," which sets out to "use simulation modeling to better comprehend the ecological responses of NC estuarine habitats facing increasing water level. The goal is to develop an estuarine habitat simulation module (HSM) linked to the NOS coastal flooding model (NOS CFM) that will forecast the effects variable water levels and shoreline stabilization on the structure and ecological function of sub-tidal, SAV, inter-tidal flat, oyster, and marsh habitats in Back and Bogue Sounds. The HSM will integrate all project components including water level and velocity from the NOS CFM, habitat size and position from a localized geographic information system (GIS), wave energy and light attenuation from a wave energy model (WEMo), and habitat attributes and biogeochemical process rates from the a suite of empirical studies Back and Bogue Sounds. The GIS will house all the accumulated data layers and permit distribution of model results across our sampling domains. Modeled rates of annual net primary production, remineralization, and secondary production for each of the 5 habitats will serve as integrative response variables for scenarios including the present rate of RSLR over the next decade, increased storm surge intensity, addition of a bulkhead, or addition of a breakwater sill. The products will include short- and long-term predictions on the functioning of estuarine habitats through different scenarios of water level rise and shoreline modifications. Resource managers and other stakeholders will be able to remotely access the maps and habitat model results and run an ecosystem level model through a devoted internet site. The proposed study will achieve multiple purposes over a range of spatial and temporal scales, integrate with NOS modeling efforts, and serve managers of coastal resources in North Carolina and other southeastern states."[371]

4 Posted online are PowerPoint slides from a November 2007 conference held in Carolina Beach, North Carolina, entitled "Everything You Always Wanted to Know About Sea Level Rise, But Were Afraid to Ask."[372]

5 A 2008 report from East Carolina University presents the future threats to the North Carolina coastline and recommendations for how to address them. "Tide gauge and historical data demonstrate that relative sea level is currently rising in northeastern North Carolina at a rate of 16 to 18 inches per century. One hundred years ago, the rate was 7 inches per century and 200 years ago it was only 3 inches per century. The rate will likely continue to increase into the future as climate continues to warm… The future will likely see accelerated rates of coastal erosion and associated loss of urban infrastructure, agricultural land, wetlands, and segments of barrier islands… Barrier dune-ridges were constructed to protect the roads but, in doing so, have curtailed the natural processes of barrier island growth and migration. Jetties have been built to stabilize the location of inlets but, in doing so, have disrupted the natural process of along-shore sediment transport… Stabilization structures, such as jetties, groins, bulkheads, and sandbags demonstrably cause erosion problems. Inlets open naturally, and we close them almost

[370] Some ongoing information about this project is available at http://www.biol.sc.edu/~morris/sealev.html and http://sitemason.vanderbilt.edu/page/e4CKrK.

[371] Center for Sponsored Coastal Ocean Research, "Stressors: Climate Change: Sea Level Rise 2005 Abstracts," National Oceanic and Atmospheric Administration (2005). http://www.cop.noaa.gov/stressors/climatechange/current/SLRabstracts.html

[372] North Carolina Beach, Inlet & Waterway Association, "2007 NCBIWA Annual Conference: 'Everything You Always Wanted to Know About Sea Level Rise, But Were Afraid to Ask'." http://www.coastalplanning.net/projects/NCBIWA/NCBIWA07.html

immediately before they can do their work of building island width by adding sand to the barrier island system. Wetlands are filled, bulkheads are constructed, and ecosystems disrupted."

The report presents the following preliminary vision of the future: "We must understand how the natural coastal system works and accept that reality. We must consider building temporary bridges across new inlets instead of closing them. We must consider letting oceanic overwash build barrier island elevation and width, and install temporary roads to allow access. We must consider the challenges of coastal change to be opportunities. We can then determine the best ways to sustain and grow our coastal economy, and new ways to make our living at the coast. We must embrace relocation as a means of adaptation to an ever-changing environment. We should embrace the historic culture and the wild, remoteness of the Outer Banks and parlay that attribute into economic advantage. Ocracoke Village and Ocracoke Island are desirable tourist destinations in large part because of their remoteness. Perhaps the other villages along the Outer Banks can be part of a 'string of pearls' of vacation destinations. Perhaps personal cars can be replaced by other means of transport (rented golf carts, trolleys, bicycles) along some portions of the barrier islands. Perhaps fast high-tech ferry systems can transport vacationers to their destinations. Perhaps rural mainland towns can become ferry hubs with motels, restaurants, service stations, parking lots, and other industry in support of this new coastal economy. Perhaps these towns can themselves become the centers of coastal tourism with estuarine cruises, wildlife tours, historic and cultural programs, hunting and fishing tours, natural history aerial field trips, black-water paddle and camping trips, etc. Adaptation strategies can be similarly developed for the southern part of our coast where the barriers can be considered to be 'islands of opportunity'."

Noting that during the 20th century, the subsistence villages that had previously inhabited North Carolina barrier islands were replaced by high-rise hotels, condominiums, and large vacation houses, the report argues that the current economic usage of the barrier islands cannot continue into the future. "Thus, it is time to rethink our approach to utilizing the island segments that are threatened by rising sea level, storms, and anthropogenic modifications. If we withdrew from some of the coastal highways and terminated the construction of barrier dune ridges, the islands would begin their natural rebirth as inlet and overwash dynamics would once more rebuild them. The eventual result would likely be a barrier island system with eight Ocracoke-style destination villages strung like a string of pearls upon a vast network of inlet and shoal environments that would afford us many new opportunities for economic development. We cannot stop major storms from striking North Carolina. We cannot stop sea-level from rising. We cannot stop the barrier islands' natural tendency to migrate landwards in response to rising sea level. We are now at a threshold. Large segments of the barrier islands have almost washed away. NC Highway 12 can no longer be relocated on narrow island segments. But we can still maintain a vital coastal economy and preserve the natural resource base."[373]

6 A 2008 report from East Carolina University presents the issue of shoreline change in the Albemarle-Pamlico Estuarine System in North Carolina, the second largest estuary in the United States. The report states: "Coastlines are constantly changing due to both natural and anthropogenic forces. On-going climate change and associated sea-level rise are reshaping our coasts. However, the oceanfront is not the only concern. Shoreline dynamics along more sheltered estuaries, like those along the Albemarle-Pamlico Estuarine System (APES) of North Carolina, have gained attention. We need to better understand and manage these boundary resources that are a critical habitat for a

[373] S. Riggs et al, "North Carolina's Coasts in Crisis: A Vision for the Future," North Carolina Coastal Geology Cooperative Research Program at East Carolina University (October 2008): 1-2, 21. http://curs.unc.edu/curs-pdf-downloads/climatechgsymp/Riggs.pdf

variety of ecosystem goods and services. Research conducted on the Neuse River Estuary demonstrates the dominance of erosion along the shore of our estuaries, regardless of shore-type (e.g. marsh, beach, bluff). Erosion rates greater than 10 feet per year over a 40 years period were measured using aerial photography from 1958 to 1998. An average erosion rate of ~1 foot per year was calculated for the entire Neuse River Estuary. These erosion rates have led property owners to attempt to halt the loss of their water front by means of shoreline stabilization structures (i.e. riprap, sills, seawalls, etc.) About 30% of the shoreline along the Neuse River Estuary has been modified with stabilization structures with little understanding of the short-term ecological impacts or the long-term effects associated with on-going climate change and sea-level rise. It is imperative that we better understand the potential changes coastal North Carolina faces in the near future so that we can manage the natural resources appropriately."[374]

7 In February 2009, FEMA announced it would award the state of North Carolina $5 million "for a statewide risk assessment and mitigation strategy demonstration of the potential impacts of climate change-induced sea level rise."

As the press release explains, "The U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) will use the results of this study to assess the long-term fiscal implications of climate change as it affects the frequency and effects of natural disasters. Information from the study will be shared with other states to inform their climate change mitigation efforts.

"According to FEMA Regional Administrator Phil May, the information and results from this study may help formulate strategies to deal with potential effects of sea level rise on the nation's coast. 'North Carolina has been very proactive in implementing and improving upon coastal zone management activities and policies,' May said. 'Although the study is focused on just the state of North Carolina, the results of the study should be applicable to other coastal states as well. In addition, the study will complement an existing study currently being performed by FEMA which focuses on the effect of climate change on the National Flood Insurance Program'."

"North Carolina's Office of Geospatial and Technology Management (GTM), part of the North Carolina Division of Emergency Management, will be managing the study. GTM oversees the state's floodplain mapping and management programs. The study will last approximately three years."[375]

8 * A 2009 Masters project from the Nicholas School of the Environment and Earth Sciences at Duke University, "Adaptation to Sea-Level Rise in North Carolina," looks at how sea level rise will exacerbate management challenges in North Carolina's coastal zone management program.

"Statutory language formally acknowledges sea-level rise as a hazard in the North Carolina Administrative Code, the NC Coastal Area Management Act, and the Federal Coastal Zone Management Act. It has been listed as a concern by the NC Legislative Commission on Global Climate Change, the OPSC Final Draft Report, and the Coastal Habitat Protection Plan [see North Carolina-Policy below for relevant mentions of sea level rise in these]. The framework exists for coastal North Carolina to begin to adapt to SLR, yet no action beyond studies and recommendations have been made. The hesitancy on the part of regulators and decision-makers may stem from the perceptions of what managing for SLR entails."[376]

[374] D. Corbett et al, "Shoreline Change Within the Albemarle-Pamlico Estuarine System, North Carolina," East Carolina University (December 2008): 3, 2. http://www.coastal.geology.ecu.edu/NCCOHAZ/downloads/NC%20Estuarine%20Shoreline%20Change.pdf

[375] FEMA, "FEMA Grants $5 Million For Sea Level Rise Study In North Carolina" (February 24, 2009). http://www.fema.gov/news/newsrelease.fema?id=47583

[376] M. McPherson, "Adaptation to Sea-Level Rise in North Carolina," Masters of Environmental Management project, Duke University (2009): 37-38. http://hdl.handle.net/10161/958

"Adapting to SLR, however, is not as intimidating as state and local planners would like to believe. Adaptation will not require massive revamping of coastal management laws and policies in North Carolina since existing statutory language and newly published reports mandate planning for SLR. The management strategy for SLR will be similar to the planning strategies used to address natural processes/disturbances like erosion and flooding, with the majority of land use decisions falling onto county and municipal governments. If SLR planning is to focus on land use decisions, it makes sense to consider the local LUP [Land Use Plan] as the proper vehicle for SLR planning."[377]

The report also includes a discussion of the public reaction to and interaction with coastal management policies:

"Due to the dynamic nature of barrier islands, in particular the portions adjacent to inlets, North Carolina coastal communities find themselves with condemned structures standing in public trust waters. Even with the current popularity of beach nourishment projects and sandbagging efforts of individual homeowners, structures are still being lost to natural coastal processes. Barrier island communities are constantly debating who will remove condemned structures from the oceanfront. Property owners wait to see if they can collect insurance pay-outs once the structure is destroyed by a storm, but local governments continue to push back, claiming the structures are interfering with the public's enjoyment of the beach. North Topsail Beach is one of several barrier island communities with condemned houses in public trust waters. The town recently announced an agreement had been reached with homeowners of six condemned duplex houses for $1.6 million, plus an additional $43,600 to demolish the structures (Topsail Voice, 2009; Figure 2.1)."[378]

"As mentioned in Chapter 1, hardened structures are allowed along the estuarine shoreline but not along the oceanfront in North Carolina. Many advocates for overturning North Carolina's ban on oceanfront hardened structures believe a solution to the challenges over beach nourishment, sandbags, and structure removal, is allowing hardened structures along the oceanfront. The mascot for overturning the ban in North Carolina has become the terminal groin. Over the last few years, property owners from Figure Eight Island have attempted to overturn the state ban on hardened structures in order to protect the northern tip of the private barrier island. Their lobbying efforts in 2008 resulted in introduction of Senate Bill 599, which proposed allowing a pilot study on a terminal groin; a type of hardened structure placed perpendicular to the shore. The bill died in committee before it could be voted on in the House, but a new bill (S.B. 832) was re-introduced in March 2009. The new bill contains fewer restrictions than the original in order to allow other communities to construct groins in addition to Figure Eight Island. Communities that stand to benefit from a new hardened structure policy have provided financial support for lobbying activities (The Brunswick Beacon, 2008)."[379]

"The growing mass of law suits and court decisions related to many of the challenges discussed here should be an indication of a need for statutory clarification of current practices along the North Carolina coast. The reliance of state agencies and local communities on shortterm solutions without serious long-term planning is a dangerous combination. Hardened structures have been proposed as an option for shoreline stabilization due to the ineffective shortterm strategies of beach nourishment and sandbagging. With rising seas, hardened structures are not necessarily the best option either, but the lack of long term, comprehensive planning along the coast currently leaves no alternatives."[380]

An illustration of the difficulties in

[377] Ibid., 19.
[378] Ibid., 24.
[379] Ibid., 25.
[380] Ibid., 32.

implementing policy in North Carolina is the issue of illegal sandbags, discussed by the thesis: "Of approximately 350 sandbag structures along the coast, 150 are illegal (Wilmington Star News, 2008)."[381] "Currently, the DCM is involved with sandbag removal efforts along oceanfront beaches. The State of North Carolina has banned hardened structures along the ocean front for decades. The ban was codified in 1985 (15A NCAC - 07H .0308 and - 07M .0201) and incorporated into the State's General Statutes in 2003 (S.L. 2003-427, Article 7, Part 3, § 113A-115.1). Sandbags were allowed on the oceanfront to temporarily protect threatened structures from erosion for up to five years, and an extension in 2000 allowed sandbags to remain in place in conjunction with an active beach nourishment project. But due to the CRC granting variances through the years and no enforcement mechanism, some property owners have had sandbags in front of their properties for decades. The May 1, 2008 deadline for illegal sandbag removal has passed and not a single sandbag has been removed."[382]

Policy

1 The massive, 600+ page "North Carolina Coastal Habitat Protection Plan" of February 2005 makes several explicit mentions of wetland impacts from sea level rise and outlines policy responses (actual policy comes from the Coastal Habitat Protection Implementation Plans, which all relevant North Carolina agencies were required to complete by July 2005; see the Division of Coastal Management's website[383] for that agency's implementation, which it completed in May 2008). The Plan contains the following relevant mentions (all emphasis original):

"Sea level is rising at a rate of approximately 1.01-1.5 ft/100 yr in North Carolina. If sea level continues to rise at the current rate, there is a 50% chance that by the year 2200, with the influence of global climate warming, the rate of sea level rise could increase two to three times greater than its current rate. An accelerated rate of sea level rise could adversely barrier islands, and increasing the loss of wetlands, which filter and trap sediment and other pollutants."[384]

"Based on a recent study of 21 field sites and then extrapolated to the entire length of estuarine shoreline in northeastern North Carolina, annual wetland losses are approximately 802 acres/year, most of which are mainland brackish marsh habitat (Riggs and Ames 2003). When the cumulative effects of permitted wetlands impacts from 1997 to 2001, unpermitted wetland impacts (after repeal of Tulloch Rule), estimated coastal erosion loss from 1993 to 2001, and total estimated wetland losses prior to 1993 (DWQ 2000a) are added together, the total loss of wetlands in DWQ coastal river basins could be as much as 2,491,515 acres (1993-2002). This total estimated wetland loss still leaves 65% of the estimated original extent of wetlands in North Carolina (DWQ 2000a). However, this figure does not account for wetlands gained through restoration or created either by natural processes or restoration/creation effort. It also does not account for losses between 1993 and 1997 that were not attributable to erosion."[385]

"CRC rules require that bulkheads and riprap be constructed landward of coastal wetland areas. However, CRC and EMC rules allow bulkhead backfilling of small, freshwater wetlands landward of coastal wetlands following the size threshold criteria for permitting wetland impacts,[386] resulting in a

[381] Ibid., 23.
[382] Ibid., 9.
[383] Division of Coastal Management, "Coastal Hazards & Storm Information :: Estuarine Shoreline Stabilization Rule Update Initiative," North Carolina Department of Environment and Natural Resources (2008). http://www.nccoastalmanagement.net/Hazards/estuarine_rule%20update.htm

[384] M. Street et al, "North Carolina Coastal Habitat Protection Plan," North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries (February 2005): 105. http://www.ncfisheries.net/habitat/chpp2k5/_Complete%20CHPP.pdf
[385] Ibid., 330.
[386] "Projects impacting less than 1/3 acre of wetland within 50 feet of the high water line are exempt from 401 water quality

cumulative loss of wetlands that might provide for marsh migration with sea level rise. *To minimize these losses, all but the most miniscule of wetland impacts should be subject to permitting.*"[387]

"Rising sea level is a major threat to coastal wetlands in North Carolina. Analyses of data from tide gauge stations in Hampton, Virginia, and Charleston, South Carolina, from 1921 to 2000 (Riggs 2001), show sea level rising along the Atlantic coast by about 3.35 mm per year (1.1 ft per 100 years). Gauge data specific to North Carolina are available only for 20 years, but suggest a slightly greater rate of approximately 4.57 mm per year (1.5 ft per 100 years). The combination of sea level rise and storm events causes erosion of wetlands at a rate of approximately 802 acres/year (Riggs 2001). The importance of coastal erosion is further emphasized by the relatively low amount of permitted coastal wetland impacts from 1999 to 2002 (WRP 2001), compared to estimated erosion losses. Compared to sea level rise, the rate of wetland building or accretion is slightly less, but of the same order of magnitude: approximately 1.20 mm per year (Hackney and Cleary 1987). Loss of wetlands from sea level rise is exacerbated along steeply sloping shorelines or where wetland migration is otherwise restricted (i.e., where bulkheads are present). A recent study of salt marsh response to sea level rise in New England found that low marsh vegetation (*Spartina alterniflora*) was replacing high marsh vegetation (*Spartina patens*, *Distichlis spicata*, and *Juncus gerardi*) (Donnelly and Bertness 2001). If the rate of sea level rise increases significantly over the next century, many low marsh areas in New England and elsewhere will likely drown (Donnelly and Bertness 2001). Buyers and owners of coastal property should be aware of sea level rise and the potential for loss of wetlands and property. *Updated and accurate coast-wide estuarine erosion rates are needed for the CRC and EMC to determine adequate development guidelines and rules along the coast (DCM 2002). Priorities for coastal wetland protection should also acknowledge sea level rise, and protect gently sloping areas upland of coastal wetlands to allow for landward migration of coastal wetlands with sea level rise.*"[388]

"*Research is needed on site-specific erosion and accretion rates and their relationship with sea level rise and storm events (Brinson and Moorhead 1989). Specific research is also needed to determine processes that control the upper limits of peat accumulation, which is the foundation of coastal wetland development in the Albemarle-Pamlico system (Moorhead and Brinson 1995).*"[389]

"In North Carolina, estuarine and riverine shoreline stabilization has traditionally utilized hard structures such as bulkheads, rock revetments or riprap, sills, breakwaters, groins, or combinations thereof. Bulkheads are the most commonly used structure. Beach nourishment is generally not utilized. Although excessive sediment loading is considered a water quality issue, erosion of sediments is a natural process that provides sand for maintenance of beaches, wetlands, and shallow water habitat. When this sand supply is cut off by a hard structure under rising sea level conditions, the long-term results are a net loss of beach and intertidal shoreline and the deepening of shallow water habitat. High quality intertidal shoreline and shallow water habitat serve as important nursery, feeding, and spawning grounds to many economically and biologically valuable fish species in North Carolina. Multiple studies have shown that the diversity and abundance of invertebrates and juvenile fish are reduced adjacent to bulkheaded areas (Mock 1966; Ellifrit et al. 1972; Gilmore and Trent 1974; O'Rear 1983; Byrne 1995; Peterson et al. 2000c; Waters and Thomas 2001). In the 2003 legislative session, House Bill 1028 was approved, which allows the CRC to establish a general permit for construction of offshore parallel rock sills for estuarine shoreline protection. Prior to this, a

certifications, as well as projects impacting less than 1 acre within 150 feet of the high water line [EMC rule 15A NCAC 02H .0506 (c)(2)]. There is no minimum area criteria for mitigation when dealing with designated unique wetlands [EMC rule 15A NCAC 02H .0506(e)]. However, unique wetlands will likely not be designated on private lands without the approval of the land owner." (Footnote in original document.)

[387] Ibid., 336.

[388] Ibid., 352.

[389] Ibid., 352-353.

major permit was required for such activity, while construction of a bulkhead required a general permit. *A comprehensive examination and revision of current CRC shoreline stabilization rules using best scientific information are still needed to minimize impacts from this activity to soft bottom, particularly intertidal estuarine shorelines. Research is needed to determine if and how oyster shell could be utilized as an alternative to rock or wooden stabilization structures to create 'living shorelines' that are effective in stabilizing the shoreline while also providing habitat value.*"[390]

2 The North Carolina Division of Coastal Management (DCM) has concluded that "more research and discussion is needed between managers and researchers to effectively address and understand the impact of shoreline stabilization methods on the habitats and productivity of estuarine systems. This conclusion was the main motivation for the formation of the Estuarine Biological and Physical Processes Work Group." The Work Group issued its final report, "Recommendations for Appropriate Shoreline Stabilization Methods for the Different North Carolina Estuarine Shoreline Types," in 2006.

As the report explains, "The Work Group was charged with the task of developing recommendations to guide the development of new estuarine shoreline stabilization rules. The Work Group did not conduct any research, but merely utilized prior research and best scientific judgment in developing this report. Beyond classification and measurement of shoreline recession rates, there has been little research that applies directly to shoreline stabilization methods in North Carolina. In spite of this shortcoming, this report includes recommendations that take into account the dynamic nature of the estuarine system and considers the benefits and impacts of various shoreline stabilization methods on the biological communities and physical processes.

"The Work Group evaluated the ecological functions and values of the different North Carolina shoreline types and the habitat changes due to the physical impacts associated with each shoreline stabilization structure or method. The recommendations of shoreline stabilization methods are based upon the Work Group's stated goal of maintaining the current shoreline type and continuation of the current ecological functions and values. Based on these criteria, the lists of stabilization measures for each shoreline type represent a ranking of options, from the option with the least potential adverse impact to the existing system (ranking of 1), to the option with the greatest potential adverse impact to the system (maximum ranking of 8).

"In summary, the recommendations for each of the shoreline types are typically different with a few similarities. The number one recommendation for all estuarine shoreline types is land planning (i.e. leave the land in its natural state). Typically, the number two recommendation is to use vegetation control because vegetation is a natural and environmentally beneficial stabilization method. In many cases, beach fill is a recommended action to maintain the current shoreline type due to its non-structural, non-hardening attributes. When shoreline hardening stabilization methods are proposed, the Work Group rank sills as the most preferred option since it is a small structure that is constructed to support wetland plantings, or the conservation of existing wetland vegetation. Groins, breakwaters, sloped structures, and vertical structures vary in ranking and were determined to be shoreline type and site specific."

"Long term response to sea level rise" is listed as a topic for the Estuarine Work Group to discuss in the future.[391]

3 In 2007, "Over 50 coastal zone managers and stakeholders from North Carolina were invited to participate in a workshop to discuss and identify potential modeling and mapping

[390] Ibid., 391.

[391] The North Carolina Estuarine Biological and Physical Processes Work Group, "Recommendations for Appropriate Shoreline Stabilization Methods for the Different North Carolina Estuarine Shoreline Types," North Carolina Division of Coastal Management (August 2006): *ii*, A-2. http://dcm2.enr.state.nc.us/estuarineshoreline/EWG%20Final%20Report%20082106.pdf

tools to plan for, and mitigate the regional impact of future sea level rise and extreme events." One of the five identified priority applications is that "Tools should forecast expected habitat changes, especially potential loss of habitats important for ecological services." The meeting summary writes, "Tracking changes in North Carolina's habitats can be done through land cover data sources to predict changes on both land and water. The percent land cover of wetlands, as well as important submerged habitats, will decrease unless efforts are made to allow unheeded migration upland by removal of all barriers such as sea walls and groins. In order to do this, North Carolina must monitor what is happening on the ground; starting with baseline measurements and continually mapping the habitat changes– thus moving beyond anecdotal evidence. Historic records of sea level rise will help with this. For conservation lands, how will habitats change? This will influence management decisions, and potentially the selection of new lands for conservation purposes, by not directing money to lands that will disappear. However, groups may want to acquire lands before those lands are affected by rising sea levels and restore them to survive if possible. They may want to 'mother' a piece of land's transition from one ecosystem to another, with an ordered emphasis on ecosystem function, structure and composition[—]a reason to acquire lands pre-sea level rise."

"The desired information products and decision-support tools that might be developed based on the ongoing modeling efforts include, prioritization maps and geo-databases, including sensitivity analyses and using GIS. There should be no static products. Another idea is a library of scenarios where the user can access the model with existing data or by having the user provide required data. The models should be related to CHPPs (Coastal Habitat Protection Plans) habitats to ensure model interfaces with CHPP classifications. A needed product could picture how sea level rise affects municipal infrastructure, i.e. septic tanks, gas lines, sewer lines, etc. There may be model accuracy issues related to marsh migration, because erosion control structures prevent marsh from migrating inland. Therefore the habitats may not respond as predicted. Models need to incorporate real time land conversions, such as development, clear cutting or other land modifications as they occur, to stay as current as possible." [392]

4 The "State of North Carolina 2007 Coastal and Estuarine Land Conservation Program (CELCP) Plan" lists wetlands among 'Lands to be Protected:' "Wetlands provide many ecological benefits, including pollution buffering, wildlife habitat, and storm surge buffering. Coastal wetlands, including marshes, riverine wetlands, pocosins, and small depression wetlands, shall be one of the state's priority project areas. Wetlands have a high threat of conversion, despite legal and regulatory protections. Wetlands are often considered an inconvenience and impediment to development, and continue to be filled in order to accommodate construction. Wetlands are also being rapidly drowned and lost due to erosion and sea level rise and/or subsidence. It is estimated that more than 50 percent of North Carolina's historic wetlands have been lost." The purpose of the CELCP is first to "participate in the competitive federal grant funding program for coastal and estuarine land conservation" and second to "create a comprehensive land conservation plan for North Carolina's coastal zone, because at present, one does not exist." To date, North Carolina projects have not yet been funded, but the Plan anticipates funding for FY 2007 and beyond.[393]

5 In the 2007-2008 Annual Report of "North Carolina's Coastal Habitat Protection Plan," under planned actions and needs for the following year, the Department of

[392] Center for Sponsored Coastal Ocean Research, "Planning for the Impacts of Sea Level Rise and Climate Change Workshop Summary," NOAA Sea Level Rise Project (February 2007): 1, 5. http://www.cop.noaa.gov/stressors/climatechange/features/SLR_mgr_mtg_summary.pdf

[393] K. Price and T. Miller, "State of North Carolina 2007 Coastal and Estuarine Land Conservation Program (CELCP) Plan," North Carolina Department of Environment and Natural Resources Division of Coastal Management (October 2007): 14, 11-12. http://dcm2.enr.state.nc.us/NC%20CELCP%20Plan%20Final-Oct%2007.pdf

Environment and Natural Resources plans to "Begin to seriously address the challenges associated with Sea Level Rise and climate change more broadly in a context consistent with the reports of the Legislative Committee on Climate Change to NC," and the Coastal Resources Commission plans to "Continue development and refinement of shoreline stabilization rules that preserve ecosystem function and consider rising sea levels and a changing land/water interface." Also, "In August of 2008, the first meeting was held by the CHPP Team to begin the 5-year review mandated by the Fisheries Reform Act of 1997. According to that legislation, every management plan must be reviewed and updated at least every 5 years. The Team will be diligently working on this review, with the goal of having it completed and presented to the respective commissions in late 2009. Included in the update will be CHPP accomplishments, emerging issues such as Sea Level Rise, pharmaceuticals and population increase, status reports on each of the six identified CHPP habitats and any additional research needs that may be identified with the emerging issues." [394]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise from the state. General wetlands restoration activities include the Natural Resources Conservation Service's North Carolina Wetlands Reserve Program, which has facilitated restoration of more than 16,000 acres of wetlands, with 10,300 acres awaiting enrollment.[395] Other initiatives include the North Carolina Wetlands Restoration Program of the Division of Water Quality,[396] and the Ecosystem Enhancement Program within the North Carolina Department of Environment and Natural Resources.[397]

2 "Despite CRC rules stating that '[w]here possible, sloping rip-rap, gabions, or vegetation shall be used rather than vertical seawalls' (15A NCAC 07H .0208 (b)(7)(E)), 'living shoreline' approaches are rarely chosen by property owners to address erosion problems. Recommendations made by the Biological and Physical Processes Work Group have only begun to be considered by the CRC, who is taking steps towards more thoroughly addressing alternatives to stabilization structures along the estuarine shore."[398] However, "TNC [The Nature Conservatory] is gearing up to implement the first SLR adaptation strategy in the state using a 'living shorelines' approach. They are planning to plant marsh grasses and build oyster reef sills to protect the Alligator River National Refuge from rising seas (Charlotte Observer, 2009). TNC will also be installing devices to manage the flow of water into former agricultural ditches to try and restore the natural hydrology of the area."[399]

"The Nature Conservancy (TNC) is a national non-profit that has already started addressing SLR and its effects on coastal marshes. Along with the U.S. Fish and Wildlife Service, TNC has begun implementing SLR adaptation methods in the Alligator River National Wildlife Refuge, a refuge composed of formerly ditched agricultural land in Dare County, North Carolina (Charlotte Observer, 2009). In more developed parts of the North Carolina coast, marshes will be unable to migrate with rising seas due to upland development. State agencies and local communities will need to seriously consider recommendations laid out in the CHPP (2005) if they hope to preserve some of the

[394] North Carolina Marine Fisheries Commission, North Carolina Coastal Resources Commission, North Carolina Environmental Management Commission, and North Carolina Department of Environment and Natural Resources, "North Carolina's Coastal Habitat Protection Plan: 2007-2008 Annual Report" (September 2008): 5, 8. http://www.ncfisheries.net/habitat/miscdownloads/CHPPAnnualReportSeptember2008.pdf

[395] Natural Resources Conservation Service, "North Carolina Wetlands Reserve Program," United States Department of Agriculture. http://www.nrcs.usda.gov/programs/wrp/states/nc.html

[396] North Carolina Wetlands Partnership, "News" (2001). http://dcm2.enr.state.nc.us/ncwp/news.htm

[397] North Carolina Ecosystem Enhancement Program, "Wetlands" (2003). http://www.nceep.net/abouteep/wetlands.html

[398] M. McPherson, "Adaptation to Sea-Level Rise in North Carolina," Masters of Environmental Management project, Duke University (2009): 10. http://hdl.handle.net/10161/958

[399] Ibid., 39.

critical services wetlands provide along the entire North Carolina coast."[400]

Oregon

Research

1 A 2000 report by the U.S. Geological Survey characterizes Oregon's coastal wetland resources: "The steep slopes of Oregon's Coast Range mountains extend to the Pacific Ocean along much of the coast, leaving little area for wetland formation. Thus, coastal wetlands are confined mainly to areas of accumulated sediment near the mouths of rivers that have cut through the mountains and to the dune regions that have formed where the Coast Range front is distant from the ocean. Estuarine wetlands have developed in the shallow, low-gradient reaches near the mouths of Oregon's coastal rivers and in their deltas. Estuarine wetlands cover about 55,600 acres, and there are about 10,000 acres of tidal fresh marsh, mostly in the Columbia River estuary (Oregon Division of State Lands and Oregon State Parks and Recreation Division, 1989). Akins and Jefferson (1973) identified three major types of estuarine wetlands in Oregon: tideflats, eelgrass beds, and salt marshes."[401]

2 The Wetlands Conservatory (TWC) finds that "Oregon does not have a statewide strategy for identifying and protecting biologically important wetlands in the state. Oregon's wetland resources have suffered substantial losses in geographic distribution and diversity. In Western Oregon, 53 percent of wetlands have been converted to other uses since European settlement." The Wetland Conservatory's "Oregon's Greatest Wetlands Statewide Conservation Plan" is "an effort in Oregon to coordinate statewide conservation efforts for biologically important wetlands. TWC envisions a comprehensive Oregon wetland conservation concept that creates a vehicle for better collaborations, partnerships

[400] Ibid., 30-31.

[401] L. Kjelstrom and J. Williams, "Oregon Wetland Resources," U.S. Geological Survey (April 2000). http://or.water.usgs.gov/pubs/Html/WSP2425/index.html

and information exchanges; assures conservation of important wetland resources; and creates a stronger position for increasing funding." The project attempts to "identify, map, and gather information on the state's most valuable wetlands. In order to conserve and restore Oregon's wetlands, The Wetlands Conservancy (TWC) is working closely with local communities, land trusts, watershed councils, individual landowners and state resource managers to build local stewardship acquire and restore wetlands."[402]

3 A 2008 report from the Subcommittee on Fish, Wildlife, and Habitat Adaptation in the Oregon Global Warming Commission lists saltwater intrusion into freshwater wetlands and water tables, and loss of tidal, coastal wetland, and estuary habitats, as effects of sea-level rise and increased storm surges. The Subcommittee offers general recommendations to address funding needs, review and revise policies, develop new institutions, conduct vulnerability assessments, monitor and evaluate management actions, create downscaled regional climate models, and conduct long-term research on climate trends and ecosystem responses. The goals should be to maintain and restore key ecosystem processes, establish an interconnected network of lands and waters that support fish and wildlife adaptation, acknowledge the risks involved with proposed management actions in the context of anticipated climate conditions, and coordinate across political and jurisdictional boundaries.[403]

4 The Oregon Governor's Climate Change Integration Group published its final report in 2008. It recognizes that "Storm surges and sea level rise will cause increasing erosion on the coast, potentially affecting beach sand, roads and other infrastructure, and property. Estuaries are likely to be affected by the incursion of more salt water caused by rising sea levels." The report also recognizes that the effect of reducing greenhouse gas emissions will not be felt for 30 to 50 years, so adaptive planning is necessary in any case.[404]

Policy

1 The 1994 "Improving Natural Hazards Management on the Oregon Coast: Recommendations of the Coastal Hazards Policy Working Group" recognizes but downplays sea level rise, stating, "Long-term sea level rise associated with global warming poses no immediate risk along the north and south coasts of Oregon because coastal emergence rates exceed long-term sea level rise. However, sea level rise is a problem along approximately 150 miles of the central coast, where coastal uplift is minimal." The only recommendation made in connection with sea level rise is construction setbacks as a non-structural alternative to hard shore protection structures (which the report strongly discourages use of).[405]

2 The 2007 Oregon Laws Chapter 907 recognizes that "Global warming poses a serious threat to the economic well-being, public health, natural resources and environment of Oregon… Also, a potential rise in sea levels threatens Oregon's coastal communities. Reduced snowpack, changes in the timing of stream flows, extreme or unusual weather events, rising sea levels, increased occurrences of vector-borne diseases and impacts on forest health could significantly impact the economy, environment and quality of life in Oregon." §2(2) reads, "The Legislative Assembly declares that it is the policy of this state for

[402] Wetlands Conservatory, "Oregon's Greatest Wetlands." http://www.wetlandsconservancy.org/oregons_greatest.html

[403] Subcommittee on Fish, Wildlife and Habitat Adaptation, Oregon Global Warming Commission, "Preparing Oregon's Fish, Wildlife, and Habitats for Future Climate Change: A Guide for State Adaptation Efforts," Defenders of Wildlife, Oregon Department of Fish and Wildlife (2008): 4, 6-17. http://www.oregon.gov/ENERGY/GBLWRM/docs/fw_adaptation_guide.pdf

[404] The Governor's Climate Change Integration Group, "Final Report to the Governor: A Framework for Addressing Rapid Climate Change," State of Oregon (January 2008): 16. http://www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf

[405] Oregon Sea Grant, "Improving Natural Hazards Management on the Oregon Coast: Recommendations of the Coastal Hazards Policy Working Group," Oregon State University (1994): 11, 47. http://seagrant.oregonstate.edu/sgpubs/onlinepubs/t94002.pdf

state and local governments, businesses, nonprofit organizations and individual residents to prepare for the effects of global warming and by doing so, prevent and reduce the social, economic and environmental effects of global warming."[406]

3 In the Department of Land Conservation and Development's January 2009 meeting, an agenda item discussed the "Role of the State Land Use Planning Program in Helping Communities Prepare For and Adapt to Climate Change." Recommended changes include amending Land Use Planning Goal 7, "Natural Hazards," to "include/emphasize climate hazards such as flood, fire, erosion, and sea level rise to the extent they are not already covered; and require plans to be revised to address climate hazards," revising Goal 17 "Coastal Shorelands" to "refer specifically to areas subject to storm surge and sea level rise," and to "Identify shoreline landform types and define their likely response to increased storms and sea level rise."[407]

4 The Oregon Shores Conservation Coalition has been making an argument for the state Land Conservation and Development Commission (a subdivison of the Department of Land Conservation and Development, which also runs the Oregon Coastal Management Program) to adopt a statewide goal requiring planning for mitigation of sea level rise resulting from climate change. Oregon Shores cites the 2007 Oregon Laws Chapter 907 §2(2), which Oregon Shores quotes as requiring "State and local governments, businesses, nonprofit organization and individual residents… [to] prepare for the effects of global warming and by doing so, prevent and reduce the social, economic and environmental effects of climate change, including sea level rise, increased storm surge as well as increased intensity of storms and the waves generated by those storms." (The quote contains extra language not found in the online version of Chapter 907—Oregon Shores may be quoting an earlier draft) Oregon Shores suggests "Goal 20" as an amendment to the Oregon Administrative Rules 660-015-0010 that would require state agencies to provide local governments with maps, detailed topographic maps, inundation models, aerial photos, and other information by which to assess vulnerability and risk within 18 months, require local governments and state agencies to complete vulnerability assessments within 26 months, and require local governments and state agencies to adopt adaptation plans within 48 months.[408]

In January 2009, Oregon Shores presented this argument for adopting new land use goals dealing with the impact of rising sea levels to the Land Conservation and Development Commission at its January 2009 meeting, arguing, "Efforts regarding global warming on the part of state and municipal authorities have been aimed at decreasing emissions to moderate the effects of greenhouse gases. To date, nothing has addressed the impact that rising sea levels will have on people and property in lower-lying coastal area, to say nothing of the impact on habitats." Oregon Shores asked the LCDC to commence hearings on the adoption of Goal 20.[409]

From the session, the LCDC asked its staff to study the issue and come back in 5-6 months with recommendations. Oregon Shores wrote that, since "the [LCDC] commission's staff had recommended that they deny our petition for a 'Goal 20'," the fact that "The Land Conservation and Development Commission (LCDC) didn't reject Oregon Shores'

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[406] Oregon Laws 2007, "Chapter 907: Relating to climate change; appropriating money; and declaring an emergency" (2007). http://www.leg.state.or.us/07orlaws/sess0900.dir/0907.htm

[407] R. Whitman et al, "Informational Briefing: The Role of the State Land Use Planning Program in Helping Communities Prepare For and Adapt to Climate Change," Land Conservation and Development Commission (January 2009): 4, 5. http://www.oregon.gov/LCD/docs/rulemaking/011509/item5_staff_report.pdf

[408] W. Kabeiseman, "In the Matter of Adopting a New Goal to Address Sea Level Rise: Petition for Goal Under ORS 197.225 and 183.390," Oregon Shores Conservation Coalition (July 2008): 2, 5. http://www.oregonshores.org/pdfs/Goal20Petition.pdf

[409] Oregon Shores Conservation Coalition, "Oregon Shores Coalition Asks LCDC for Goal Protecting Coast Towns" (January 2009). http://www.oregonshores.org/pdfs/Goal20PR20090102.doc, http://www.oregonshores.org/narrative.php5?nid=441

proposal for a new goal related to climate change impacts at its January 15 meeting [is] actually a surprisingly positive development."[410] However, Oregon Shores went on to issue a Q&A document criticizing "The seeming unwillingness of DLCD staff to use the tools at their disposal to address these most important issues… DLCD's proposal of additional rules never comes to grips with what is needed here, namely a dialogue between LCDC and the citizens of Oregon about the consequences of sea level rise and storm surges to their pocketbooks and their Oregon coast." Oregon Shores argues that most DLCD rules are insufficient, and that one (presumably potentially effective) rule on hazards has never been properly implemented (Oregon Shores is pursuing a case relating to the failure of implementation).[411]

In a July 2009 letter, Governor Theodore Kulongoski responds to Oregon Shores, writing, "After weighing the option of a Goal 20 adoption versus the approach proposed by [DLCD director] Richard [Whitman] and [DLCD] staff, I clearly favor the broader approach proposed by staff. Addressing climate change issues throughout our land use planning system more closely aligns with my philosophy and approach. In that approach, it is noteworthy that staff is recommending that the Department of Land Conservation and Development work with at least two coastal communities and two inland communities to develop strategies for addressing the effects of climate change. In so doing, I believe that other communities will see the benefits of such planning and initiate their own efforts. I encourage Oregon Shores to support the broader approach to climate change issues being recommended to the LCDC. Further, Oregon Shores could play a very important role in helping to identify and support the two coastal communities that would pilot the kind of climate change adaptation planning that is needed."[412]

Oregon Shores responded to this letter by saying, "We believe the Governor's backing of the Department of Land Conservation and Development (DLCD) staff position recommending no Goal 20 on climate change adaptation, shortchanges Oregon, the Coast and Oregonians in general. Failing to take strong action now on the land use aspects of climate change and the adaptation that is needed will minimize future chances of getting statewide buy-in to mitigation efforts. With our good land use program, we as a state should never be in the position of New Orleans and Louisiana and Mississippi after the Katrina Hurricane in allowing redevelopment in places like the lower 9th ward, where devastation is likely to happen again. Yet failure to anticipate what will happen when the results of climate change occur, such as sea level rise-storm surge, less water because of less snow pack, more flash floods from more rapid runoff, and more forest fires and pest infestations, put us in the same reactionary role as the southern states."[413]

The latest development was a scheduled vote by the DLCD on July 31 on whether or not to deny the petition of Oregon Shores to more forward with its proposed Goal 20. In prepared testimony for the Chair and Commissioners of the LCDC, Oregon Shores writes, "We have reviewed the July 17 staff reports dealing with the Planning for Climate Change work program and our petition to you to undertake a Goal 20. While we would prefer that the Commission not deny our petition and commence a Goal-rule making now, we believe, with staff, that the proper focus is on the 2009-2011 work program for the agency. In the work program we urge you to retain the option for a climate change goal, as you have instructed the staff to do several times, and which they appear to resistant." In

[410] Oregon Shores Conservation Coalition, "Sea Level Goal Jumps First Hurdle with State Panel" (January-February 2009). http://www.oregonshores.org/narrative.php5?nid=453

[411] Oregon Shores Conservation Coalition, "Question and Answers For 'Proposed Sea Level Rise/Storm Surge Adaptation Goal 1/15/09" (January 2009): 1, 2, 4. http://www.oregonshores.org/pdfs/Goal20QA.pdf

[412] T. Kulongoski, Letter to William Kabeiseman (July 2009). http://www.oregonshores.org/pdfs/Kulongoski-OS_090730.pdf

[413] Oregon Shores Conservation Coalition, "LCDC to Vote on Goal 20" (2009). http://www.oregonshores.org/narrative.php5?nid=561

addition to other criticism, Oregon Shores writes, "it is clear from the reports and from other presentations made at various places, including the June 6, 2009 conference on climate change and sea level rise that Oregon Shores sponsored in Newport, that staff is still locked in a mind set of prevention and does not grasp the significance and importance of adaptation. In Oregon, we should not have to repeat the foolishness engaged in by the people of the Lower 9th Ward in New Orleans after Katrina of rebuilding where there will be problems in the future. Avoidance and prevention are worthy goals, and Oregon Shores supports the mitigation efforts outlined by staff, but the processes already set in motion are immutable and will need to be responded to through our planning process. For example, public infrastructure should not be replaced where inundation or other damage caused by climate change will happen again and again."[414] At the time of this writing, neither the LCDC nor Oregon Shores websites have any information as to the outcome of the vote.

5 In 2009, the Oregon Coastal Management Program published "Climate Ready Communities: A Strategy for Adapting to Impacts of Climate Change on the Oregon Coast" to help coastal decision-makers, legislators, and the public prepare for possible effects of global climate change on the Oregon coast and create "resilient, Climate-Ready Coastal Communities." It notes, "Over time, some of the likely effects of climate change, such as substantially higher tidal elevations in estuaries, may create unprecedented conditions in coastal communities. New legal or policy tools will be needed to address complex and unprecedented conditions created by rising sea level and tidal elevations or changes in vegetation and distribution of habitats. Other tools may be technical and involve ocean observing technologies and modeling to project future conditions and effects. Innovative approaches may be needed to adapt the requirements of the statewide planning program and other laws to the realities of climate change."

The Strategy also recognizes that "Estuarine wetlands are vulnerable to rising sea level and tidal elevations, depending on rate of sediment deposition, the nature of the shoreline, and pace of sea level rise. Freshwater tidal wetlands may be inundated more frequently by saline waters, triggering changes in wetland communities. Because most Oregon estuaries are sharply bounded by steep hillsides or dikes and levees, fringe wetlands will be unable to migrate landward and will be inundated due to increased tidal elevation. An adequate supply of sediments to the estuary could enable tidal wetland elevations to keep pace with rising tidal elevation… Habitat restoration projects in coastal shorelands should consider effects of future climate change."[415]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise.

2 The Oregon Habitat Joint Venture, a loose coalition of private conservation organizations working with government agencies to protect and restore important habitats, has a number of projects related to coastal habitats. Projects include numerous tidal wetland restoration and land acquisition, usually involving the restoration or acquisition/protection of 100-400 acre areas. The largest project listed is the full acquisition via donation of 3,400 acres of island previously managed by the Fish and Wildlife service for 25 years.[416]

[414] Allison Asbjornsen and Oregon Shores Conservation Coalition, "Reference: Climate Change and Sea Level Rise -- LCDC 29-31 July 2009 -- Brookings meeting — Agenda Items 16 and 17," Letter to Chair Van Landingham and LCDC Commissioners (July 2009). http://www.oregonshores.org/pdfs/OS-DLCD_090729.pdf

[415] Oregon Coastal Management Program, "Climate Ready Communities: A Strategy for Adapting to Impacts of Climate Change on the Oregon Coast," Department of Land Conservation and Development (January 2009): 1, 9, 15, 17. http://www.oregon.gov/ENERGY/GBLWRM/docs/climate_ready_communities.pdf

[416] Oregon Habitat Joint Venture, "Coast Range Projects" (November 2002). http://www.ohjv.org/projects/coast_range.html

3 "The Oregon Coastal Program, in partnership with Ducks Unlimited, the Siletz Indian Tribe, and the Oregon Department of Fish and Wildlife, is working to restore 100 acres of estuarine wetland at Siletz Bay National Wildlife Refuge. This project is one of the largest estuarine wetland restoration projects on the Oregon Coast." Other projects of the Oregon Coastal Program are to restore coastal grasslands, creating open sand habitat for the plover, and using GIS analysis and field investigations to identify and prioritize sites for tidal wetland restoration.[417]

4 Since 2003, the Coastal Program in Oregon of the U.S. Fish and Wildlife Service "has leveraged over $1.25 million dollars of partner contributions, representing a greater than 1-to-5 match and restoring over 300 acres of high priority coastal habitats. All Coast Program goals continue to be met annually and in 2008 approximately 18 projects will be under way on the Oregon coast."[418]

5 The Wetlands Conservatory produces and sells the publication "Heroic Tales of Wetland Restoration," which "tells of 12 rural landowners, who changed their farming practices to reclaim wetlands, streams and rivers. Their stories span Oregon. They have worked hard to restore oxbows, lush with sedges and cattails, forging partnerships with landowners, state and federal agencies, non-profits and community groups. The first section of this book includes these tales of vision, passion, perseverance, and economic survival. The second section describes land conservation options and a range of state and federal technical assistance and funding programs. The last section includes descriptions of the restoration techniques employed by the landowners, as well as recommendations for the future. It outlines difficulties experienced by landowners working with federal and state incentive programs."

Also on sale are the video "Wetland Restoration: Steps to Success" and the publication "Trees, Tools, and Transformation: A collection of restoration stories from schools and community groups in and around Portland," a "140 page book highlight[ing] the stories, successes, frustrations and failures of 25 citizen or school group initiated restoration projects in the Portland metro region. The book also contains a technical advice section providing tips and tools on how to choose, plan, design, implement and maintain a restoration project, as well as potential funding and in-kind sources of technical assistance and materials, and how to choose, solicit and work with partners."[419]

[417] The Oregon Coastal Program, "The Coastal Program: Success in Oregon," U.S. Fish & Wildlife Service (January 2004): 2. http://www.fws.gov/Pacific/ecoservices/habcon/coastal/documents/Oregon%20Coast%20fact%20sheet.pdf

[418] Oregon Fish & Wildlife Office, "Newport Field Office - Oregon Coastal Program," U.S. Fish & Wildlife Service (July 2008). http://www.fws.gov/oregonFWO/FieldOffices/Newport/CoastalProgram/CoastalProgram.asp

[419] The Wetlands Conservatory, "Publications." http://www.wetlandsconservancy.org/resources.html

Pennsylvania

Research

1 Pennsylvania's only tidal coastline is 57 miles along the Delaware Estuary. The Pennsylvania Coastal Zone Management Program within the Department of Environmental Protection manages this, as well as the 63-mile Lake Erie coastline. Coastal erosion is listed as a concern only for the Lake Erie shoreline, although coastal flooding is a threat for both coastal zones.[420]

2 A 2004 report prepared by the Delaware Valley Regional Planning Commission for the Pennsylvania Coastal Zone Management Program, entitled "Sea Level Rise Impacts in the Delaware Estuary of Pennsylvania," supplements a 2004 EPA-funded study by the Commission that attempted to "distinguish areas likely to be protected from erosion and inundation as seas rise from areas where shores will be left to retreat naturally" and examine policies in place to protect the ecological resources of the Pennsylvania Delaware Estuary.

In assessing the threat, the report notes that in the past century, sea level along the shores of the Delaware Estuary rose about 30 cm, twice the global rate. The report anticipates local rise will continue at a rate approximately 1.5 mm/yr greater than the global average, barring possible disintegration of ice sheets. Pennsylvania has a relatively small area of low-lying land: only six square kilometers (which is about 1480 acres), consisting mostly tidal wetlands (which, unlike in most places, are not saltwater wetlands but freshwater wetlands), are less than 1.5 meters above sea level (compared to Florida's 12,000 square kilometers lying less than 1.5 meters above sea level). However, the state anticipates impacts beyond inundation, including increased erosion, increased flooding, and the migration of the salt line up tidal rivers and streams.

Historically, "Coastal wetlands have also been preferred locations for landfills, hazardous waste disposal, and the deposition of dredge spoils. As of 2002, southeastern Pennsylvania had 1,466 acres of tidal wetlands. Nontidal wetlands within the project study area, i.e., the 'coastal zone', totaled 1,664 acres." Unlike other states, detailed estimates of wetland loss have not been done in Pennsylvania. Loosely adapting other estimates, it is likely that "a one to two meter rise in sea level would destroy most existing—and create little new—tidal wetlands in the Delaware Estuary."

While not containing any unique information or original research, the remainder of report presents an good summary of the basic issues associated with sea level rise impacts on wetlands. The majority of the report's discussion is quoted below:

"Although the nationwide and local loss of coastal wetlands due to draining, dredging, filling, and leveling has slowed drastically over the past three decades, during the next century, conversion of tidal coastal wetlands to open water due to sea level rise will become a serious threat to the nation's coastal wetland ecosystems. Most tidal wetlands lie less than one meter above sea level. Accordingly, a one-meter rise in sea level could eliminate a sizable portion of our tidal coastal wetlands. However, such a rise does not mean that tidal wetlands would disappear entirely. Two compensating factors will work to offset the loss of tidal wetlands: (1) a rise in sea level would flood areas that are now dry land, creating new wetlands; and (2) wetlands can grow upward by accumulating sediment and organic material, a process known as wetland accretion.

"While these processes will create new wetlands, their potential to stave off tidal

[420] Department of Environmental Protection, "Fact Sheet: The Pennsylvania Coastal Zone Management Program," Commonwealth of Pennsylvania (June 2002): 1. http://www.dep.state.pa.us/river/about/Docs/PACRMFactSheet.pdf. Note that Pennsylvania has the smallest tidal shoreline of any state considered in this survey. Infoplease.com, "Coastline of the United States" (2007). http://www.infoplease.com/ipa/A0001801.html

coastal wetland loss in Pennsylvania may be limited. Wetland migration along Pennsylvania's coast will in many cases be blocked by development just inland of existing wetlands. It is unlikely that much of the built-up coast will be readily abandoned to allow wetland migration. As for wetland accretion, while it has kept pace with the amount of sea level rise over the past hundred years (approximately 2.7 mm/yr in the Delaware Estuary), it is not likely to keep pace with the accelerated rate expected during the next century.

"The presence of development in upland areas will in many cases prevent wetland migration. Seawalls, bulkheads and other forms of shoreline armoring, built to protect existing and future development, will block wetland migration, substantially increasing the loss of wetlands beyond what would occur naturally. In the Delaware Estuary, the impacts could be so severe that all tidal coastal wetlands may be lost.

"Although environmental regulations in Pennsylvania generally prevent or discourage people from filling in or building on wetlands, they have not prevented people from building structures, and protecting those structures, just inland of wetlands… wetlands can be completely squeezed out between an advancing sea and bulkheads erected inland of existing wetlands. Because the Pennsylvania coastal zone is heavily developed, wetlands in this region will have few opportunities for inland migration, barring changes in future development patterns. The point at which development will prevent new wetlands from forming depends on the extent to which development is set back from tidal coastal wetlands. Along much of Pennsylvania's coast, there is little separation between existing development and tidal wetlands. In Maryland, by contrast, the Chesapeake Bay Critical Areas Act forbids most new development within 1,000 feet of existing tidal wetlands in order to enable some degree of wetland migration. Pennsylvania has no such law, and existing development is in many cases much closer than 1,000 feet away from tidal wetlands areas."

"Future losses of wetlands from sea level rise in the Delaware Estuary could be reduced by (1) slowing the rate of sea level rise by reducing greenhouse gas emissions, (2) enhancing wetlands' ability to keep pace with sea level rise, (3) decreasing human interference with natural process by which wetlands adapt to sea level rise, or (4) holding back the sea while maintaining coastal wetlands artificially. Although reducing greenhouse gas emissions to sustainable levels is the most effective way to avoid sea level rise, it is the most difficult to contemplate in the near term. Moreover, even if greenhouse gas emissions were reduced to sustainable levels immediately, a 'lag effect' associated with previous emissions would still cause sea level to rise. A detailed discussion of global climate change science and politics is beyond the scope of this paper, but it is important to remain aware of the root cause of the current acceleration of sea level rise and to remember that it is largely the result of the burning of fossil fuels and the release of greenhouse gases by industrial societies.

"Increasing the 'growth rate' of wetlands could enable them to survive rising seas. It is possible to enhance the rate of wetland accretion by spraying sediment onto a wetland in a manner that imitates natural flooding. Although this technology has been demonstrated to work in site-specific applications, it is not now, nor will it be in the foreseeable future, cost-effective on large scales.

"The primary adaptation of wetlands to rising sea level is landward migration. To allow migration, however, communities must either prevent development of areas upland of existing wetlands, or remove structures at a later date if and when the sea rises. Preventing the development of upland areas would require either purchasing undeveloped land adjacent to coastal marshes or instituting regulations that curtail the right to build on this property. The former option would be costly to taxpayers, while the latter option would be costly to property owners and would face legal challenges that might result in

requirements for compensation. Making room for coastal wetland migration may be costly, but it will probably be the most important method for insuring the survival of coastal wetlands as seas rise. With that said, it should be noted that the economics of protecting or purchasing land for wetland migration in Pennsylvania are probably not favorable when compared to other larger, less developed low-lying areas such as those found in southwestern New Jersey or the coastal estuaries of North Carolina.

"Finally, it might be possible to hold back the sea and maintain wetlands artificially. For small amounts of sea level rise, tidal gates might be installed that open during low tide but close during high tide, thereby preventing saltwater intrusion and lowering average water levels. For larger rises, levees and pumping systems could be installed to maintain wetland water levels below sea level. Although these measures would be expensive, they would also help to protect developed areas from the sea.

"As stated, the most effective way to insure the survival of tidal coastal wetlands is to allow them to migrate inland. While the presence of development in Pennsylvania leads to the conclusion that wetland migration is unlikely along most of Pennsylvania's coast, the transformation of the region's waterfronts that is just now beginning offers the opportunity to address wetland loss at an early stage. The transition of the region's waterfront districts from centers of heavy industry to mixed-use communities that emphasize public access and open areas along the water will complement efforts to create a buffer between development and rising seas. The replacement of abandoned factories and derelict properties with open space areas along the water's edge would obviate the need for expensive shoreline armoring schemes. Moreover, an un-armored shoreline will mean that wetlands can migrate inland where conditions are favorable. Of course, wetland migration will need to be balanced with demands for active recreation spaces and continuous public access along the shoreline."[421]

Policy

1 The Pennsylvania Coastal Resources Management Program's 2006 "Assessment and Strategy" quotes the legislative objective, "Preventing or significantly reducing threats to life and destruction of property by eliminating development and redevelopment in high hazard areas, managing development in other hazard areas, and anticipating and managing the effects of potential sea level rise and Great Lakes level rise." Sea level rise is characterized as a "Medium Risk" (out of "High," "Medium" and "Low"). Towards this, the Program's programmatic objectives are to: "I. Direct future public and private development and redevelopment away from hazardous areas, including the high hazard areas delineated as FEMA V-zones and areas vulnerable to inundation from sea and Great Lake Level rise.
II. Preserve and restore the protective functions of natural shoreline features such as beaches, dunes and wetlands.
III. Prevent or minimize threats to existing populations and property from both episodic and chronic coastal zones."[422]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise.

[421] Delaware Valley Regional Planning Commission, "Sea Level Rise Impacts in the Delaware Estuary of Pennsylvania," prepared for Pennsylvania Coastal Zone Management Program (June 2004): 1-2, 5-16.
http://www.dvrpc.org/reports/04037.pdf
[422] Coastal Resources Management Program, "Section 309 Assessment and Strategy Pennsylvania's Coastal Resources Management Program," Pennsylvania Department of Environmental Protection (June 2006): 35.
http://www.dep.state.pa.us/river/reference/Docs/309Jun

South Carolina

Research

1 A 1988 publication, *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*, contains a chapter detailing a case study at Charleston, South Carolina: "We surveyed twelve wetland transacts to determine elevations of particular parts of the marsh, frequency of flooding, and vegetation at various elevations. From these transacts, we developed a composite transect representing an average profile of the area. Using this information and estimates of the sediment provided by nearby rivers, we then estimated the shifts in wetland communities and net loss of marsh acreage associated with three possible scenarios of sea level rise for the year 2075: (1) the current trend, which implies a rise of 24 cm (0.8 ft), relative to the subsiding coast of Charleston; (2) a low scenario of 87 cm (3.0 ft); and (3) a high scenario of a 159-cm rise (5.2 ft). We examine background information concerning global warming and future sea level rise, the ecological balance of coastal wetlands, and the potential transformation of these ecosystems as sea level rises. Next, we examine the wetlands in the Charleston study area and describe a field study in which we developed wetland transacts. Finally, we discuss the potential impact of future sea level rise on Charleston's wetlands, and suggest ways to improve our ability to predict the impact of sea level rise on other coastal wetlands."[423]

"Our basic assumption was that the wetland habitats' advance toward land ends at 200 cm NGVD (185 cm above mean sea level). Dikes or bulkheads would be constructed under certain protection scenarios at that elevation on the date in question to prevent further inundation." The study found that "Total marsh acreage would decrease from 7,700 acres to 3,925 acres (2075 low scenario), or 750 acres (2075 high scenario), under the assumed mitigation[.] The net change in areas under the various scenarios listed [here] indicates that all habitats mould undergo significant alteration. Even under the baseline scenario, which assumes historical rates of sea level rise, 20-35 percent losses of representative marsh areas are expected by 2075. Protection under the low scenario (as outlined by Gibbs 1984) would have virtually no effect on high or low marsh coverage; but it would cause a substantially increased loss of transition wetlands. Under the high scenario with protection, highland would be saved at the expense of all transition and high marsh areas and almost 90 percent of the low marsh. Even under the low scenario, sea level rise would become the dominant cause of wetland loss in the Charleston area."[424]

The chapter's lead author, in a 2007 conference presentation, argues that this 1988 study is still relevant. [425]

2 A study published in 1999 examined 465 sample plots to determine the status of South Carolina's wetlands from 1984-1989. The study estimated that South Carolina had approximately 451,500 acres of estuarine wetlands. During the five years, estuarine wetlands declined by 109 acres, a statistically insignificant loss.[426]

[423] T. Kana et al, "Chapter 2: Charleston Case Study," *Greenhouse Effect, Sea Level Rise, and Coastal Wetlands*, ed. J. Titus. Washington, D.C.: U.S. Environmental Protection Agency (1988): 37. http://www.epa.gov/climatechange/effects/downloads/toc-wet_chap2.pdf

[424] Ibid., 48-50.

[425] T. Kana, "Sea Level Rise Impacts on Beaches and Wetlands – Problems you may not know," 2007 North Carolina Beach, Inlet & Waterway Association Annual Conference 'Everything You Always Wanted to Know About Sea Level Rise, But Were Afraid to Ask' (November 2007): 2. http://www.coastalplanning.net/projects/NCBIWA/pps2007/2%20Tim%20Kana.pps

[426] T. Dahl, "South Carolina's Wetlands: Status and Trends, 1982-1989," U.S. Fish & Wildlife Service Division of Habitat Conservation Habitat Assessment Branch (1999): 6. http://library.fws.gov/Wetlands/SCWetlands99.pdf

3 * The analysis given in Suzanne Moser's 2005 paper[427] (see Maine-Research-5) reveals a persistent political back-story to coastal management in South Carolina: "SC [South Carolina] first began addressing ocean-front management with its first coastal act passed in 1977. Its management program was administered at first through an independent Coastal Council until 1993 when the program became incorporated into the state's Department of Health and Environmental Control. From the beginning the program's emphases reflected concerns with maintaining coastal wildlife habitat and beaches for the ever-more important coastal tourism sector and with protection from coastal hazards. SC's coastal law was significantly strengthened—with academic, business and other stakeholder input—in 1988, one year *prior* to Hurricane Huge, which devastated the state's shoreline. This revision recognized the growing problem of coastal erosion and gave the state greater regulatory authority over oceanfront development.

"Interestingly, the 1993 revised coastal law does not recognize SLR in its text, but educational documents from the program do. Interviewees suggested that awareness had been raised throughout the late 1980s and early 1990s, but that the issue was strategically left out of the law to limit controversy and ensure the revised law's passage. The act… defines critical areas along the oceanfront to which regulations and permitting requirements apply, allows shoreline hardening as a last resort measure only if they would not cause negative impacts on adjacent areas, establishes a 40-year retreat policy implemented via setback and relocation requirements after damaging storm events, but includes no mandatory planning or zoning provisions for local communities."

"Implementation of these stricter shoreline development rules has been put to the test of political will and in legal batters (in particular, the Lucas case which challenged SC's regulations on the basis of the constitutional right to private property all the way to the Supreme Court) (e.g., Lyman, 1993). The state also had several opportunities to take SLR into account in its management decisions and did not do so (e.g. in the Charleston Harbor development project or the revamping of the Charleston storm water drainage system in a city that already during heavy storms had several streets under water). Importantly, institutional changes that moved coastal management from an independent state agency with policy-making and permitting authority to a sub-bureau within another agency no longer with the authority to proactively propose forward-thinking policies may have curtailed the program's ability to proactively address long-term issues like SLR."[428]

Moser also notes, "South Carolina interviewees explicitly denied that their coastal policies were put in place in response to climate change-driven SLR. However, the issue is officially recognized and valuable mechanisms that can be applied to the management of SLR are in place…"[429]

4 The North Inlet-Winyah Bay National Estuarine Research Reserve, spanning 12,000 acres of salt marshes, tidal creeks and estuarine waters,[430] has a project studying the response of emergent vegetation in salt marshes to sea level rise. "The long-term goal of this project is to assess the effects of rising sea level on the spatial dynamics of salt marsh vegetation communities of North Inlet. This information is critical to predicting the ability of marsh communities to migrate inland in the face of accelerated rates of sea level rise due to global warming. Previous studies have shown annual net aboveground production of *Spartina alterniflora*, the dominant emergent vegetation in North Inlet, to be positively correlated with annual anomalies in mean sea

[427] S. Moser, "Impact assessments and policy responses to sea-level rise in three US states: An exploration of human-dimension uncertainties," *Global Environmental Change* 15 (2005): 353–369. http://www.isse.ucar.edu/moser/pdf/GEC_Moser_final.pdf

[428] Ibid., 361.
[429] Ibid., 363.
[430] Cooperative Institute for Coastal and Estuarine Environmental Technology, "Program Brief: CICEET & South Carolina," University of New Hampshire. http://coastalmanagement.noaa.gov/mystate/docs/south_carolina_brief.pdf

level. However, the effects of interannual variation and long-term change in sea level on the spatial dynamics of salt marsh macrophyte communities, particularly the high-marsh communities, remain unclear. Thus, this project specifically seeks to address how the spatial structure of the salt marsh vegetation community (species composition, stem density, canopy height, and above-ground biomass) varies along an elevation gradient, from creek bank to upland edge, in response to changes in tidal height and flooding frequency due to sea level rise. Data on sediment deposition and net accretion rates, sediment characteristics (organic content and bulk density), and porewater chemistry (salinity, nutrients, and sulfide concentrations) are also collected along each transect to quantify the interactions between sediment accretion rates, pore-water chemistry and vegetation community dynamics along the elevation gradient as a function of the frequency and duration of tidal inundation."[431]

Work by South Carolina Sea Grant Consortium researcher James T. Morris, a marine scientist and director of the University of South Carolina Belle W. Baruch Institute, suggests that half the salt marshes in the North Inlet-Winyah Bay National Estuarine Research Reserve in Georgetown County would drown by the 2050s or 2060s at current rates of acceleration of global sea-level rise.[432]

5 * An article in the Summer 2009 issue of *Coastal Heritage* (a quarterly publication of the South Carolina Sea Grant Consortium) gives a qualitative and often anecdotal but accessible and comprehensive overview of sea level rise globally and in South Carolina. The article writes, "In 1988, South Carolina's legislature enacted the Beachfront Management Act to guide the state through a retreat from the sea. New homes had to be set back from the ocean, and construction of new seawalls was prohibited. Today, a seawall built before 1988 cannot be rebuilt if 50 percent of it has been destroyed by a storm. The Beachfront Management Act, however, doesn't apply to the state's marshfronts and bayfronts—only to ocean beaches. When the law was passed in 1988, state lawmakers and resource managers weren't thinking about potential future losses of marshes to sea-level rise. But marshes are also migrating inland and will continue to do so. A crucial underpinning of the 1988 state law is that when coastal storms would destroy the state's older beachfront seawalls, shorelines would be allowed to naturally migrate inland over time. This beach migration would eventually undermine oceanfront property and homes. Homes would collapse or they would have to be abandoned or relocated farther inland. The seawall provision, then, is an important regulatory mechanism intended to drive society's retreat from the ocean, particularly after storms. But enforcing the seawall provision would eventually mean that some coastal property owners would lose homes and land without compensation from the state. Only one private-property owner — Helen James of Edisto Beach—on the South Carolina coast has lost an entire seawall to the ocean since 1988, but she was able to rebuild it because of unique circumstances. Edisto Beach's erosion rate was so extreme during the late 1990s and early 2000s that the state's beachfront-setback rules didn't keep pace with changing conditions there. The setback rules are updated every 10 years. After her seawall and home were destroyed in a storm, James still had enough high land to construct a seawall landward beyond the state's jurisdiction. The dry section of her beachfront property fell within the jurisdiction of the town of Edisto Beach, which allowed her to rebuild the seawall. She has not rebuilt her home.

"The reality is that the state's seawall provision in regard to reconstruction—a linchpin of the S.C. Beachfront Management Act—has never been challenged in court. No one has lost a seawall and been prohibited from rebuilding. More than 20 years after its passage, 'the crux of the Beachfront Management Act—of retreat—has not been

[431] North Inlet-Winyah Bay National Estuarine Research Reserve, "Current Research." http://www.northinlet.sc.edu/research/current.html
[432] J. Tibbetts, "Sea-Level Rise: Adapting to a Changing Coast," Coastal Heritage 24(1) (Summer 2009): 6. http://www.scseagrant.org/pdf_files/ch_summer_09.pdf

tested,' says Braxton Davis, director of the policy and planning division of the S.C. Department of Health and Environmental Control-Office of Ocean and Coastal Resource Management (SCDHEC-OCRM)."[433]

Policy

1 The NOAA Office of Ocean and Coastal Resource Management gives South Carolina as a case study of rolling easements: "In 1984, the South Carolina Coastal Council commissioned a Blue Ribbon Committee to address coastal erosion and sea level rise. Stemming from the Committee's report, the South Carolina legislature passed the South Carolina Beach Front Management Act of 1988 which established a setback line for ocean-front property of forty times to annual erosion rate. When the setback line was drawn, some property lacked a sufficient developable area after the setback or ended up being entirely seaward of the setback line. David Lucas, who owned property that was now 'undevelopable' due to the new setback line, sued the Coastal Council for compensation. The trial court for the landmark shoreline management case, Lucas vs. the South Carolina Coastal Council found that the setback line resulted in a 'takings'. The state has to compensate Lucas for the lost use of his property. The Lucas decision and Hurricane Hugo prompted the legislature to amend the Beach Front Management Act in 1990 to allow for a rolling easement on any lot seaward of the setback line to avoid the need for 'takings' compensations. As a result, lots seaward of the setback line can be developed but no hard shoreline stabilization structures can be used to protect the property. However, some 'soft' erosion control methods can be used including beach renourishment, building up artificial dunes, and temporarily placing small sandbags around a home. If homes are damaged or destroyed during a storm, they are allowed to rebuild as long as high ground still exists. If the lot is submerged during high tide, rebuilding/repairing is no longer allowed."[434]

2 The South Carolina Coastal Zone Management Program's "Assessment and Strategy 2006-2010" lists sea level rise as presenting a "High" level of risk, writing, "South Carolina has not assessed the impact of sea level rise on coastal communities and critical habitats such as coastal wetlands. As an example, a conservative estimate of potential land loss in the northeastern coastal region of North Carolina over the past 25 years on 1,593 miles of mapped estuarine shoreline is 537 acres per year (Stanley Riggs, Shoreline Erosion in North Carolina Estuaries, The Soundfront Series, NC Sea Grant, Raleigh, NC, Pub. UNC-SG-01-11, 68 pp.). An analysis of South Carolina beachfront and estuarine shorelines is necessary to determine if similar risks exist in this state. DHEC-OCRM [Department of Health and Environmental Control Ocean and Coastal Resource Management] has several ongoing initiatives to improve data acquisition and planning for coastal hazards:
– Information on coastal hazards will be collected as part of the NOAA performance measure tracking efforts.
– DHEC-OCRM is acquiring a comprehensive data set for the Critical Area that will include tidal creeks, stormwater ponds, docks, bridges, piers, and marsh vegetation. This data will be acquired from high-resolution (0.25m^2) aerial photography obtained by both the DNR and DHEC-OCRM, and can be used for improved assessments of shoreline change." The Assessment also adds, "For the next five years, DHEC-OCRM will focus most of its 309 resources on building coastal communities' resilience to shoreline change from storms (including hurricanes), sea-level

[433] J. Tibbetts, "Sea-Level Rise: Adapting to a Changing Coast," Coastal Heritage 24(1) (Summer 2009): 8-10. http://www.scseagrant.org/pdf_files/ch_summer_09.pdf

[434] Office of Ocean and Coastal Resource Management, "Shoreline Management: Utilize Erosion Control Easements," National Oceanic and Atmospheric Administration (October 2007). http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_easements.html. For the case, see Lucas vs. South Carolina Coastal Council, Supreme Court of the United States 505 U.S. 1003 (1992).

rise, and other natural and anthropogenic forces." [435]

3 A NOAA review of the South Carolina Coastal Management Program (SCCMP) begun in January 2008 found that "a growing body of research on shoreline change and sea level rise has shown possible negative effects on the state's coast line. As a result, the SCCMP developed a multi-year Shoreline Change Initiative in 2007 to organize existing data collection and research efforts, identify additional research needs, and formulate policy options to guide the management of South Carolina's estuarine and beachfront shorelines." The NOAA report listed as an accomplishment that "The SCCMP continues to work with local governments in the revisions to local comprehensive beach management plans and worked with the City of Isle of Palms to develop its initial comprehensive beach management plan. The SCCMP has also initiated a multi-year Shoreline Change Initiative to organize existing data collection and research efforts, identify additional research needs, and formulate policy options to guide the management of South Carolina's estuarine and beachfront shorelines in light of continued pressures on those resources," and offers the suggestion that "The SCCMP should assume a leadership role in working with the Governor's Office, coastal local governments, members of the General Assembly, chambers of commerce, and others to capitalize and fund the State Beach Renourishment Trust Fund."[436]

4 The South Carolina Office of Ocean and Coastal Resource Management submitted a proposal to the NOAA for a 2007 Coastal Management Fellow to study shoreline change. The proposal identifies problems facing the Office: While developments are generally prohibited from encroaching into tidal marshes and the transitional banks of marshes, there is no policy of retreat, and the setbacks established by the important Beachfront Management Act do not apply to non-beachfront shorelines. Furthermore, "permit applications for bulkheads and revetments appear to be increasing over the past few years, and permits are not required for erosion control devices constructed landward of the 'Critical Line' as defined by the agency. Therefore, the percentage of shoreline that is hardened is presently unknown, and trends are difficult to evaluate because permits were not tracked (or were not consistently tracked) prior to 2001." The Office of Ocean and Coastal Resource Management proposes to have a fellow to achieve six primary goals and objectives:
1) Develop a "State of Knowledge" report on sea level rise, erosion, and shoreline development in South Carolina.
2) Assess the status and trends of erosion control structures along South Carolina's coastline based on an analysis of permit trends.
3) Inventory beachfront structures based on aerial imagery.
4) Assist with revisions to baselines and setbacks for beachfront development by working directly with the Staff Oceanographer.
5) Develop a database of beach nourishment projects, monitoring, and results.
6) Draft policy recommendations for SCDHEC-OCRM.[437]
The outcome of this proposal is not given on the Office's website.

5 As of the latest (September 2008) revision of the South Carolina Code, Chapter 30 "Department of Health and Environmental Control--Coastal Division" §30-1-C(4) reads,

[435] South Carolina Coastal Zone Management Program, "Section 309 Assessment and Strategy 2006-2010," Office of Ocean and Coastal Resource Management, South Carolina Department of Health and Environmental Control (May 2007): 15-16, 23. http://www.scdhec.gov/environment/ocrm/pubs/docs/309/SC_309_Final.pdf

[436] Office of Ocean and Coastal Resource Management, "Final Evaluation Findings: South Carolina Coastal Management Program, August 2004 through March 2008," National Oceanic and Atmospheric Administration National Ocean Service (December 2008): 18-19. http://coastalmanagement.noaa.gov/mystate/docs/southcarolinacmp2008.pdf

[437] Office of Ocean and Coastal Resource Management, "Planning for Shoreline Change in South Carolina: A Proposal to the NOAA Coastal Services Center 2007 Coastal Management Fellowship Program," South Carolina Department of Health and Environmental Control (2007): 2-5. http://www.scdhec.gov/environment/ocrm/science/docs/2007_CSC_Shoreline.pdf

"It has been clearly demonstrated that the erosion problems of this State are caused by a persistent rise in sea level, a lack of comprehensive beach management planning, and poorly planned oceanfront development, including construction of hard erosion control structures, which encroach upon the beach/dune system. Sea level rise in this century is a scientifically documented fact. Our shoreline is suffering from its effects today. It must be accepted that regardless of attempts to forestall the process, the Atlantic Ocean, as a result of sea level rise and periodic storms, is ultimately going to force those who have built too near the beachfront to retreat." The policy goes on to reject construction of new erosion control devices "and adopts retreat and renourishment as the basic state policy towards preserving and restoring the beaches of our state."[438]

6 "South Carolina has established a Shoreline Change Advisory Committee to consider longstanding management practices and challenges in the light of new sea-level rise projections. The 23-member committee is expected to release a report later in 2009."[439] According to the schedule given on the Committee's website,[440] it is currently in the process of holding forums with community leaders across the South Carolina coast.

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. However, as per South Carolina-Policy-6 above, the state is moving to address the issue in terms of policy. The state has also taken actions generally towards protection and restoration. A list of wetlands preserved and protected from development, and open for public recreation, is available on the "South Carolina Great Outdoors" site.[441]

2 The Natural Resources Conservation Service's South Carolina Wetlands Reserve Program has, since Fiscal Year 1996, received $11 million, which it has put towards 12,500 acres currently enrolled in the program and 3,000 acres submitted for restoration.[442]

[438] South Carolina Code of Regulations, "Chapter 30. Department of Health and Environmental Control--Coastal Division" (September 2008). http://www.scstatehouse.gov/coderegs/c030.htm

[439] J. Tibbetts, "Sea-Level Rise: Adapting to a Changing Coast," Coastal Heritage 24(1) (Summer 2009): 5. http://www.scseagrant.org/pdf_files/ch_summer_09.pdf

[440] South Carolina Department of Health and Environmental Control, "OCRM - Science and Policy" (2009). http://www.scdhec.gov/environment/ocrm/science/shoreline_comm.htm

[441] M. Adams, "Handbook of South Carolina Wetlands," SCIway.net (2009). http://www.scgreatoutdoors.com/hb-wetlands.html

[442] National Resources Conservation Service, "South Carolina Wetlands Reserve Program." http://www.nrcs.usda.gov/programs/wrp/states/sc.html

Texas

Research

1 A series of reports for the Texas Coastal Coordination Council by the University of Texas at Austin entitled "Coastal Hazards Atlas of Texas: A Tool for Hurricane Preparedness and Coastal Management" provides technical information to coastal planners, with each volume of the series dealing with a specific portion of the Texas coastline. One report notes, "During the last half of the 20th century along the south Texas coast, the rate of relative sea-level rise has been about 0.133 inches per year (about 7.3 inches in 55 years) as measured by the Port Isabel tide gauge in Port Isabel… Global warming scenarios predict an increase in the rate of global sea-level rise, but even if that does not happen and relative sea-level rise continues at its present rate there is reason for concern and special planning." It continues to note, "If coastal development or steep upland slopes do not provide the room for low-lying environments to expand landward as the sea rises then important habitat will be lost." The reports recognizes that rise could inundate beaches, drown significant areas of marsh, and lead to permanent flooding and loss of land and wetlands, as already "Thousands of acres of vegetated wetlands have been submerged by subsidence and replaced by open water in the Galveston Bay System."[443]

2 A 2004 update to the 1996 "Texas Coastwide Erosion Response Plan" recognizes that "there is not enough sediment in the depositional system to balance the effects of rising relative sea level and the impacts from coastal storms. The natural response by the coastal depositional environments is to migrate landward and upward in space and time. However, many man-made structures are placed in areas adjacent to the beaches without sufficient knowledge of the dynamics of the coastal ecosystem and changing shoreline. In eroding areas, the on-going landward movement of the Gulf will threaten structures, and the public beaches adjacent to them will narrow or disappear if no action is taken to restore the beach. Projects that reduce erosion hazards (e.g., beach nourishment) are not cheap and take a lot of effort and coordination among many interest groups."

The report identifies, "The greatest cause of episodic erosion of the Gulf shoreline is from storms, but the long-term erosional trend suffered by 64% of the Gulf shoreline is caused by the rate of relative sea level rise and the lack of sediment input into the coastal system to keep it in balance. Many of the bay shorelines are eroding as well. Factors influencing bay shoreline change and the method for response are the geology, setting with respect to wind and wave direction, shoreline armoring, and the proximity to major ship traffic."

After a detailed analysis of the geomorphic features of the different regions along the Gulf coast, the report offers several recommendations, including to:
– Reestablish marshes with appropriate dredge material;
– Consider impacts of relative sea level rise in the design of erosion response projects;
– Acquire threatened properties and coastal wetland areas prior to development;
– Remove derelict structures located along the shoreline and acquire upland properties to allow natural marsh and shoreline migration.
– Commit to long-term monitoring of the shoreline at and adjacent to erosion response project locations that may alter the public beach or downdrift beaches;
– Commit to long-term project monitoring to evaluate project effectiveness and improve future project designs; and
– Be aware of subsidence effects when

[443] J. Gibeaut et al, "Final Report: Coastal Hazards Atlas of Texas: A Tool for Hurricane Preparedness and Coastal Management–Volume 1, The Southeast Coast" Texas Coastal Coordination Council (June 2000): 3-5, 17. http://www.beg.utexas.edu/coastal/presentations_reports/hazardsatlas_v1_2000.pdf. "Volume 3–The South Coast" (August 2003). http://www.beg.utexas.edu/coastal/presentations_reports/hazards_atlas_v3_2003.pdf

selecting projects and designs, recognizing that there may be ongoing subsidence.

The report also recommends that "Regional bay system management plans should include the evaluation of each bay as a whole for shoreline erosion, sediment management, wetland and habitat losses, seagrass degradation, and freshwater inflow," and that "Public education should be a high priority for describing coastal issues such as shoreline erosion, freshwater inflow, and the ephemeral nature of natural channels through barriers."[444]

3 In 2003, the Texas General Land Office (GLO) created "Coastal Texas 2020," a statewide initiative to "promote the environmental and economic health of the Texas coast." One goal of the project is to secure greater federal funding; "In the 95 years the federal government has given the states money to fight coastal erosion, Texas has received only one percent of the total money allocated. Florida, however, has gotten 32 percent of that money. New Jersey has netted 27 percent."[445] The GLO presented the final report to the 79th Texas Legislature in 2005. The recommendations contained in the Executive Summary relate mainly to increasing federal and state funding.[446]

In a public participation process, participants were asked to rank 17 regional issues affecting critical areas. The most critical issues was "Bay Shore Erosion," with a score of 71, followed second by "Wetland/Habitat Issues." "Sea Level Rise" ranked ninth, with a score of 24.[447] Out of the five regional reports, only Regions I and II explicitly identify sea level rise as an issue, although all five regions show concerns about erosion.[448]

4 The University of Texas at Austin has prepared a series of six reports entitled "Status and Trends of Wetland and Aquatic Habitats on Texas Barriers" for the Texas General Land Office, each discussing a section Texas coastline and together covering the entire shoreline. The final 2007 report provides a summary of the reaction of coastal wetlands to sea level rise from the previous five reports as well as earlier studies by the same authors: "Previous studies by the Bureau of Economic Geology (BEG) of wetland status and trends along the Texas coast, for example in the Galveston Bay system (White et al. 1993 and 2004) indicate substantial losses in wetlands have occurred due to subsidence and associated relative sea-level rise. Some of the losses on Galveston Bay barriers have occurred along surface faults that have become active as a result of underground fluid production. In contrast to the Galveston Bay system, studies of wetlands on barrier islands in the Corpus Christi Bay area by the BEG, Texas Parks and Wildlife Department, and Texas A&M University at Corpus Christi (White et al. 1998) show that marshes have expanded as a result of relative sea-level rise. Between these two bay systems is the Matagorda Bay/San Antonio Bay complex, where extensive wetlands on barrier islands and peninsulas have also undergone changes, including the Colorado River delta and associated diversion channel, which were investigated by White et al. (2002). Results of these kinds of studies improve our understanding of marsh changes on Texas barriers and pinpoint wetlands threatened from erosion, faulting, subsidence, and other processes. These data provide site-specific information for implementing marsh

[444] K. McKenna, "Texas Coastwide Erosion Response Plan: 2004 Update," Texas General Land Office (December 2004): *i*, 45-46. http://www.glo.state.tx.us/coastal/cerp/pdf/TCERP_2004.pdf

[445] J. Suydam, "News Release: Coastal Texas 2020: a clear vision for the future of the Texas coast" Texas General Land Office (June 2003). http://www.glo.state.tx.us/news/archive/2003/pdfs/06-24-03-Coastal2020.pdf

[446] Texas General Land Office, "Coastal Texas 2020: A Clear Vision for the Texas Coast, Executive Summary" (February 2005). http://www.glo.state.tx.us/coastal/ct2020/2005report/HomeDocuments/CT2020_Executive_Summary.pdf

[447] Texas General Land Office, "Texas Coastwide Summary: Regional Issues Affecting Critical Areas Identified through CT2020," Coastal Texas 2020 (February 2005). http://www.glo.state.tx.us/coastal/ct2020/2005report/HomeDocuments/CT2020_Coastwide_Issues_Graph.pdf

[448] Regional reports can be accessed from: Texas General Land Office, "Coastal Texas 2020: A Clear Vision for the Texas Coast" (February 2005). http://www.glo.state.tx.us/coastal/ct2020/2005report/index.html

protection and restoration programs."[449]

The study also summarizes historical sea-level rise tidal gauge data: "The tide gauge at Pier 21 at Galveston Island provides the longest continuous record of sea-level variations along the Texas coast. The average rate of sea-level rise from1909 to 2003 was 0.65 cm/yr. Rates of sea-level rise recorded by the tide gauge reached a high of 1.9 cm/yr from 1963 to mid 1975. The mean sea-level trend at Sabine Pass is approximately 6.54 mm/yr."[450]

5 * A 2007 report from the Texas Sea Grant at Texas A&M University and the National Sea Grant Law Center at the University of Mississippi entitled "The Resilient Coast: Policy frameworks for adapting the Wetlands to climate change and growth in coastal areas of the U.S. Gulf of Mexico" provides an excellent analysis of the issues surrounding addressing climate change impacts on coastal habitats. Its purpose is to "review legal and policy frameworks that might hinder or enable adaptation to the next 100 or so years of climate change, in terms of impacts on coastal estuarine wetlands." This report limits itself to sea level rise impacts only, though recognizing that there will be other impacts on coastal wetlands associated with climate change. [451]

A key argument made by the report is that "Loss of existing coastal non-deltaic wetlands with sea level rise is inevitable, and not much can be done to avoid that loss. As sea level rises, water will become too deep where wetlands are now, converting those areas to open water and eliminating all of the functions and benefits that accrue from coastal wetlands, for example essential fish habitat. Even the most conservative estimates of a half foot sea level rise will drown many wetlands… There are really only two management options to insure that some coastal wetlands will be present in the coming decades and centuries in this changing environment: raise the elevation of drowned areas by creating/restoring new wetlands, or insure that replacement wetlands can form as inundation occurs through a process of managed retreat."[452]

For the first option, "It is possible to create new wetlands in areas where the water has become too deep to sustain wetland vegetation. The science and practice behind estuarine marsh creation has made great strides within the past two decades. While it is not yet possible to suggest that equally productive replicas of natural wetlands can be created, we are getting much closer and we have a much better understanding of how to create such wetlands.

"Texas lost at least 59,000 acres of fringing estuarine wetlands between the 1950s and the early 1990s due to subsidence associated with industrial and municipal groundwater removal (Moulton et al., 1997). Thirty five thousand acres of that loss occurred in Galveston Bay, approximately 20 percent of the estuarine marshes there. (White et al 1993). Few of these wetlands were naturally replaced, both because of the rapidity of the change and because… inundation proceeded up to the steep slope but did not rise above it.

"In response to this massive and rapid loss of wetlands, considerable local, state, and federal resources have been mobilized to restore these wetlands, primarily through the placement of fill and the planting of wetland vegetation. Dredging of the Houston Ship Channel and other waterways provided and continues to provide an abundant and steady source of fill material. A Beneficial Uses Group (the 'BUG' group), for example, was formed to marshal resources to build as many new wetlands as possible using dredge-spoil material. Many other groups and agencies are

[449] White et al, "Status and Trends of Wetland and Aquatic Habitats on Texas Barriers: Upper Coast Strangplain-Chenier System and Southern Coast Padre Island National Seashore," Bureau of Economic Geology at the University of Texas at Austin, prepared for the Texas General Land Office (April 2007): 14. http://www.glo.state.tx.us/coastal/statustrends/chenier-pins/BarrierWetlandsChenier-PINS.pdf

[450] Ibid., 44.

[451] J. Jacob and S. Showalter, "The Resilient Coast: Policy frameworks for adapting the Wetlands to climate change and growth in coastal areas of the U.S. Gulf of Mexico," Texas Sea Grant (August 2007): 7. http://www.urban-nature.org/publications/documents/ResilentCoastWetlands-sm.pdf

[452] Ibid., 23.

also involved in wetland restoration projects that involve some combination of elevation and plant transfer. Marsh Mania is an annual event involving several entities and sites that draws hundreds of volunteers for marsh plantings.

"In spite of these impressive accomplishments, only about 1,500 acres of marsh were created between the mid-1970's and 2002, according to the Galveston Bay Estuary Program's State of the Bay (Lester and Gonzalez, 2002), or less than 5 percent of the loss. No data was provided as to the success of these projects, but there is little doubt of the success of the more recent projects from about the last decade.

"These creation and restoration projects involve very careful control of the bottom elevation for the new marshes. Fill material is placed to an elevation that guarantees success for current conditions. To our knowledge, few restoration projects are designed with future sea level rise in mind. Most of the wetlands constructed to date will be lost to sea level rise even under the most conservative scenarios. But these wetlands are today performing essential functions, and from a policy adaptation viewpoint, what is learned today from wetland construction projects will be useful in the future to help build replacement wetlands. Given the expense and difficulty of building new wetlands, it is not certain that wetland creation through elevation could be a major adaptation to rising sea levels. Certainly, it could be an important tool for replacing specific wetland functions in certain high value, critical areas, but it is difficult to know if wetland construction could have widespread impact. Depending on the rate of sea level rise, these creation projects, as currently designed, would have to be redone every decade or so. It would not be all that difficult to engineer constructed wetlands projects in the estuarine zone to allow for some degree of sea level rise: berms or marsh mounds that are a little wider and taller, for example."[453]

The report authors also write that "to our knowledge, no land trusts are currently focusing on preserving near-shore inundatable lands as a buffer for sea level rise impacts. Most of these NGOs are focused on areas where significant loss is occurring right now, and few have the luxury to think decades ahead."[454] Thus, while recognizing the importance and potential of restoration, and the role of non-governmental land trusts, the report argues that the most crucial and necessary action is government-enforced managed retreat to insure that replacement wetlands can form as inundation occurs.

In examining how to achieve managed retreat, the report first searches through existing legislation for possible legal justifications. "Existing wetlands receive some protection from development under a variety of federal, state, and local laws… There are no explicit provisions, however, to protect *future* wetlands on lands that may be inundated under SLR. A few existing policy instruments could be used to insure the availability of inundatable lands for the formation of new wetlands."[455]

The report considers the existing legal and institutional framework. The Clean Water Act, it analyzes, "prohibits fill or destruction of existing wetlands, but makes no provision for protecting lands that would become wetlands as a result of sea level rise." While the Clean Water Act has had less than ideal success, as there is usually little proactive investigation of illegal filling activities, and there is evidence that many mitigation projects are performing below design. "These deficiencies are pointed out not to criticize this system, but as important considerations in terms of how well specific policies, and their execution, might enable adaptation to climate change in terms of wetlands in the Gulf Coast region. The issue of proactive enforcement, in particular, has implications for thinking ahead in terms of the future impacts of climate change." While there is no legal requirement to protect potentially inundatable lands, the CWA does not preclude such requirements. Furthermore, the "No Net Loss" policy could theoretically

[453] Ibid., 26-27.

[454] Ibid., 17.

[455] Ibid., 5.

apply to cover potentially inundatable lands, although there has been "little if any discussion" about this possibility. "It is more a question of political will than a policy impediment. If anything, the current policy of No Net Loss should encourage the [Army] Corps and other agencies to take a more proactive stance with respect to replacing wetlands lost to sea level rise."[456]

The report also offers an interpretation of the Magnuson-Stevens Fishery Conservation and Management Act and the 1996 Sustainable Fisheries Act amendment to it. As over 90% of commercial fisheries species depend on coastal wetlands, coastal wetlands could be interpreted as "essential fish habitats" to receive protection. Another possibly applicable federal-level policy is Marine Protected Areas (MPAs), established by President Clinton with Executive Order 13158. While not establishing any new regulatory authority, the related National Marine Sanctuaries Act in conjunction with MPAs could provide an opportunity for integrated management of ecosystems that cover both the marine and coastal environments. The 1972 Coastal Zone Management Act (CZMA), in devolving considerable jurisdiction to the state level, enables the possibility of proactive approaches to wetland protection at the state level. Special Area Management Plan (SAMP) provisions within the CZMA "could provide a useful policy framework for dealing with climate change wetland impacts, especially on a regional basis," especially as SAMPs are used to assist in long-term planning as opposed to case-by-case permit reviews.[457]

In discussing examples on individual states, the report notes that only Michigan and New Jersey have taken the option offered by the CWA to have the state assume administration of the federal §404 permit program. Only Florida has enacted a regulatory program more expansive than the federal wetlands program, by including "isolated" wetlands falling outside federal jurisdiction, and by regulating all land disturbances that could impact state waters whether or not the activity occurs in state waters. "From a SLR adaptation perspective, this kind of scope could enable Florida to provide protection to dry, potentially inundatable lands, although there is no indication that they are doing so now."[458]

These interpretations of legislation could provide the legal justification for managed retreat, but there are several options for how such retreat could actually be carried out. This discussion cites and largely follows from the work of James Titus in 1998.[459] Titus gives four options for protecting inundatable lands by carrying out a policy of managed retreat: rolling easements, prevention of development, deferred action, and a 'combination' or 'hybrid' approach.

Aside from the discussion adapted from Titus, this report discusses the Texas Open Beaches Act, arguing that "The most promising and perhaps most easily applicable legal framework for wetlands protection would be the adoption of a mechanism similar to the rolling easement provisions of the Texas Open Beaches Act."[460] The report explains, "Unique among most states, Texas maintains a 'rolling easement' on the Gulf shores to protect public access to the state's beaches. The Texas Open Beaches Act (TOBA) was passed in 1959 to assure that the public has the 'free and unrestricted right of ingress and egress to and from' public beaches, defined as the area between the line of vegetation and the mean low tide line. The TOBA further prohibits the construction of an 'obstruction, barrier, or restraint of any nature which would interfere with the free and unrestricted right of the public to access the beach. Holding back the sea, either through bulkheading or seawalls is, therefore, not permitted along public beaches. Buildings located seaward of the vegetation line must be removed if those

[456] Ibid., 11-12.
[457] Ibid., 16.
[458] Ibid., 17-18.
[459] J. Titus, "Rising sea levels, coastal erosion, and the takings clause: How to save wetlands and beaches without hurting property owners," Maryland Law Review (57) (1998): 1279-1399.
[460] Ibid., 17.

buildings become an impediment to public access to the beach, as they do when the vegetation line shifts. A structure is an impediment to public access merely by being in the public access zone. Because the vegetation and low tide line shift due to natural coastal processes, the demarcation lines for public beaches are not static. The public's right of access, or easement, moves as well… As might be expected, property owners affected by changing vegetation lines do not take kindly to having to move their houses. Litigation occurs after every major storm when any number of houses end up seaward of the vegetation line, but the Texas courts have uniformly upheld the validity of law since its inception in 1959." Most objections are based on the Takings Clause of the Fifth Amendment, but Texas has more recently partially protected itself by requiring "that deeds for properties sold after October 1, 1986 contain a disclosure statement to warn buyers of the potential loss of their homes or buildings due to the movement of the vegetation lines. Such statements notify owners that they do not have a right to maintain structures seaward of the vegetation line."[461]

6 * A 2009 study from Texas A&M University, Cambridge University in the UK, the University of Alaska, the University of Southern Mississippi, and James Cook University in Australia "challenges the paradigm that salt marsh plants prevent lateral wave-induced erosion along wetland edges by binding soil with live roots and clarifies the role of vegetation in protecting the coast. In both laboratory flume studies and controlled field experiments, we [the study authors] show that common salt marsh plants do not significantly mitigate the total amount of erosion along a wetland edge. We found that the soil type is the primary variable that influences the lateral erosion rate and although plants do not directly reduce wetland edge erosion, they may do so indirectly via modification of soil parameters." The study concludes that "coastal vegetation is best-suited to modify and control sedimentary dynamics in response to gradual phenomena like sea-level rise or tidal forces, but is less well-suited to resist punctuated disturbances at the seaward margin of salt marshes, specifically breaking waves."[462]

7 The Texas General Land Office's 2009 report to the 81st Texas Legislature lists "Rising sea levels from global climate change" as a cause of coastal erosion. The report notes, "Texas has approximately 367 miles of Gulf-facing shoreline mostly comprised of low elevation sand beaches that are part of several long and narrow barrier island complexes. Along the Texas mainland coast an additional 3,300 miles of bay shoreline exists behind the barrier island systems as numerous shallow-water embayments formed at mouths of river systems. Most of these sandy beach and bay systems are experiencing varying degrees of continual coastal erosion." Over the past 70 years, of the total 367.0 coastline miles, 229.4 miles or 63% are critically eroding.[463]

A related report is the 2006-2010 "Assessment and Strategies Report" of the Texas Coastal Management Program, which lists "sea level rise and subsidence" as a threat of "High" significance (out of "High," "Medium" and "Low").[464]

8 A presentation given at the June 2009 "Caring for the Coast: Texas Coastal Conference 2009" presented a study that compared the responses of salt marsh ecosystems to different restoration techniques. "Pierce Marsh is an estuarine marsh complex located within the lower Galveston Bay system. Like many marsh complexes along the Texas Gulf coast, vegetated aquatic communities within Pierce marsh have suffered from the effects of subsidence and relative sea level rise.

[461] Ibid., 21-22.

[462] R. Feagin et al, "Does vegetation prevent wave erosion of salt marsh edges?" PNAS 106(25) (June 23, 2009): 10109. http://www.pnas.org/cgi/doi/10.1073/pnas.0901297106

[463] Texas General Land Office, "CERPA Coastal Erosion Planning & Response Act: Report to the 81st Texas Legislature" (January 2009): 3, 5. http://www.glo.state.tx.us/coastal/erosion/CEPRA-LegReport2009/CEPRALegeReport2009.pdf

[464] Texas Coastal Management Program, "Section 309 Assessment and Strategies Report 2006 - 2010," Texas General Land Office. http://www.glo.state.tx.us/coastal/cmp/309/Section309-AssessmentandStrategies_2006-2010.pdf

Between 1999 and 2005, marshes were restored using four techniques: linear grid, zigzag, and sinusoidal terraces, and levied fill. Limited data is available indicating which restoration technique most successfully replaces marsh growth and function relative to a natural reference site. We examined plant, animal and bacterial communities, and sediment characteristics from four restored sites in Pierce marsh, according to the design of the restored site; data were compared to a natural reference site within Pierce marsh. All restored and reference sites were dominated by smooth cordgrass (*Spartina alterniflora*), but *S. alterniflora* cover was highest in the reference site. Vascular plant diversity and *S. alterniflora* root and shoot biomass were higher in all three types of terraces than in the levied fill or reference sites. The reference sites had higher clay content, higher epifaunal density and diversity, and lower epifaunal and *S. alterniflora* tissue nitrogen content than all restored areas. Heavy metal concentrations in the sediments from the restored sites were generally higher than in the reference sites. Overall productivity, calculated from chlorophyll and density data, did not vary significantly among the reference or restored sites. In general, terrace communities were similar regardless of their shape, but there were large differences between restored terraces, restored fill habitats, and reference areas."[465]

9 A presentation given at the June 2009 "Caring for the Coast: Texas Coastal Conference 2009" presented the results of a study to construct a composite relative sea-level curve of subsidence plus eustatic rise for the Texas coastal region. According to the presentation abstract, the "rate of [sea level] rise has increased by almost an order of magnitude over the past century in response to warming and expansion of oceans and melting of mountain glaciers. There is growing consensus within the scientific community that the rate of eustatic rise will reach 5.0 mm/yr by the end of this century. The current rate of relative rise varies widely along the coast due to variable subsidence. This is largely due to changes in the depth of the Pleistocene surface and thickness of overlying sediments, which controls subsidence due to compaction. A comparison of our composite curve to Caribbean sea-level curves (areas where subsidence is minimal) suggests that coastal subsidence within the study area over the past several thousand years has been minimal.

"The new sea-level curve is being used in an ongoing study to help predict coastal change this century. Our approach is to study the evolution of the Texas coast and bays at times when the rate of sea-level rise was at or near that predicted for this century (3 to 5 mm/yr). The result of this analysis indicates that in coming decades the coast will experience more dramatic change than is occurring today. Texas bays will be most severely impacted. Diminished sediment supply and human intervention will only exacerbate the problem. Our predictions are limited by the lack of a detailed sediment budget for the Texas coast and by uncertainties about the frequency and magnitude of tropical storm activity. Ongoing research is also aimed at establishing a detailed sediment budget and a record of past storm frequency and impact for the Texas Coast… When it comes to facing the challenge of coastal sustainability this century, Texas is a 'State of Denial', having done little to prepare for the changes that will occur along our coasts."[466]

Policy

1 Texas laws and administrative rules make several explicit mentions of sea level rise, although not necessarily in the context of

[465] J. Dobberstine et al, "Comparing Salt Marsh Ecosystem Responses to Different Restoration Techniques," Caring for the Coast: Texas Coastal Conference 2009 (June 2009): 1. http://www.glo.state.tx.us/coastal/tcc/hottopics/conference2009abstracts/03-Concurrent%20Sessions130-300pm/Session2-CoastalHabitatRestoration-RegulatoryUpdates/Dobberstine.pdf

[466] J. Anderson et al, "Past, Present and Future Sea Level and Subsidence Record for Texas Used to Predict the Future of Our Coast," Caring for the Coast: Texas Coastal Conference 2009 (June 2009): 1. http://www.glo.state.tx.us/coastal/tcc/hottopics/conference2009abstracts/02-Concurrent%20Sessions1040am-12pm/Session1-CoastalVulnerabilityinaChangingGlobalClimate/Anderson.pdf

climate change (however, while not in a statement of policy, the Coastal Erosion Planning & Response Act program of the Texas General Land Office does make mention of global climate change as a cause of sea level rise, see Texas-Research-7 above). In the Texas Parks and Wildlife Department rules, Chapter 14 "Powers and Duties Concerning Wetlands," §14.002(b)(15) reads that the "State-owned Wetland Conservation Plan… shall include… consideration of sea level rise as it relates to coastal wetlands."[467] In the Texas Administrative Code Title 31 "Natural Resource and Conservation," Part 16 "Coastal Coordination Council," Chapter 501 "Coastal Management Program," Subchapter A Rule §501.3(a)(1)(J) defines "Adverse effects or adversely affect" as "Effects that result in the physical destruction or detrimental alteration of a CNRA [Coastal Natural Resource Area]," including "alterations that increase losses of shore areas or other CNRAs from a rise in sea level with respect to the surface of the land, whether caused by actual sea-level rise or land surface subsidence."[468]

2 A 2004 report from the Bureau of Economic Geology, "Living with geohazards on Galveston Island: a preliminary report with recommendations" makes recommendations relating to development occurring at Galveston Island's west end. The report recommends establishing construction setbacks of a minimum of 20 years based on historical shoreline change rates, and discouraging construction in highly variable areas that should be considered high-risk areas. Related to habitat change, the report recommends:
"1. The City should implement an ordinance for the purpose of managing wetlands.
2. Current wetland maps should be used to define broad areas in need of protection.
3. Canal and channel dredging should be discouraged in wetland areas, even if wetlands are not directly excavated. This is because of the potential for increased erosion and deterioration of wetlands by increased exposure to currents, waves, and in some cases isolation of wetlands from the upland areas.
4. Tidal creeks and their immediate drainage areas should be protected because they supply sediment to marshes and allow space for the landward migration of wetlands during sea-level rise, which Galveston Island is experiencing.
5. Buffer areas of gently sloping topography should be preserved around wetlands to allow landward migration during rising sea level.
6. Development practices that cut off sediment supply to wetlands or create a barrier to wetland migration should be discouraged."[469]

3 The Texas General Land Office's 2006 "Agency Strategic Plan: Fiscal Years 2007-2011" summarizes the agency's objectives. The report states, 'Through the Coastal Erosion Planning and Response Act (CEPRA), the GLO is working to combat coastal erosion head-on, as it continues to threaten public beaches, marshes, homes, businesses, and public infrastructure. The agency has developed innovative program plans and works towards effective, long-term management practices that will stem erosion, preserve valuable habitat, protect public infrastructure and enhance the tax base of coastal communities."[470]

Another plan of the GLO is to open large tracts of land on the outer-continental shelf (OCS) to oil and natural gas (O&G) production "with the hope that O&G production in the OCS will decrease U.S.

[467] Texas General Land Office, "State-Owned Wetlands Conservation Plan" (September 2003). http://www.glo.state.tx.us/coastal/sowcp.html
[468] Texas Administrative Code, "Title 31: Natural Resource and Conservation; Part 16: Coastal Coordination Council; Chapter 501: Coastal Management Program; Subchapter A: General Provisions; Rule §501.3: Definitions and Abbreviations" (October 2006). http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=31&pt=16&ch=501&rl=3

[469] J. Gibeaut et al, "Living with geohazards on Galveston Island: a preliminary report with recommendations." Prepared for and submitted to the Galveston, Texas City Council (July 2004): 2-4. http://www.beg.utexas.edu/coastal/presentations_reports/galvestongeohazardspanelrpt.pdf
[470] Texas General Land Office and Veterans Land Board, "Agency Strategic Plan: Fiscal Years 2007-2011" (July 2006): 12. http://www.masgc.org/gmrp/plans/TX%20GLO3.pdf

dependence on foreign oil, and also lower current gas prices for businesses and consumers. Royalties from OCS production will increase the availability of federal funds for Gulf state projects such as beach and wetland restoration.[471]

A stated objective of the GLO is to "Protect and maintain 20 percent each year of developed, accessible, and eroding gulf shorelines and protect or restore 0.5% each year of all other coastal shorelines, including bay, marshes, and navigation channel." The success of this objective is measured in the percent of shorelines maintained, protected and restored, and percent of federal funds leveraged.[472]

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. However, as Texas has the third-largest shoreline in the United States, much of which is critically eroding, Texas has a large number of projects addressing coastal erosion including ones that address impacts on beaches and wetlands.

2 * The 1996 "Texas Coastwide Erosion Response Plan" showed the Texas legislature that the "Long-term, episodic, and human-induced erosion of the bay and Gulf shorelines has resulted in habitat loss, navigational challenges, and coastal structures on the public beach or at the line of vegetation." In response, in 1999 "the Texas legislature enacted the Coastal Erosion Planning and Response Act (CEPRA). The CEPRA program, administered by the General Land Office, has provided a public forum and technical assistance in choosing the appropriate method for erosion response. There have been improved cooperative local, state, and federal partnerships. The CEPRA program has funded beach fill for sand-starved areas of the upper coast (Coastal Texas 2020 [CT2020] Regions I and II) impacted by tropical storms and hurricanes, and long-term shoreline retreat. Improved sediment management practices allowed wetlands to be restored using material dredged from the GIWW and ship channels. Historic sites were protected from ship wakes in CT2020 Region III. Bay shore parks were renewed with beach sand and infrastructure to allow greater public use in CT2020 Region IV. And, in CT2020 Region V, the practice of placing beach-quality sand on eroding Gulf beaches helps generate tourism income while maintaining shipping lanes vital to the local economy." However, while "The projects funded by the CEPRA program are making positive impacts in local responses to erosion," the 2004 update to the "Texas Coastwide Erosion Response Plan" notes that "the impacts are localized and there are several coastal communities and citizens that haven't received the attention or funding for projects."[473]

Furthermore, as the 2004 update notes, "The 1999 to 2003 beach nourishment and veneer-fill projects (most funded by CEPRA) in Galveston County do not qualify as beach nourishment for storm-damage reduction as the average amount placed on the Gulf beaches was about 32 cubic yards/linear foot of beach… While any sediment placed on an eroding beach is generally welcome, these amounts are insufficient for maintaining the width of the public beach and are insignificant to the long-term erosion trend. Even the amounts extracted out of Rollover Pass from 1999 to 2003 (962,400 cubic yards (Shiner Moseley and Associates, 2004)) are not enough to lessen the impacts of storms and long-term erosion. Much of the material may be too fine to maintain an equilibrium profile because it is more likely to be winnowed out of the beach fill by waves. To address the deficit, substantial amounts of sand must be located in close proximity to the deprived beach… The need for beach-quality sand for Gulf beach nourishment projects has led to the establishment of a cooperative sand

[471] Ibid., 36-37.
[472] Ibid., 44.
[473] K. McKenna, "Texas Coastwide Erosion Response Plan: 2004 Update," Texas General Land Office (December 2004): *iv*. http://www.glo.state.tx.us/coastal/cerp/pdf/TCERP_2004.pdf

resource search and public database established by Rice University and the Bureau of Economic Geology (BEG). The database is available to the public via Internet and provides the vibracore locations and sediment texture data.[474] Researchers and consultants use the location and texture information as a guide for determining the appropriate sites for dredging offshore." [475]

"The CEPRA program has funded several combination projects that have renewed the eroded shorelines of marshes and tidal flats, and restored wetlands and recreational use. One innovative technique was the creation of 'marsh mounds' from dredged material and vegetative plantings to restore habitat (e.g., Jumbile Cove in Region II). Rock revetment and vegetation was used to prevent saltwater intrusion and the destruction of wetlands (e.g., GIWW at McFaddin National Wildlife Refuge in Region I). CEPRA provided partial funding for a 3000 foot beach nourishment project and 2000 feet of structural protection (e.g., Indianola Historic Site in Region III). The combination of beach nourishment and structural protection can be costly; however, there has been greater public use of the Indianola Historic Site since the project was completed. Combination projects (rock breakwater and vegetative planting) have high success rates and sometimes can be relatively inexpensive (e.g., East Bay north shoreline in Region II - about $200,000/mile). Other combination projects have been explored by the USACE in cooperative efforts to protect marshes and fishery habitat (e.g., Keith Lake Fish Pass in Region I). The cost of planting vegetation is about $50 to $100 per linear foot of shoreline (Technical Advisory Committee, 2004)."[476]

3 ***** As reported by a 2000 article in the magazine *Erosion Control*, "Edward Seidensticker, a resource conservationist with NRCS in Baytown, TX, on the Galveston Bay, has pioneered some much-needed erosion control methods for the backbay area. 'We've got a lot more erosion going on back there than we do on the front beach or on the open gulf,' he points out. 'Those get the most attention, but there are places in the bay where we're having as much as 6-10 feet of erosion a year.

"'My job is in demonstration and development,' states Seidensticker. He has innovated several bioengineering solutions. For sites where revegetation efforts are underway, he has protected smooth cord grass plantings by constructing temporary wave barriers from surplus military cargo parachutes. Three-ft.-wide strips from the parachute canopy are fashioned into fences. 'Cargo parachutes are different than standard parachutes in that they have openings or slits,' he explains. The slits allow air to flow through the parachute canopy and prevent it from ripping out when descending with a heavy piece of cargo or equipment. The cargo chutes work the same way in the water. 'It doesn't stop the wave energy, it just slows it enough to allow the plantings to establish themselves.' Once the vegetation is established, usually within two years, the fences are removed. 'That's about as long as the parachutes last,' he adds.

"Seidensticker's recent projects involve a more permanent solution: creating oyster reefs for erosion control. 'The reefs, in conjunction with the shoreline, act as a natural wave break. Even though the reef is subsurface, it trips the wave energy enough before it impacts the shore that you can get vegetation started on the shoreline,' he describes. By dissipating wave energy, the oyster reefs also encourage the deposition of sand.

"A 1,700-ft. reef in Dickinson, TX, and a 2,000-ft. reef in East Galveston Bay both show promising results. The Dickinson project started in 1997. 'We've cut the erosion rate in half over there, even with the oyster reef just starting to function. We're waiting now until the reef gets well established and colonized with oysters, then we'll start planting vegetation,' Seidensticker reports. Conditions in East Galveston Bay allowed

[474] http://gulf.rice.edu/coastal. As of the time of writing, this site was unavailable.
[475] Ibid., *vi*, *viii*.
[476] Ibid., *viii-ix*.

planting to start immediately after the reef was built. 'We've gotten a stand of grass already and essentially stopped the erosion.'

"Public response to the project has been enthusiastic. 'The oyster reef in itself is excellent habitat. In Galveston Bay we've lost a lot of our shallow oyster reef habitat because of subsidence and a lot of other things. And coincidentally, that's when our big erosion process started - when we lost that habitat,' he notes. Grants from the National Estuary Program, the US Environmental Protection Agency, the National Fish and Wildlife Foundation, and the Shell Oil Company Foundation have helped fund the projects."[477]

4 The Texas General Land Office has carried out wetland restoration and protection projects. One in 1999 was to restore Shamrock Island, which "is the remainder of a recurved barrier spit that once extended southwestward from Mustang Island into Corpus Christi Bay. The Island was separated from Mustang Island by Hurricane Celia in 1970. The Shamrock Island Preserve is owned by The Nature Conservancy of Texas. The Island is one of the most productive colonial waterbird nesting areas on the Texas coast. Coastal wetlands on or adjacent to Shamrock Island include marshes, mangroves, and seagrasses. Erosion is seriously threatening the Island's wetlands and other habitats. Plans are to protect the highly erosive, north and northwest shorelines with a 4,000 ft long geotube breakwater, nourish the southern shoreline with sand from the submerged part of the former spit, and plant five acres of marsh grass on the leeward side of the geotube. Construction began on December 7, 1998 and was completed on March 3, 1999. Marsh plantings occurred in September 1999 and the following spring."[478] Another action is that the General Land Office leases about 11,000 acres of state-owned land across four sites to the Texas Coastal Preserve Program to manage as coastal preserves.[479]

5 Since its inception, the Coastal Management Program (CMP) and the Coastal Erosion Planning and Response Act (CEPRA) program of the Texas General Land Office (GLO) has funded and carried out numerous projects. The CMP finalized an agreement with the U.S. Army Corps of Engineers "to beneficially use dredged material to nourish Texas beaches or create marshes." During the 76th Texas Legislative cycle (discussed as "Cycle 1," as this was the year the biannual Texas Legislature established CERPA) in 1999, "the GLO implemented the CEPRA program and built partnerships with coastal communities, state and federal agencies, technical experts, and affected landowners to combat erosion on barrier islands, tidal marshes, and bay shorelines. The GLO allocated funds to 34 erosion response projects and three scientific studies in Cycle 1. One-third of the projects focused on gulf beach restoration or dune construction, while two-thirds of the projects related to Bay Shore stabilization, marsh restoration, or bay beach restoration. Less than five percent of the state erosion response funds were spent on studies. Project partners were required to provide a 25% minimum-funding match of local funds or in-kind services for CEPRA projects in Cycle 1. By leveraging the initial $15 million with federal, local, and other sponsor funding, projects funded under Cycle 1 exceeded $22 million. Cycle 1 project achievements included restoration or protection of 23 miles of shoreline." Similarly, in 2001 (Cycle 2), the CERPA carried out 40 erosion response projects and nine related studies at a cost of $30 million. 28 of the projects involved construction that restored or protected 39.7 miles of shoreline. The activities included "placing sand on recreational gulf beaches as well as replenishing eroded bay beaches and providing shoreline protection to bay shorelines. Some erosion protection projects were coupled with marsh restoration work that will provide a habitat for wildlife in

[477] J. Kaspersen, "Beachfront Reinforcement," Erosion Control (July-August 2000). http://erosioncontrol.biz/july-august-2000/beach-front-reinforcement.aspx

[478] Texas General Land Office, "Coastal Issues - Shamrock Island" (March 2006). http://www.glo.state.tx.us/coastal/shamrock.html

[479] Texas General Land Office, "CCC - Texas Coastal Preserve Program" (November 2004). http://www.glo.state.tx.us/coastal/coastpres.html

addition to shoreline protection." In 2005 (Cycle 4), the CERPA funded 17 projects, including "several beach nourishment, marsh restoration and beach renourishment projects, sand source studies, beneficial use projects and shore protection projects."[480] In 2007 (Cycle 5), CERPA carried out a total of 58 projects at a cost of about $45 million (of which $17 million came from the state, and $28 million came from matching funds), including an erosion response project that protects "over 2,000 acres of wetland habitat at the Port Aransas Nature Preserves," engineering design for a project that will restore approximately 10,000 acres of degraded wetland complex in the Laguna Atascosa National Wildlife Refuge (project on hold pending funding), the second phase of an engineering study to evaluate the feasibility of restoring circulation to 20,000 acres of wetland, engineering design and permitting of 4,800 feet of segmented breakwater and armored shoreline revetment to address erosion along the Mad Island Wildlife Management Area, analysis of options to protect a five-mile long critically eroding segment of shoreline that includes 10,000 acres of fresh to intermediate marsh, the demolition of one structure, and the relocation of 15 structures.[481]

6 * In Galveston Island State Park in Texas, a wetland restoration project arranged the placement of fill material into a grid pattern, onto which vegetation was transplanted. "The grid provides for maximum edge, the single most important factor in the ecological success of constructed tidal wetlands."[482] An aerial view of the restoration project is available from Google Maps,[483] and aerial and orthographic views are available from Bing Maps.[484]

7 In 2008, The Commissioner of the Texas General Land Office announced $17.3 million in funding for the Coastal Erosion Planning and Response Act program, fulfilling funding goals and needs identified by the "Coastal Texas 2020" initiative. The funding is devoted to fewer but larger-scale projects, with $9.6 million of the total going towards four projects, including "$5 million for the biggest beach restoration effort in Texas history in Galveston, $2.1 million to renourish more than a mile of beach in South Padre, $1.1 million for shoreline stabilization in Surfside and $1.4 million for a shoreline stabilization and beach renourishment project along the Houston Ship Channel… Other projects funded through the coastal grants include the removal of private houses off the public beach, smaller beach renourishment efforts to patch up storm-ravaged beaches and sand source studies. Also included are vital U.S. Army Corps of Engineers studies to determine the cause and severity of erosion along the Texas coast, and to suggest erosion response alternatives. These studies help Texas qualify for federal funding."[485]

8 * A presentation given at the June 2009 "Caring for the Coast: Texas Coastal Conference 2009" discussed a new technique used by the Armand Bayou Nature Center to restore wetlands: "Armand Bayou is a tidal stream located in southeast Harris County Texas near Galveston Bay. There has been an estimated 93% reduction in tidal marsh habitat since the 1950's due largely to the effects of subsidence in the Armand Bayou watershed. Armand Bayou Nature Center

[480] Texas General Land Office and Veterans Land Board, "Agency Strategic Plan: Fiscal Years 2007-2011" (July 2006): 29-30. http://www.masgc.org/gmrp/plans/TX%20GLO3.pdf

[481] Texas General Land Office, "CERPA Coastal Erosion Planning & Response Act: Report to the 81st Texas Legislature" (January 2009): 13-30. http://www.glo.state.tx.us/coastal/erosion/CEPRA-LegReport2009/CEPRALegeReport2009.pdf

[482] J. Jacob and S. Showalter, "The Resilient Coast: Policy frameworks for adapting the Wetlands to climate change and growth in coastal areas of the U.S. Gulf of Mexico," Texas Sea Grant (August 2007): 26. http://www.urban-nature.org/publications/documents/ResilentCoastWetlands-sm.pdf

[483] http://maps.google.com/maps?ll=29.201023,-94.970112&spn=0.020154,0.038581&t=h&z=15

[484] http://www.bing.com/maps/default.aspx?v=2&FORM=LMLTCP&cp=nw0wbp72kbnv&style=b&dvl=1&tilt=-90&dir=0&alt=-1000&phx=0&phy=0&phscl=1&scene=35375642&encType=1

[485] Texas Coastal Connection, "Patterson marks progress in fight against coastal erosion," Texas General Land Office (January 2008). http://www.glo.state.tx.us/coastal/tcc/hottopics/2008jan-CoastalErosion.html

(ABNC) has conducted extensive marsh restoration efforts for over a decade in an effort to mitigate these impacts using traditional planting strategies. Recent efforts have focused on a new innovative technique, which mimics the horticultural practice of using 'peat pots' which have been modified for the marine environment.

"These baskets are constructed by enclosing a three-gallon rootball of California bulrush (*Schoenoplectus californicus*) in chicken wire. Three to four fist size pieces of concrete ballast are added under the root ball to ensure that the basket is held on the bayou bottom during early root development. This ballast is of particular importance during high wind and wave activity when young propagules may be uprooted in the turbulent environment.

"After the basket construction is complete they are deployed by boat by simply tossing them over the side. The wire decomposes over a relatively brief time period allowing rhizome growth to expand.

"There are many advantages to using this technique. First they are easy to deploy by gently tossing them into the restoration site. Secondly, plants have an excellent success rate with approximately 80% surviving. Third, these propagules are capable of surviving in deeper water than those installed using traditional planting techniques. Fourth, the ability to establish intermediate marsh in these deeper zones translates into greater marsh acreage created."[486]

[486] M. Kramer, Bulrush Baskets-An Innovative Approach to Wetland Restoration in Armand Bayou," Caring for the Coast: Texas Coastal Conference 2009 (June 2009): 1. http://www.glo.state.tx.us/coastal/tcc/hottopics/conference2009abstracts/03-Concurrent%20Sessions130-300pm/Session2-CoastalHabitatRestoration-RegulatoryUpdates/Kramer.pdf

Virginia

Research

1 * A 2001 paper from the Virginia Institute of Marine Science at the College of William and Mary reviews the existing knowledge base of tidal salt marsh restoration in the Chesapeake Bay.[487] It emphasizes "creation of oligohaline (5 - 12 ppt), mesohaline (12-22 ppt), and polyhaline (>22 ppt) marshes" and includes "recommendations for determining appropriate siting, design, and construction methods. Three constructed salt marsh projects are reviewed and recommendations for improvements in design and construction are presented."[488]

Citing studies as well as personal experience of the authors, the study notes that causes for failure include positioning created marsh too far from a tidal source, loss of plantings due to too large a fetch and/or excessive wave activity, grazers (such as muskrats and geese), foot and boat traffic, and collection of floating debris on new plantings.

"In a 1996 Virginia Institute of Marine Science survey of ecologists and managers on created salt marshes, sent out and compiled by the first author [Perry], improper elevation was the most common problem the respondents encountered. This was followed closely by erosion of plantings due to natural causes or boat wakes, and poor planting techniques. Several responders noted problems with invasive species (*Phragmites australis*), poor plant stock (improper handling), improper planting techniques, and poor substrate (high clay content). Inherent in the construction of marshes is the problem associated with the destruction of plants by

[487] J. Perry et al. "Creating tidal salt marshes in the Chesapeake Bay," Journal of Coastal Research, Special Issue 27 (2001): 170-191. http://ccrm.vims.edu/livingshorelines/documents/HowTo/Creating_Tidal_Salt_Marshes.pdf

[488] Ibid., 170.

various animals and the invasion of the newly constructed marsh by undesirable plant species. Three of the most destructive animals are geese, muskrats, and nutria… Geese will uproot vegetation and consume roots and rhizomes resulting in 'eat out' patches within a marsh (Kerbes *et al*, 1990; Miller *et al*., 1996). Geese have been reported to remove as much as 1 m^2 of *Carex subspathacea* in one hour (Kerbes *et al*., 1990) and graze for up to 18 hours per day on salt marsh flats (Bazely and Jefferies, 1986). Griffith (1940) noted that a flock of 5,000 geese can strip a 300 acre *Spartina alterniflora* marsh in 6 weeks, and Reimold *et al*. (1975) reported a 70% reduction in primary production in a grazed *Spartina alterniflora* - *Distichlis spicata* marsh as compared to an ungrazed marsh. Goose 'eat outs' can lower the marsh surface by as much as 5 cm (Griffith, 1940) with soil disruption to 20 cm (Lynch *et al*., 1947). Muskrats, as with geese, can cause patchy 'eat out' areas in marshes. Muskrats tend to disrupt marshes by feeding on the stems, rhizomes, and tubers (Fuller *et al*., 1985). New shoots are heavily grazed (Linscombe *et al*., 1980), and muskrats appear to have a preference for rhizomes (Campbell and MacArthur, 1994)."[489]

"Ankney (1996) advocates a change in management regulations to allow more harvesting as a method for reducing geese populations. Wire enclosures are successful in protecting marsh vegetation but may be cost prohibitive for expansive areas (Bazely and Jefferies, 1986; Ankney, 1996). There have been anecdotal reports that stretching wire or rope across marshes may prohibit geese from landing, and the application of some commercially available substances to plants may make them unpalatable to geese; however, empirical data are lacking. Trapping is recommended as the most effective means to control overpopulation of muskrats with harvesting starting when muskrat density reaches one house per acre (Dozier, 1953)."[490]

Other recommendations are to avoid small peninsulas or points of land reaching into a body of water as a choice for planting marshes, and to avoid areas with historically high erosion rates or highly erodible soils. The correct substrate elevation is critical to the success of created tidal marsh. When possible, the study recommends determines the correct substrate elevation by consulting nearby marshes. When not possible, the study presents a method based on using tide gauge data. The study warns against "cation rich soils (cat-soils), which occur both naturally and as the result of anthropogenic processes (previously drained marsh soils). Upon rehydration, hydrogen sulfides form in the soil, pH decreases, and re-vegetation becomes nearly impossible. Liming of these soils has shown some positive effects (Broome, 1990)."[491]

The paper contains other observations and recommendations, as well as three case studies.

2 From 1993 to 2004, Virginia approved a total of 229.2 miles of shoreline erosion control structures, consisting usually of about 5 miles of bulkheads and 10-20 miles of revetments.[492]

3 According to data from the Virginia Institute of Marine Sciences at the College of William and Mary and the National Wetlands Inventory, as of 2005 Virginia had 222,368 acres of vegetated tidal wetlands, and 116,210 acres of non-vegetated tidal wetlands. In 2001, 2002, and 2004, vegetated tidal wetlands lost about 5-6 acres a year, and in 2003 vegetated tidal wetlands lost about 25 acres. In 2001 and 2004, non-vegetated wetlands losses about 33-34 acres; losses were 69 acres in 2002, and 112.5 acres in 2003. As of 2005, there was no available information about publicly acquired, restored or created wetlands in Virginia.[493]

[489] Ibid., 174-175.
[490] Ibid., 179.
[491] Ibid., 176-178.
[492] Virginia Institute of Marine Science, "Annual Summary of Permitted Tidal Wetland Impacts - 2004," The Virginia Wetlands Report 20(1) (Spring 2005): 3. http://ccrm.vims.edu/publications/publications_topics/vwr/VWR%202005%20Spring.pdf
[493] Virginia Coastal Zone Management Program, "Draft - Enhancement Area Assessments & Strategies: Wetlands," Virginia Coastal Needs Assessment (2006): 1. http://www.deq.virginia.gov/coastal/documents/06309wet.pdf

4 * A 2006 Masters thesis from the School of Marine Science at the College of William and Mary entitled "Wetland vegetation dynamics and ecosystem gas exchange in response to organic matter loading rates" includes the finding that adding large amounts of mulch can be indirectly detrimental to wetland health. The raised ground surface makes soil dry out more quickly and remain dry longer, allowing upland plants to invade. This study is part of a group at the School of Marine Science that studies created wetlands.[494]

5 The Department of Environmental Quality (DEQ) has "drafted a ten-year strategy for wetland monitoring and assessment in Virginia that is based upon EPA monitoring and assessment protocols. Rather than focusing on intensive monitoring of the quality of wetlands for the purposes of setting wetland water quality standards, Virginia's strategy is to use a three-tiered approach to wetlands assessment, which is currently being developed by Virginia in conjunction with other EPA-Region III states. This approach is designed to generate a nested data set, with a common minimum data set available for all identified wetlands in the state, and more extensive information available for selected subsets of wetlands and watersheds. This assessment approach will generate data used to conduct biannual reporting on the status and trends of wetlands as part of Virginia's 305(b)/303(d) Integrated Report, and to evaluate the effectiveness of regulatory and voluntary programs in meeting Virginia's mandate of a) no net loss of wetland resources through regulatory programs, and b) a net resource gain through voluntary programs. Development of DEQ's Wetland Monitoring and Assessment Strategy is being funded by a State Wetland Program Implementation Grant from the U.S. Environmental Protection Agency."[495]

6 A 2007-2008 study out of the Virginia Institute of Marine Science at the College of William and Mary created maps of "anticipated loss to tidal wetlands habitat in the Lynnhaven River watershed attributed to sea level rise. The project uses remote sensing techniques and high-resolution imagery to delineate current wetlands distribution. High resolution elevation data generated from LIDAR [was] used to compute the horizontal and vertical inundation due to sea level rise." The project cost $31,462 and was funded by the Virginia Environmental Endowment.[496]

7 A seminar in 2008 focused on aspects of designing and building 'living shoreline' projects. Slides from the seminar are available online.[497]

8 "The Chesapeake Bay Program's Scientific and Technical Advisory Committee projects that sea levels in the Chesapeake Bay region will be 0.7-1.6 meters (2.3-5.2 feet) higher by 2100. Specific impacts will vary by location, depending on changes in land elevation."[498]

9 * In December 2006, the Chesapeake Bay National Estuarine Research Reserve in Virginia hosted the Living Shoreline Summit in Williamsburg, Virginia. The summit "included individuals from local, state and federal government, county and city wetlands boards, non-profit organizations, environmental consultants, state and local regulatory boards, academicians, marine contractors, local nurserymen, and private landowners." The majority of state representatives were from Virginia, Maryland, and North Carolina. The proceedings of this summit were published in 2008 as

[494] The Crest, "Research Helps Created Wetlands Come to Life," Virginia Institute of Marine Science Coastal Research. http://www.vims.edu/_docs/created_wetlands82.pdf. Thesis by D. Bailey. http://www.vims.edu/research/topics/coastal_research/index.php

[495] Ibid., 6.

[496] Center for Coastal Resources Management, "Annual Report 2008," Virginia Institute of Marine Science (2008): 15. http://ccrm.vims.edu/publications/annual_reports/08AnnRpt.pdf and http://ccrm.vims.edu/publications/completed_projects/index.html

[497] CCRM Presentations, "Putting Nature to Work: How to Design and Build Living Shoreline Projects - October 24, 2008" (October 2008). http://ccrm.vims.edu/education/seminarpresentations/fall2008/index.html

[498] Governor's Commission on Climate Change, "Final Report: A Climate Change Action Plan" (December 2008): 5. http://www.deq.virginia.gov/export/sites/default/info/documents/climate/CCC_Final_Report-Final_12152008.pdf

"Management, Policy, Science and Engineering of Nonstructural Erosion Control in the Chesapeake Bay."[499]

The paper "Integrating Habitat and Shoreline Dynamics Into Living Shoreline Applications" analyzes the overall status of living shorelines: "The use of 'Living Shorelines' techniques is an evolving science. There has not been as much study of the different techniques involved in the living shoreline approach in contrast to armored shoreline techniques. Nor has there been much development of guidance to the types of approaches that work best within different ecological settings. Therefore, as we move forward to determine what techniques most effectively reduce erosion and provide habitat, we need to also consider how these techniques fit into and work with the natural environment where they will be constructed. It is important to emphasize that most shoreline property owners are primarily concerned about shore erosion. Contractors and others who provide consultation on shoreline matters are typically only asked to visit a shoreline when there is an erosion 'problem.' In many cases, there is no 'problem' at all. For the most part, erosion is a natural process and one that is critical to the ecological health of estuarine areas, providing sediment for new habitat, creating new habitat in eroded shores, and if not accelerated through anthropogenic activity, useful in transporting accumulated nutrients and organisms downstream. However, erosion is certainly considered a problem by shoreline property owners who may be losing large areas of property to wave and tidal energies. Hence, the erosion issue is a critical part in developing a living shoreline project. As a relatively new approach, living shorelines need property owner acceptance and even a few failures can severely impede adoption by other owners for a fledgling erosion strategy. Many owners are skeptical of living shoreline practices and may only be interested if they see that these methods work elsewhere; only then will the methods be employed."[500]

The paper "Design Criteria for Tidal Wetlands" notes, "The design and construction of tidal wetlands can often be a perplexing, mystifying process. Many of the techniques are solely the domain of practicing professionals which leaves many individuals and organizations at a loss when contemplating a project." The paper sets out to "present practical guidelines that can be used by the lay person as well as restoration practitioners for the successful construction of tidal wetlands. These include screening criteria for site selection that will help avoid inherent problems with a particular site and design criteria to guide the development of wetland hydrology and the successful establishment of wetland vegetation." Design criteria are landscape position, elevation (including taking future sea level rise into account), slope, hydrology, substrate, salinity consideration, zonation and salinity regimes, planting materials and methods, fertilizer, planting times, and maintenance. Each is briefly discussed.[501]

In a panel session, "Current Understanding of the Effectiveness of Nonstructural and Marsh Sill Approaches," panelists' "collective experience revealed that planted tidal marshes and supporting structures can be effective alternatives to revetments and bulkheads. Site-specific engineering is required to ensure they provide functional ecological benefits, particularly in medium and high energy settings. Another important factor for effective projects is landowner acceptance of dynamic shoreline conditions and the level of protection provided. Additional project tracking and research is needed to further investigate positive and adverse effects of created tidal marshes and supporting structures." One panelist described, "Qualitative field evaluations of 36 tidal marsh protection structures were conducted in 2004 and 2005 in six localities on the Northern Neck and Middle Peninsula of

[499] S. Erdle, J. Davis, and K. Sellner, eds., "Management, Policy, Science and Engineering of Nonstructural Erosion Control in the Chesapeake Bay: Proceedings of the 2006 Living Shoreline Summit," CRC Publication No. 08-164, Gloucester Point, VA (2008). http://web.vims.edu/cbnerr/pdfs/2006LivingShorelineProceedings/2006_LS_Full_Proceedings.pdf

[500] Ibid., 9.

[501] Ibid., 25-31.

Virginia… Several practices were found to be less effective for reducing erosion or they adversely impacted habitat functions of the tidal marshes. For the marsh protection structures, tidal exchange within the marsh was sometimes restricted by tightly packed stone or the structure height. Structures placed adjacent to spit marsh features were also found to be less effective. For the nonstructural methods, planted marshes were most successful where regular high tides do not reach the upland bank and when the vegetation was planted in early spring. Graded banks without a marsh terrace or a dense cover of riparian vegetation remained vulnerable to erosion and storm waves. Due diligence by property owners and contractors for routine inspections and repairs was another common factor in effective projects, both structural and nonstructural."[502]

The paper "A Comparison of Structural and Nonstructural Methods for Erosion Control and Providing Habitat in Virginia Salt Marshes" takes results from a recent field survey of 36 tidal marsh stabilization structures, permitting records, and other monitoring data, and used these results to evaluate the effectiveness of marsh stabilization structures (marsh toe revetments and sills), planted tidal marshes, and bank grading for preventing erosion and providing habitat. A table summary lists advantages and disadvantages of each method. Marsh toe revetments and sills reduced waves and had longevity, but interrupted fish/wildlife movement and diffracted waves. Planted tidal marshes (at grade) provided fish/wildlife habitat and buffered nutrient and sediment inputs, but erosion protection was limited, and the planted marshes required diligent maintenance and storm repairs. Bank grading was easily combined with other methods, and improved access for maintenance, but led to sediment runoff during land disturbance, and necessitated toe protection in the wave strike zone.[503]

The paper "Regulatory Program Overview for Virginia's Submerged Lands and Tidal Wetlands and Options for Promoting Living Shorelines" describes the "state and local regulatory process for submerged lands and tidal wetlands as it relates to shoreline erosion control projects in Virginia," discusses "initiatives currently underway or [in] planning by the Virginia Coastal Zone Management Program to improve shoreline management and promote the use of living shorelines," and reviews "the options for promoting living shorelines identified during the Living Shoreline Summit panel discussion."

Another paper is a NOAA presentation about its Shoreline Management Technical Assistance Toolbox.

The paper "Living Shorelines: A Strategic Approach to Making it Work on the Ground in Virginia" notes that 85% of tidal shoreline in the Chesapeake Bay and its tributaries is privately owned, so coastal management can only be achieved with the involvement of individual landowners, marine contractors, municipal governments, and local conservation organizations. "Wetlands Watch, a conservation group in southeastern Virginia, examined ways to influence those landowner/contractor/local government decision points on shoreline alteration. We found little published social science and policy guidance on possible approaches to this task. We did assemble a range of fairly simple policy and programmatic initiatives that could translate Bay-wide living shoreline visions into a more effective strategy for locally based activities." The paper recommends a strategic approach with the following elements:
1) Strategic investment in demonstration products;
2) Enhanced attention to the outreach and education elements of funded projects;
3) Better understanding of how the regulatory process impedes or speeds these projects;
4) Development of a contractor community capable of delivering desired services as demand is built;
5) Analysis of approaches used to change behavior/adopt new technologies in other areas, such as the adoption of no till-farming;

[502] Ibid., 37-38.
[503] Ibid., 41, 46.

6) Work on model zoning and planning tools to create regulatory incentives for living shorelines; and
7) Creation of financial incentives for living shorelines.[504]

The concluding paper, "Living Shorelines in the Chesapeake Bay: Needs and Recommendation for Future Action" identified five areas that the summit participants had identified as key issues: outreach and education, incentives, data and tools, research, and planning/policy/regulation.[505]

Policy

1 In 2005, the Virginia Coastal Zone Management Program created a five-year Assessment and Strategy for 2006-2010, the sequel to a five-year plan the Program created in 2000.[506]

In characterizing coastal hazards, the Strategy lists sea level rise as posing a "medium" level of risk (out of low, medium and high) in both 2000 and 2005. It states, "Although Sea Level Rise has not contributed to any documented risk in the past, there is a growing concern about its impact on shoreline management. Researchers at USGS have estimated relative sea level rise along the mid-Atlantic coast at 4 millimeters per year. However, wetland accretion rates are estimated at only 2 millimeters per year. The long-term result could be vast submergence of coastal wetlands. Coupled with both episodic and chronic shoreline erosion, this could become an even greater problem. While research is being conducted at the Virginia Institute for Marine Science (VIMS) on the potential impact of this combination, a management strategy has yet to be developed to address it."[507]

The Strategy also notes, "The lack of accurate, current information on shoreline erosion remains another significant impediment… There is a need to better understand the degree to which this condition (i.e. shoreline erosion) persists and is problematic within the coastal zone. There are no regional studies that report shoreline erosion or accretion trends in Virginia after 1983. Related to shoreline erosion, there is also a lack of information on the effect of sea level rise on coastal development *and* marshes. Another major impediment is the ability to acquire land for shoreline protection. Coastal land values continue to rise, making public acquisition of easements, purchase of development rights, or other acquisition increasingly difficult."[508]

It recommends, "A gap that could be filled by the Coastal Program would be to fund regional studies on shoreline erosion and accretion trends, as well as the effect of sea level rise on coastal development *and* marshes. More specifically, the Shoreline Inventory should be updated, shoreline evolution studies conducted, and shoreline management techniques identified and assessed." Also recommended is advocacy for 'living shorelines' and acquisition of the necessary technology for GIS-based mapping.[509]

In characterizing wetlands, sea level rise is listed as not having been evaluated in 2000, but is now evaluated as a threat of "High" significance (out of "High," "Medium" and "Low"). "Two issues associated with sea level rise cause threats to tidal wetlands. First, the methods commonly used to protect shorelines against erosion reduce the amount of sediment available in the littoral system for marshes to trap and keep pace with historic sea level rise; consequently, current rates of sea level rise appear to be out-pacing the capacity of some wetland communities to

[504] Ibid., 99, 101-103.
[505] Ibid., 125.
[506] Virginia Coastal Zone Management Program, "Final Draft: Section 309 Needs Assessment," Virginia Coastal Needs Assessment (October 2005): 1. http://www.deq.virginia.gov/coastal/documents/06309intro.pdf
[507] Virginia Coastal Zone Management Program, "Draft - Enhancement Area Assessments & Strategies: Coastal Hazards," Virginia Coastal Needs Assessment (2006): 1. http://www.deq.virginia.gov/coastal/documents/06309ch.pdf
[508] Ibid., 5.
[509] Ibid., 6.

maintain appropriate elevations. Second, where shorelines are hardened wetlands cannot shift inland as the sea level rises, so wetlands are lost as they convert to subaqueous land."[510]

"The next logical step in managing Virginia's wetlands is to develop a 'Net Gain' policy including specific measures that would help the state achieve this goal." To do this, the Strategy recommends increasing personnel to help identify sites for restoration, creation and acquisition, and to monitor such sites after restoration, creation or acquisition. As the value of coastal properties has increased as much as 400% from 1999-2005, new funding sources are needed to acquire coastal wetlands.[511]

2 The 2005 "Interagency Shoreline Management Consensus Document" gives a preferred order for shoreline stabilization approaches. From most preferable to least preferable, the options are no action, marsh planting, bank grading with restoration of natural vegetation, sill/marsh toe protection, breakwater, groins (alone) with adequate sand supply, revetment, and bulkhead. The order of this preference is based primarily on least adverse environmental impacts. The document also gives preferred protection for shoreline habitats, which ranks habitats based on importance of water quality functions. From most preferable to least preferable, the habitats are: vegetated wetlands greater than 16 feet in width, natural mixed-strata/forested riparian area, vegetated wetlands less than 16 feet in width, single line of trees, nonvegetated wetlands, and lawn.[512]

3 In 2006, Governor Timothy Kaine signed Executive Order 21, renewing the Virginia Coastal Zone Management Program. The 'Policy Goals' make no explicit mention of climate change or global warming, or sea level rise, but Goal 4 is "To reduce or prevent the losses of coastal habitat, life and property caused by shoreline erosion, storms, and other coastal hazards in a manner that balances environmental and economic considerations."[513]

4 The Commission on Climate Change, established by Governor Timothy Kaine in 2007, issued its final report in 2008. It notes that Virginia' 112 miles of coastline and 3,300 miles of tidal shoreline make it particularly vulnerable to sea level rise, and that "Coastal wetlands, a critical habitat for many of the Chesapeake Bay's plants and animals, are being lost as sea levels rise, and freshwater coastal wetlands are similarly threatened by saltwater intrusion." It also notes, "coastal wetlands that are expected to become 'squeezed' between rising sea levels and the built environment." The report recommends, "The Secretary of Natural Resources should lead an inter-agency and intergovernmental effort to develop a Sea Level Rise Adaptation Strategy by January 1, 2011. The Sea Level Rise Adaptation Strategy should encompass the full range of policies, programs, and initiatives that will be required to adapt in the areas of natural resources, economy, and infrastructure and any other area impacted by sea level rise." The report recommends preparing for at least a 2.3 ft rise in sea level.[514]

5 In 2006, the Virginia Coastal Zone Management Program held a "Living Shoreline Summit" in December 2006, with peer reviewed proceedings published in 2008 (see Virginia-Research-9). This was part of an effort by the Virginia Coastal Zone

[510] Virginia Coastal Zone Management Program, "Draft - Enhancement Area Assessments & Strategies: Wetlands," Virginia Coastal Needs Assessment (2006): 3. http://www.deq.virginia.gov/coastal/documents/06309wet.pdf

[511] Ibid., 9.

[512] Center for Coastal Resources Management, Virginia Institute of Marine Science, "Interagency Shoreline Management Consensus Document," Virginia Coastal Program and Department of Environmental Quality (May 2005): 8, 10, 12. http://ccrm.vims.edu/publications/pubs/shoreline_project_elements_3.pdf

[513] Office of the Governor, "Executive Order 21: Continuing the Virginia Coastal Zone Management Program," Commonwealth of Virginia (2006): 2. http://www.governor.virginia.gov/Initiatives/ExecutiveOrders/pdf/EO_21.pdf, http://www.deq.virginia.gov/coastal/exorder.html

[514] Governor's Commission on Climate Change, "Final Report: A Climate Change Action Plan," Virginia Department of Natural Resources (December 2008): 7, 62, 36, 60. http://www.deq.virginia.gov/export/sites/default/info/documents/climate/CCC_Final_Report-Final_12152008.pdf

Management Program to target shoreline management and focus on promoting living shorelines. Beyond this summit, the Program has slated $750,000 over a five-year period to revise guidelines, improve data and research, produce guidance documents, conduct outreach, and establish training programs.

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. However, as mentioned above in Virginia-Policy-1, the Coastal Zone Management Program has recognized this gap. In addition to promoting living shorelines, Virginia has numerous restoration projects and related initiatives, some aspects of which are described below.

2 "The first freshwater tidal mitigation bank, the Heartquake Wetlands Bank, was established by JPM, Inc. [an entrepreneurial venture] in 2003. Located in King and Queen County, the bank consists of 35 acres along the Heartquake Creek. Also, the first saltwater tidal mitigation bank has been created in response to the new Wetlands Compensation Mitigation Policy. The Libertyville Tidal Wetlands Bank consists of about 7.5 acres of created wetlands in the city of Chesapeake to be sold as compensation for shoreline development that encroaches on wetlands. This is a positive first step in the implementation of the new policy and bears watching in the coming years."[515]

3 The 2006 "Virginia Coastal Needs Assessment" recognizes that "Virginia's Wetlands Mitigation-Compensation Policy for tidal wetlands from 1993-2004 did not accomplish the 'no net loss' goal, as there was a net loss of 132 permitted tidal acres during this period." One problem was that "this policy allowed projects affecting less than 1,000 square feet of tidal wetlands to proceed without mitigation requirements… this allowance was probably the cause of the wetlands losses for the previous 10 years." To respond to this, the Virginia Marine Resources Commission used a 2005 grant from "to adopt revisions to the Wetlands Mitigation-Compensation Policy, which intend to achieve 'no net loss' of tidal wetlands by requiring 'compensation of all permitted tidal wetlands losses.' This updated policy removes all minimum area exemptions and allows compensation requirements to occur through mitigation banks. Compensation can happen on or off site, through mitigation banks, or, as last resort, in the form of in-lieu fees. In-lieu fees would be applied to wetlands restoration and creation projects."[516]

4 "There are several restoration and creation programs throughout the state for both tidal and nontidal wetlands. However, comprehensive data concerning the numbers and functions of the various created and restored wetlands has been difficult to acquire. The Virginia Department of Environmental Quality (DEQ) and the Virginia Marine Resources Commission (VMRC) report that wetland restoration and creation have served to offset permitted non-tidal wetland losses. However, losses due to unregulated activities are the main contributor to the net loss of wetlands in Virginia… Several private and public sector groups are working to restore wetlands in Virginia. The Elizabeth River Project (ERP) has been involved with and worked with the cities of Chesapeake and Norfolk on small tidal wetland restoration projects. Also, through ERP's River Stars Program, several businesses along the river have funded their own wetland restoration projects on site. These projects are small; usually far less than one acre and total numbers of acres are not known. Furthermore, the Navy has been restoring tidal wetlands as a part of Superfund at a rate of about one acre per year."[517]

[515] Virginia Coastal Zone Management Program, "Draft - Enhancement Area Assessments & Strategies: Wetlands," Virginia Coastal Needs Assessment (2006): 8. http://www.deq.virginia.gov/coastal/documents/06309wet.pdf

[516] Ibid., 5.

[517] Virginia Coastal Zone Management Program, "Draft - Enhancement Area Assessments & Strategies: Wetlands," Virginia Coastal Needs Assessment (2006): 2.

Washington

Research

1 A worksheet prepared for a King County Conference on Climate Change in October 2005 lists strategies to prepare Washington State for climate change, including discouraging development in coastal hazard areas, moving or abandoning shoreline infrastructure, preserving ecological buffers to allow for inland beach migration, restoring wetlands for run-off storage and flood control, and recognize negative consequences for shoreline habitat.[518]

2 * A 2006 report presented to the Puget Sound Action Team "is an evaluation of alternatives to traditional shoreline armoring practices and applications in Puget Sound. Alternatives are described for this study as any techniques of shoreline stabilization or erosion control other than conventional concrete, rock, or log bulkheads. This report presents the findings of the study. It includes discussion of project design and application effectiveness in addressing perceived and observed site slope stability and erosion concerns on Puget Sound shorelines and offers some general recommendations for future applications."

"Our findings indicate that the process of advocating for, permitting, designing, and installing/constructing alternatives to traditional bulkheads would benefit from more coordinated objectives and guidelines from permitting agencies. It appeared that site characterization in some instances was deficient in assessing geologic, hydrologic, and coastal geomorphic processes contributing to the issues being addressed in the project implementation, and that plantings did not always consider local site conditions.

"Perceived issues and concerns of the property owner, those triggering the property owner's initial shoreline modification permitting request, were over-emphasized at some sites, leading to apparent over-design of, and possibly unnecessary mitigation.

"Vegetation planted at some sites, even when native to the region, often did not thrive, likely due to unsuitable site conditions. In Table 1 we document our observations on geology, slope processes, and vegetation for each site for comparison between sites.

"Requiring more complete, and possibly interdisciplinary, site characterization as part of the permitting process could ultimately reduce project costs and environmental impacts. Additional improvements need to be made in the depth and availability of information provided to shoreline property owners, who are being asked to consider alternatives to the traditional log, concrete, and rock armoring. We found shoreline property owners, although often willing to be test cases, commonly lacked readily accessible information on the rationale for implementing shoreline armoring alternatives, and received minimal guidance on how to pursue implementing these alternatives.

"We learned from our interviews with contractors that there is a need for information and guidance on material resources and design specifications for these alternative projects. They felt sediment-size specifications for 'beach nourishment' components often seemed arbitrary, and locating sources for the specified materials was difficult. Several contractors commented on the lack of engineering specifications for anchor pull-out design in the beach environment, forcing a 'best guess' and possibly overly conservative approach.

"Providing this type of information, and stream-lining the permitting process, could lessen the uncertainty, confusion, and frustration currently experienced by homeowners and contractors, and would

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http://www.deq.virginia.gov/coastal/documents/06309wet.pdf

[518] J. Kay et al, "Coasts Breakout Session," University of Washington Climate Impacts Group (October 2005): 1. http://cses.washington.edu/db/pdf/kc05coast474.pdf

serve to encourage more alternative projects."[519]

3 A 2007 Masters of Marine Affairs thesis from the University of Washington examines barriers and opportunities in responding to sea level rise for the regulatory and institutional structures surrounding coastal zone management in Puget Sound, Washington. The author gives four recommendations for local government: "1) Increase the update frequency for floodplain maps to more accurately reflect environmental changes. 2) Include consideration of a dynamic shoreline when making shoreline armoring, cumulative impacts, and no net loss of ecological function determinations. 3) Use shoreline designations in the Shoreline Management Act to tailor responses to the coastal environment. 4) Leverage the Federal Consistency and funding provisions of the Coastal Zone Management Act to enhance response options."[520]

The author of this thesis also gave related a presentation at the 15th Biennial Coastal Zone Conference in Portland, Oregon in 2007, entitled "Adapting decision making to uncertainty when addressing sea level rise response in Puget Sound."[521]

4 A 2007 report from the National Wildlife Federation "investigates the potential impact of sea-level rise on key coastal habitats in the Pacific Northwest. In addition to raising awareness of the threat, the results of the study will assist coastal managers and other relevant decision-makers identify and implement strategies to minimize the risks. We used the Sea Level Affecting Marshes Model (SLAMM), which simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea-level rise. This model was applied to 11 different sites in Puget Sound and along the Pacific Coast in southwestern Washington and northwestern Oregon.

"Our analysis looked at a range of Intergovernmental Panel on Climate Change (IPCC) sea-level rise scenarios, from a 0.08 meter (3.0 inch) rise in global average sea level by 2025 to a 0.69 meter (27.3 inch) rise by 2100. We also modeled a rise of up to 2 meters (78.7 inches) by 2100 to accommodate for recent studies that suggest sea-level rise will occur much more rapidly during this century than the IPCC models have projected. Results for each study site are based on relative sea-level rise for the given region, taking into consideration regional changes in land elevation due to geological factors, such as subsidence and uplift, and ecological factors such as sedimentation and marsh accretion. Full model results are available from the National Wildlife Federation.

"Model results vary considerably by site (see Table 1), but overall the region is likely to face a dramatic shift in the extent and diversity of its coastal marshes, swamps, beaches, and other habitats due to sea-level rise. For example, if global average sea level increases by 0.69 meters (27.3 inches), the following impacts are predicted by 2100 for the sites investigated:
– Estuarine beaches will undergo inundation and erosion to the tune of a 65 percent loss.
– As much as 44 percent of tidal flat will disappear.
– 13 percent of inland fresh marsh and 25 percent of tidal fresh marsh will be lost.
– 11 percent of inland swamp will be inundated with salt water, while 61 percent of tidal swamp will be lost.
– 52 percent of brackish marsh will convert to tidal flats, transitional marsh and saltmarsh.
– 2 percent of undeveloped land will be inundated or eroded to other categories across all study areas."

The report has three main recommendations

[519] W. Gerstel and J. Brown, "Alternative Shoreline Stabilization Evaluation Project: Final Report," prepared for the Puget Sound Action Team (September 2006): 3-4. http://courses.washington.edu/lkwasrvy/spo/files/PSAT_Alt_Shoreline_Report.pdf

[520] A. Petersen, "Anticipating Sea Level Rise in Puget Sound," University of Washington M.M.A. Thesis (2007): Abstract. http://www.cses.washington.edu/db/pdf/petersenthesis559.pdf

[521] Center for Science in the Earth System, "Publications: View: Abstract," University of Washington. http://www.cses.washington.edu/db/pubs/abstract541.shtml

for coastal management officials: account for global warming in habitat restoration efforts; explicitly consider climate uncertainties; and incorporate sea-level rise in coastal development plans.[522]

5 A September 2007 guide, written jointly by the University of Washington and the International Council for Local Environmental Initiatives (ICLEI), strives to help decision-makers in local, regional and state governments prepare for climate change. Increased erosion for coastal natural features and loss of wetlands from sea level rise are listed as sample potential climate change impacts. A suggested Guiding Principle is to increase the adaptive capacity of natural systems including wetlands, and protecting riparian wetlands is given as an example of a "win-win" action that reduces impacts of climate change while providing other environmental, social and economic benefits.[523]

6 A January 2008 report by the University of Washington Climate Impacts Group and the Washington Department of Ecology reviews available sea level rise projections. As a medium estimate, in Puget Sound local sea level rise will closely match global rates, and at the northwest Olympic Peninsula, tectonic uplift will result in very little relative sea level rise. Less data is available for the central and southern Washington coast, but what information does exist suggests that these areas will experience uplift but at a rate less than that of Olympic Peninsula.

The study stresses that (1) the calculations have not formally quantified the probabilities, (2) sea level rise cannot be estimated accurately at specific locations, and (3) the provided numbers are for advisory purposes and are not actual predictions.[524]

7 A 2009 Master of Marine Affairs thesis at the University of Washington examines climate change impacts to state-owned aquatic lands, and proposed adaptation strategies for the Washington Department of Natural Resources (WDNR) Aquatic Resources Program. The first 'priority planning area' identified by the thesis is sea level rise, which presents several management challenges.

The shifting location of state-owned aquatic lands is the first management challenge. While the Washington Administrative Code 332-30-060 defines tidelands dynamically by high tide and low tide, and takes into account accretion and erosion, cases of avulsion (defined as "a sudden and perceptible change in the shoreline of a body of water," i.e. either erosion or accretion that happens at a fast rate) do not cause a change in boundary lines. Bluff landslides and breaches of barriers and spits would classify as avulsion events, potentially complicating management. Furthermore, legal frameworks have not anticipated sea level rise and thus do not address the case of gradual and permanent inundation (which is not, strictly speaking, erosion).

A second challenge is the lack of state jurisdiction of projected future state-owned aquatic lands. WDNR currently has no authority to stop waterfront property owners from armoring their shorelines, which carries all the problems of preventing wetland and beaches from migrating inland. One solution would be for the State legislature expanded WDNR's jurisdiction to projected future state-owned aquatic lands.

Recommendations in this thesis are for the Aquatic Resources Program to declare a formal program-wide position on preparing for climate change, to dedicate staff time to

[522] P. Glick et al, "Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon," National Wildlife Federation (2007): *ii-iii*, *viii*. http://www.nwf.org/sealevelrise/pdfs/PacificNWSeaLevelRise.pdf

[523] A. Snover, R. Sims, M. Wyman et al, "Preparing for Climate Change: A Guidebook for Local, Regional and State Governments," Center for Science in the Earth System (The Climate Impacts Group) Joint Institute for the Study of the Atmosphere and Ocean, University of Washington (September 2007): 41, 94, 111. http://www.icleiusa.org/action-center/planning/adaptation-guidebook

[524] P. Mote et al, "Sea Level Rise in the Coastal Waters of Washington State," University of Washington Climate Impacts Group and Washington Department of Ecology (January 2008): 3. http://cses.washington.edu/db/pdf/moteetalslr579.pdf

climate change adaptation activities and form an internal climate change adaptation work group, to have staff participate in state and regional efforts to address climate change, to advocate for the creation of a formal interagency climate change adaptation work group, to develop the technical capacity to create inundation maps, and to determine future boundaries between land classifications as the sea level rises. In terms of near-term actions, the thesis recommends implementing conservation measures articulated in the Aquatic Lands Habitat Conservation Plan, including banning all new bulkheads on state-managed lands and gradually replacing existing ones with softer shoreline protection methods, and banning fixed or attached breakwaters in favor of floating breakwaters. The Aquatic Resources Program should also try to ban construction of new bulkheads on lands adjacent to state-owned lands, although the thesis recognizes that WNDR has very limited authority to do so. Long-term recommendations include increasing restoration and protection of existing habitat, implementing a policy of managed retreat and rolling easements, and establishing buffer areas for beach and wetland migration.[525]

8 In response to a Legal Services Request from the author of the above Master of Marine Affairs thesis, "Assistant Attorney General of Washington's Natural Resources Division Joseph V. Panesko has prepared a memorandum on sea level rise, accretion, avulsion, submersion, and boundary issues… This is an initial step towards answering the question, 'Will boundaries shift only in cases when erosion or accretion can be determined, or will they shift in the event of inundation as well?' Panesko determines that 'in general, absent future legislation touching the subject, courts would probably apply the common law principles regarding moving boundaries to most sea level rise situations.' (Attorney General of Washington, 2009)."[526]

9 The Center for Science in the Earth System at the Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, has several studies relating to coastal management. Studies not available for download but available upon request include a 1998 M.M.A. thesis, "Sensitivity of the coastal management system in Washington state to the incorporation of climate forecasts and projections," and a 2002 M.M.A, thesis, "Potential impacts of climate variability and change on water quality in south Puget Sound: A management perspective." A report in review is "Climate impacts on the coasts of the Pacific Northwest." It will be Chapter 9 in a forthcoming book from the MIT Press by A. K. Snover, E. L. Miles, and the Climate Impacts Group, entitled *Rhythms of Change: An Integrated Assessment of Climate Impacts on the Pacific Northwest.*[527]

Policy

1 A 2007 University of Washington Master of Marine Affairs thesis analyzes the applicability of existing legislation to sea level rise: "Washington State's Shoreline Management Act (RCW 90.58) and its implementing regulations are the core of the State's Coastal Zone Management Program and provide more than one avenue for addressing sea level rise. The first of these is the legal requirement that 'local master programs[528] shall include policies and regulations designed to achieve *no net loss* of those [shoreline] ecological functions' (WAC 173-26-186 8b, emphasis added). Consideration of *no net loss* is a new addition to the SMP Guidelines, adopted in 2002, and the process for making this determination is still being developed. The SMA Guidelines state that determination should be made with consideration of the

[525] A. Fredrickson, "Preparing for Climate Change Impacts to State-owned Aquatic Lands: A Climate Change Adaptation Strategy for the Washington Department of Natural Resources Aquatic Resources Program," University of Washington M.M.A. thesis (2009): 108-149. http://cses.washington.edu/db/pdf/fredricksonthesis682.pdf

[526] Ibid., 128.

[527] Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, "Publications: Coastal Environments" (2009). http://cses.washington.edu/db/pubs/topic6.shtml

[528] Washington state's term for local management programs

'…cumulative impacts of *reasonably foreseeable future* development…' (WAC 173-26186 8d emphasis added) and '…circumstances affecting the shorelines and *relevant natural processes'* (WAC 173-26-186 8di emphasis added)."[529]

2 One goal of the 2007 King County Climate Plan is to collaborate with climate scientists and FEMA to evaluate and plan for potential impacts of coastal flooding associated with sea level rise, including impacts to shoreline natural resources.[530]

3 The 2008 "Preparing for the Impacts of Climate Change in Washington" recognizes the threat of coastal habitats being squeezed between rising sea levels and upland barriers, and that habitats with heavily armored shorelines are most in danger. To address this, the report suggests land use and hazard mitigation planning strategy that incorporates monitoring and future predictions, and coastal nearshore habitat restoration and protection that includes habitat reclamation from armored/diked shorelines. While a revision to the Shoreline Management Act discourages hard shoreline armoring, the Act does not specifically address sea level rise impacts, and the report suggests revising this and other processes to incorporate sea level rise and climate change considerations. Revisions to other state programs to incorporate sea level rise considerations into land use and shoreline planning are also underway, including Shoreline Master Programs and the Growth Management Program.[531]

The report states, "Permanent protection is the intent of conservation easements and habitat area purchases. Habitat protection and restoration investments in the coastal area should explicitly consider implications of sea-level rise and other climate change impacts to achieve the intended permanent protection of priority shoreline habitat… There are numerous public and private efforts (and significant investments) currently underway to restore and protect the Pacific Northwest's wetlands, beaches, and other coastal habitats, and the fish and wildlife species they support. The increased emphasis on ecosystem-based approaches and adaptive management principles in many of these plans will no doubt help the region deal with the multitude of stressors at play, including some climate change. However, failure to explicitly take the effects of sea-level rise and other climate change impacts into consideration in the region's coastal habitat restoration and protection plans will make it much more difficult, if not impossible, to meet our important long-term conservation goals. For example, increasing the resiliency of coastal habitats to sea-level rise may require expanding the areas of restoration to accommodate for habitat migration, or restoring a greater diversity of habitat types in a given area to better support ecosystem functions."[532]

4 The state of Washington has recently made revisions to its laws for Wetland Mitigation Banking, effective October 2009, completing a process that started in 1998. A wetland mitigation bank is defined as "a site where wetlands are restored, created, enhanced, or in exceptional circumstances, preserved, expressly for the purpose of providing compensatory mitigation in advance of unavoidable impacts to wetland or other aquatic resources that typically are unknown at the time of certification." As explained in the "Concise Explanatory Statement and Responsiveness Summary for the Adoption of Chapter 173-700 WAC, Wetland Mitigation Banks," "Due to the low success rate of compensatory mitigation; the Washington State Legislate initiated a review of the implementation of wetland protection rules during their 1998 session. As a result, state lawmakers adopted RCW 90.84, *Wetlands*

[529] A. Petersen, "Anticipating Sea Level Rise in Puget Sound," University of Washington M.M.A. Thesis (2007): 47. http://www.cses.washington.edu/db/pdf/petersenthesis559.pdf

[530] King County, "King County 2007 Climate Plan," King County, Washington (February 2007): 113. http://www.metrokc.gov/exec/news/2007/pdf/climateplan.pdf

[531] Preparation and Adaptation Working Groups, "Leading the Way: Preparing for the Impacts of Climate Change in Washington, Chapter 3," Washington State Department of Ecology (February 2008): 129-135. http://www.ecy.wa.gov/pubs/0801008c.pdf

[532] Ibid., 139.

Mitigation Banking. The law expressed the Legislature's support of banking as an important option for providing compensatory mitigation. The law affirms the state's authority to regulate banking. The law set minimum guidelines for establishing banks and directed [the State of Washington Department of] Ecology to develop a statewide mitigating banking certification rule… Ecology used two distinct collaborative processes (a negotiated rule and a pilot rule) with extensive public involvement and outreach during the rule development process. Ecology convened a negotiated rule team in 1998 to draft rule language. Draft rule language was proposed for Chapter 173-700 WAC in 2001. A pilot program testing the draft rule language was conducted from 2004 to 2009. Ecology has not finalized the rule language based on the lessons learned through the pilot program and comments."

"The purpose of this rule is to establish statewide certification process for wetland mitigation banks; and to ensure that these banks are ecologically sustainable and provide adequate compensation for unavoidable impacts to wetlands."[533]

An economic study conducted by the Department of Ecology found that "[where] values are quantifiable, wetland mitigation banking could provide net benefits of $2.3 million per year, as compared to current practice. Quantitative analysis also indicates that avoiding impacts to wetland is preferred to both concurrent mitigation and wetland mitigation banking. This supports the current priority of minimizing development impacts to existing wetland, and counteracts concerns that mitigation banking creates an economic incentive to relocate all wetlands."

This analysis notes that "it is arguable [that] the authorizing statue creates a WMB [Wetland Mitigation Bank] industry. While participation in any industry is voluntary, this rule has requirements the industry must comply with. This interpretation that the rule imposes costs on an existing industry is similar to the case of regulation of other industries in the state. Consequently, Ecology does not believe the rule creates real compliance costs for developers seeking mitigation for unavoidable wetland impacts…" Since "participating in the WMB is a voluntary choice for developers seeking mitigation, who have the option of choosing WMB or the existing CM [concurrent mitigation] method… any party wanting to mitigate wetland impacts will only choose WMB over existing CM methods if banking is the less costly mitigation option for them."[534]

5 The Washington Department of Natural Resources' Aquatic Resources Program is developing an Aquatic Lands Habitat Conservation Plan, which it calls the first in the United States. Originally scheduled for completion in Spring 2009,[535] WDNR now gives winter 2009 as the completion time for the draft, with public review scheduled for the winter of 2009/2010. This plan for state-owned aquatic lands will "define the actions we take to avoid and minimize impacts on at-risk species and balance public benefits for the people of Washington.[536] The Plan will give consideration to changes in sea level as a result of climate change, such as how bulkheads on private land may come under state ownership.[537]

[533] Y. Holder and L. Driscoll, "Concise Explanatory Statement and Responsiveness Summary for the Adoption of Chapter 173-700, Wetland Mitigation Banks," State of Washington Department of Ecology (August 2009): 1-1, 2-6. http://www.ecy.wa.gov/pubs/0906022.pdf

[534] K. Patora, "Final Cost-Benefit and Least Burdensome Alternative Analysis: Chapter 173-700 WAC -Wetland Mitigation Banking," State of Washington Department of Ecology (August 2009): *i*, 4. http://www.ecy.wa.gov/pubs/0906026.pdf

[535] Aquatic Lands Division, "Aquatic Lands Strategic Plan for Washington's State-owned Aquatic Lands," Washington State Department of Natural Resources (December 2008): 5. http://www.dnr.wa.gov/Publications/aqr_aquatic_lands_strategic_plan_2008.pdf

[536] Washington State Department of Natural Resources, "Aquatic Lands Habitat Conservation Plan" (2009). http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHCP/Pages/aqr_esa_aquatic_lands_hcp.aspx

[537] Aquatic Resources Program, "HCP Science Review Panel Final Report Comments and Recommendations on Covered Species and Potential Effects Analysis," Washington Department of Natural Resources (January 2007): 8. http://www.dnr.wa.gov/Publications/aqr_esa_review.pdf

Actions

1 Currently none explicitly addressing habitat loss from sea level rise. However, the 2009 EPA "Climate Ready Estuaries Synthesis" cites examples of bulkhead removal from Washington State as addressing sea level rise.[538] From November 2004 to February 2005, the Seahurst Bulkhead Removal and Beach Restoration removed 1,400 feet of ailing shoreline armoring. The armoring had been installed in the 1970s, and since then, it had caused beach elevations to drop three to four feet. The project was led by the City of Burien, partnering with the Army Corps of Engineers, at a cost of $190,500 from the Salmon Recovery Funding Board, $190,500 from the City of Burien, and $707,000 from the Army Corps.[539]

[538] Environmental Protection Agency, "Synthesis of Adaptation Options for Coastal Areas." U.S. Environmental Protection Agency Climate Ready Estuaries Program (January 2009): 7. http://www.epa.gov/cre/downloads/CRE_Synthesis_1.09.pdf

[539] Water and Land Resources Division, "Seahurst Bulkhead Removal and Beach Restoration Construction in Burien - Salmon Habitat Recovery in the Green/Duwamish and Central Puget Sound Watershed (WRIA 9)," King County Department of Natural Resources and Parks (June 2009). http://www.govlink.org/watersheds/9/plan-implementation/SRFB-seahurst-park-bulkhead-construction.aspx