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

Florida Coastal and Ocean Coalition

Caribbean Conservation Corporation, Environmental Defense Fund, Gulf Restoration Network, Natural Resources Defense Council, National Wildlife Federation, Ocean Conservancy, Reef Relief, The Surfrider Foundation

Preface

With more coastline, diversity of marine habitats and offshore area than any state in the continental U.S., Florida is the epitome of an ocean state. Yet Florida's coastal and ocean heritage stands to be severely harmed by global warming. Indeed, scientific evidence shows that damage to our coastal and marine systems is inevitable. The Florida Coastal and Ocean Coalition, formed in 2006, is committed to addressing this threat and, with the release of this report, calls upon our leaders to take the necessary steps to address the expected impacts of global warming on the state's unique coastal and marine resources.

The good news is that Florida is in a powerful position to emerge as a bold leader in the environmental effort to preserve natural resources in the face of global warming, both by taking action to reduce greenhouse gas emissions and by implementing sound coastal and ocean policies. The Governor, through his Action Team on Energy and Climate Change, and the Legislature have set the stage for Florida to lead with vision on the critical issue of coping with global warming. Responsible actions undertaken now can ensure the continued vitality of Florida's environment and economy and can serve as an important model around the nation and the world.

Who We Are

The Florida Coastal and Ocean Coalition is a group of organizations working together to conserve, protect and restore Florida's coastal and marine environment. Our steering committee organizations represent millions of citizens across the country and over 200,000 activists in Florida, all deeply concerned for the state's unique coastal and marine resources.

The Coalition emphasizes an ecosystem-based approach to coastal and ocean management, as well as recognition of the crucial link between the health of Florida's economy and the health of its beaches and dunes, coral reefs, mangroves, sea grasses, wetlands and other natural resources.

The Coalition calls on Florida's Congressional delegation, Governor, Cabinet and Legislature for action and leadership to achieve the goal of healthy coastal and ocean ecosystems. In 2006 the Coalition published Florida's Coastal and Ocean Future: A Blueprint for Economic and Environmental Leadership, which outlines the most pressing environmental issues impacting our oceans and coasts (the report is available at our website www.flcoastalandocean.org). Since its release, 160 coastal and ocean businesses, civic, outdoor, and conservation organizations have endorsed the Blueprint.

This current report is intended to provide guidelines for concrete, science-based action on the critical issues Florida faces in light of global warming and to stimulate informed debate for the preservation of the signature natural resources that make her unique.

Sylvia A. Earle, Marine Biologist

As a longtime Florida resident, as well as an ocean lover, explorer and scientist, I am deeply aware of the essential role that the coasts and ocean play in the life of this great state. From the coral reefs in the Keys to the glorious Panhandle beaches, from the quiet bays near Clearwater, where I grew up, to the oyster beds of Apalachicola Bay, the surfing beaches of the Atlantic and the estuaries of the Gulf, Florida possesses a rich coastal and ocean heritage. This heritage is threatened today as never before. Sea-level rise, extreme weather patterns, warming waters and increasing ocean acidification are all predicted to result from the build up of CO_2 in the atmosphere. No state is more likely to suffer these impacts than Florida, with its low-lying and flood-prone areas, extensive coastline and high coastal population density. Florida can and must be a leader not only in curbing the build up of CO_2 and other greenhouse gases in the atmosphere, but also in implementing smart, common-sense coastal and ocean policies that will help preserve the state's natural coastal and ocean heritage. This guide, put together with careful thought by an impressive coalition of conservation organizations, lays out a roadmap for State policymakers to follow in preserving that heritage. The pathway is clear; what is needed now is action.

Sylvia A. Earle, marine biologist, is the former chief scientist of the National Oceanic and Atmospheric Administration. She is chairman of Deep Ocean Exploration and Research and has served as explorer-in-residence at the National Geographic Society since 1998. She is a trustee of Florida's Mote Marine Laboratory and graduated from St. Petersburg College and Florida State University (Duke PhD). She serves on various corporate and nonprofit boards, including the Ocean Conservancy, the Explorers Club and as honorary trustee of the Natural Resources Defense Council.

Child Watching Dolphins Play, iStockphoto

Acknowledgements

Special thanks to science icon, ocean adventuress, and longtime Florida resident Sylvia Earle for not only the foreword to this report but for her life's work committed to better understanding and conservation of our oceans.

Many thanks to Patty Glick, primary author of this report, for her patience, dedication, and hard work. Sincere appreciation as well to David Conrad, Senior Resource Specialist, National Wildlife Federation; Raychelle Daniel, Conservation Scientist, Ocean Conservancy; Robert E. Deyle, Professor, Department of Urban and Regional Planning, Florida State University; Terry Gibson, Projects Editor, Florida Sportsman Magazine; Dennis Heinemann, Senior Scientist, Ocean Conservancy; Charles Pattison, President, 1000 Friends of Florida; Lisa Suatoni, Ocean Scientist, Natural Resources Defense Council; Craig Quirolo, Marine Projects Director, Reef Relief; Amanda Staudt, Global Warming Scientist, National Wildlife Federation; and Hal Wanless, Professor of Geology, University of Miami for providing meaningful comments and guidance in the development of this report. In addition, thank you to John Wark with Florida Media Strategies for shepherding this report through final design and public release. Special thanks to World Wildlife Fund for contributing resources toward the report's release.

The Steering Committee members of the Florida Coastal and Ocean Coalition each developed, directed, and authored significant portions of this report. Steering Committee members are: Gary Appelson, Caribbean Conservation Corporation; Sarah Chasis, Natural Resources Defense Council; Ericka D'Avanzo, The Surfrider Foundation; Paul Johnson, Reef Relief; Gerald Karnas, Environmental Defense Fund; Joe Murphy, Gulf Restoration Network; and David White, Ocean Conservancy. The Steering Committee would like to thank and recognize its Coordinator, T.J. Marshall, and his Assistant, Georgia Bell, for their professional and dedicated work in keeping us on track and schedule in preparing this report.

Finally, the Steering Committee wishes to express its gratitude and appreciation to the Directors of the Elizabeth Ordway Dunn Foundation and the Curtis and Edith Munson Foundation. Their belief in and generous support of the Coalition's mission to conserve, protect, and restore Florida's unique coastal and marine environment made this report possible. We also sincerely thank the Doris Duke Charitable Foundation for its generous support for this work and for their commitment to developing a meaningful national strategy to cope with the serious impacts of global warming.

About the Primary Author

Patty Glick, Senior Global Warming Specialist at the National Wildlife Federation (NWF), has more than 18 years experience working on the issue of climate change. She has developed a targeted campaign at NWF to build greater awareness and understanding of the known and potential impacts of climate change on North America's fish and wildlife and identify and implement meaningful solutions. Ms. Glick has led several research studies on sea-level rise and coastal habitats in Florida, the Chesapeake Bay, and the Pacific Northwest, and she is the author or co-author of numerous public reports, including *An Unfavorable Tide*; *Coral Reefs and Climate Change*; *A Great Wave Rising*; and *The Gardener's Guide to Global Warming*. Ms. Glick has a Master's Degree in economics from the University of North Carolina at Chapel Hill.

This report is printed on Forest Stewardship Council Certified Recycled Paper

About the Authoring Organizations

Caribbean Conservation Corporation and Sea Turtle Survival League
Caribbean Conservation Corporation (CCC), founded in 1959 by Dr. Archie Carr and based in Florida, is the oldest sea turtle conservation organization in the world. It is dedicated to the conservation of sea turtles through research, training, advocacy, education and protection of habitats. Learn about CCC and Florida's sea turtles at www.cccturtle.org.

Environmental Defense Fund
Environmental Defense Fund, a leading national nonprofit organization, represents more than 400,000 members. Since 1967, Environmental Defense Fund has linked science, economics, law and innovative private-sector partnerships to create breakthrough solutions to the most serious environmental problems. Visit us at www.edf.org or www.oceansalive.org.

The Gulf Restoration Network (GRN) is a network of environmental, social justice, and citizens' groups and individuals committed to restoring the Gulf of Mexico to an ecologically and biologically sustainable condition. The GRN was formed in 1994 to raise awareness of environmental issues in Gulf States and to increase communication and coordination of member activities across the region. We are playing a pivotal role in providing our members and partners with the technical information, Gulf-wide networking opportunities, and communication that empowers local communities to successfully address the environmental threats that they face. Visit us at www.healthygulf.org.

Natural Resources Defense Council
NRDC (Natural Resources Defense Council) is a national nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, and Beiijing. Visit us at www.nrdc.org.

National Wildlife Federation
National Wildlife Federation inspires Americans to protect wildlife for our children's future. Through a nationwide network—a federation of grassroots activists and wildlife enthusiasts dedicated to protecting wildlife and wild places, NWF has built a national coalition of members who carry our message to cities and rural communities, homes and town halls, Congress and state legislatures, elementary schools and universities, courts and international venues. Visit us at www.nwf.org.

Ocean Conservancy
Ocean Conservancy works to protect ocean ecosystems and conserve the global abundance and diversity of marine wildlife. Through research, education and science-based advocacy, Ocean Conservancy informs, inspires, and empowers people to speak and act on behalf of the oceans. Learn more at www.oceanconservancy.org.

Reef Relief
Reef Relief is a nonprofit grassroots membership organization dedicated to Preserve and Protect Living Coral Reef Ecosystems through local, regional and international efforts. Visit us at www.reefrelief.org.

The Surfrider Foundation
The Surfrider Foundation is a nonprofit environmental organization dedicated to the protection and enjoyment of the world's oceans, waves and beaches for all people, through conservation, activism, research and education. Represented by over 50,000 members and 64 local chapters in the U.S., the Surfrider Foundation also has affiliations in Australia, Japan, France, and Brazil. Visit us at www.surfrider.org.

Contents

Executive Summary

Florida is unique not only for her beauty and wealth of marine resources but her position of leadership and ability to forge a path for coastal communities worldwide to proactively face the looming and potentially devastating impacts of climate change. The Florida Coastal and Ocean Coalition, a group of environmental organizations working together to conserve, protect and restore Florida's coastal and marine environment examines an ecosystem-based approach to coastal and ocean management in light of climate change, along with the important linkages between the health of Florida's economy and the health of its beaches and dunes, coral reefs, mangroves, sea grasses, wetlands and other natural resources.

Florida's coastal and marine habitats and the numerous ecological and economic resources they provide are invaluable to the millions of people who live in Florida or visit the state each year. The world class beaches generate tens of billions of dollars from tourism and recreation and provide habitat for numerous species of birds, sea turtles, and other wildlife. Coastal marshes, mangrove forests, seagrass beds, and other habitats remove excess nutrients and pollutants, act as a buffer against flooding, and support the vast majority of Florida's marine fish and shellfish. And the coral reefs in the Southeast and the Florida Keys are home to thousands of marine species, support a thriving tourism industry, and protect Florida's coasts from erosion and storm damage. These coastal and marine systems define Florida and frame the lives of Floridians.

Unfortunately, Florida's coastal and marine systems already have experienced serious degradation as a result of a variety of factors, including pollution, poorly sited coastal development, altered freshwater flows, and harmful fishing practices. Numerous restoration and protection efforts have been undertaken to tackle these problems, but the future of Florida's coastal and ocean resources also depends on addressing the very real threat of global warming. With Florida's human population expected to grow considerably in the coming decades, proactively confronting these challenges today is of paramount importance.

Leatherback Sea Turtle Hatchlings Emerging From Their Nest
Sebastian Troeng, Caribbean Conservation Corporation

Global Warming and Florida

Few coastal states are as vulnerable to the consequences of global warming as Florida, and we are already starting to see its effects. Average temperatures in parts of the state have increased by about 2 degrees Fahrenheit since the 1960s (U.S. EPA, 1997). Without a significant reduction in global emissions of carbon dioxide (CO_2) and other heat-trapping greenhouse gases over the next few decades, average temperatures in Florida will continue to increase in the coming decades, with average low temperatures in winter increasing 3 to 10 degrees Fahrenheit and average high temperatures in summer increasing 3 to 7 degrees Fahrenheit by 2100 (Harwell, Gholz, and Rose, 2001).

Global warming means more than just hotter weather. It is contributing to higher ocean temperatures, more-extreme weather events, and rising sea levels. In addition, the higher concentration of CO_2 in the atmosphere is directly altering the chemistry of our oceans, causing the water to become more acidic (Kleypas, et al., 2005). Left unchecked, all of these changes will have a profound impact on Florida's coastal and marine ecosystems:

- *Rising sea levels will increase erosion of beaches, cause saltwater intrusion into water supplies, inundate coastal marshes and other important habitats, and make coastal property more vulnerable to storm surges.*
- *More-extreme weather events, including intense rainfall, floods, droughts, and tropical storms, will alter freshwater flows into estuaries and lagoons, exacerbate polluted runoff and water supply problems, and damage coastal habitats and property.*
- *Higher ocean temperatures will cause extensive coral bleaching, enhance marine diseases, alter species' ranges and population abundances, and harm fisheries.*
- *Higher ocean acidity will inhibit the ability of corals and other marine organisms to build up calcium carbonate, the substance that forms their protective skeletons.*

Meeting the Challenge

While it may seem daunting, Florida has a real opportunity to confront these collective problems – but it will take a concerted effort on two important fronts: minimizing global warming by reducing greenhouse gas emissions, and preparing for changes that are already underway.

First and foremost, Florida and the rest of the nation must work to lessen the impact of global warming by reducing the pollution causing it. In particular, the State of Florida, Congress and the Administration must place mandatory limits on the nation's global warming pollution to ensure we meet the necessary target of an 80 percent reduction in emissions below current levels by 2050 [see Box 1 on page 12].

However, even if we successfully achieve critical greenhouse gas reduction goals, Florida is still facing impacts from climate change over the coming decades due to the continuing effects of greenhouse gases that are already in the atmosphere and those that we will continue to emit while transitioning to new energy sources. New and enhanced ecosystem restoration and adaptation strategies will be needed.

This report outlines the issues and concerns, but more importantly, identifies a series of recommended actions for local, state and federal agencies to cope with the significant challenges posed by rising sea levels, more-extreme storm events, higher ocean temperatures, and acidification of ocean waters. Some of the recommended actions will require Florida's Governor, Legislature, and Congressional delegation to provide the directives, funding mechanisms, and leadership to move forward. However, many programs and policies are already in place and can be used to begin making adaptive changes to a warming world. These recommendations, more fully detailed within, can be summarized as follows:

Preparing For Sea-Level Rise

To prepare for sea-level rise, Florida and the federal government must take steps to implement ecologically and economically sound adaptive policies and strategies that discourage development in vulnerable areas and support efforts to site structures farther landward of eroding shorelines. This is essential not only to help reduce the serious risks to human safety and well being of communities, but also to ensure the preservation of beaches, dunes, and other natural coastal habitats that are so important to our economy and quality of life. For example:

- *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.*
- *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.*
- *Federal, state, and local governments 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.*

Dealing With Extreme Weather Events

To deal with extreme weather events, such as heavy downpours and droughts, Florida and federal agencies must emphasize the protection and restoration of shoreline and streamside riparian vegetation and wetlands, upgrade stormwater management to take account of more frequent and heavier rainfall events, and increase water use efficiency and opportunities for beneficial reuse. For example:

- *The Florida Department of Environmental Protection should upgrade stormwater regulations, taking the likelihood of heavier rainfall events into consideration. Policies should focus on Low Impact Development methods, both for new developments and retrofits in existing developed areas.*
- *The Florida Department of Environmental Protection should evaluate/revise the Florida Water Plan (and regional water management plans) to explicitly address climate change.*
- *The States of Florida, Georgia, and Alabama should actively engage in a collaborative effort to develop and implement a long-term regional water management plan that incorporates climate change and takes a more coordinated approach to water management.*

Reducing The Impacts Of Higher Ocean Temperatures

To reduce the impacts of higher ocean temperatures, Florida and federal agencies must work to protect and restore coastal and marine ecosystems in order to enhance their ability to deal with the additional stresses caused by climate change. For example:

- *The Florida Department of Environmental Protection should evaluate and monitor the effectiveness of the state's collective coastal and aquatic managed areas and coastal zone management programs in supporting biological diversity among fish and wildlife species and should develop strategies to strengthen these programs.*
- *The Fish and Wildlife Conservation Commission should promote the rebuilding of depleted coastal and ocean fish populations since depleted populations will have a harder time dealing with the additional stresses posed by climate change and warming waters.*
- *Congress should enact climate adaptation legislation that would provide funding as well as require federal and state agencies to protect and strengthen the health of coastal and ocean ecosystems.*

Addressing Acidification

To address acidification, Florida and the nation must be leaders in efforts to minimize global warming through significant reductions in greenhouse gas emissions, in addition to supporting research and monitoring efforts to assess and mitigate the impacts of acidification on fish and wildlife. For example:

- *Federal and state agencies should make monitoring of ocean pH and calcification rates a part of the coral monitoring plans in the Tortugas Ecological Reserve, the Florida Keys National Marine Sanctuary, Biscayne National Park, and Oculina Bank Habitat Area of Particular Concern.*
- *Relevant federal and state agencies should invest in studies to better understand the ecological impacts of ocean acidification.*

By implementing these and the other recommendations, we can help change the forecast for Florida's coastal and ocean resources and ensure that the economic opportunities, ecological benefits, and outdoor traditions they provide will endure for generations to come.

[Box 1]

Avoiding Catastrophe

Scientists are optimistic that the impacts of global warming can be lessened if significant action is taken now and within the next few decades to reduce the emissions of CO_2 and other greenhouse gases to stabilize their concentrations in the Earth's atmosphere. Without such action, the projected impacts are likely to be catastrophic for people and wildlife alike.

Research shows that 20-30 percent of species worldwide are likely to be at increased risk of extinction if increases in average global temperatures exceed 3.6 degrees Fahrenheit above pre-industrial levels (IPCC, 2007b). These extinctions will be accompanied by major changes in the structure and function of ecosystems. This 3.6 degree Fahrenheit threshold is also critical to the ultimate survival of the world's coral reefs, including those in Florida and the Caribbean, which are threatened by extensive bleaching due to higher ocean temperatures as well as acidification of ocean waters (Hoegh-Guldberg, 2007).

According to the Intergovernmental Panel on Climate Change (IPCC), the only way to keep temperatures from increasing more than 3.6 degrees Fahrenheit in the next century is to take substantial steps immediately to reduce global warming pollution. To have a reasonable chance of staying below 3.6 degrees of warming, greenhouse gases in the atmosphere need to stay below 450 parts per million of CO_2 equivalent (IPCC, 2007c). To reach this level, the growth in global greenhouse gas emissions will need to be halted within the next ten years and overall emissions cut by 50-85 percent below current levels within the next 50 years. For industrial nations, particularly the United States, this will mean a reduction on the order of 80 percent below current levels by mid-century, followed by further reductions toward zero by 2100.

Florida Governor Charlie Crist has taken a critical step forward by signing Executive Order 07-127, which established a set of greenhouse gas emission reduction targets for the state of Florida, culminating in a reduction by 80 percent of 1990 levels by 2050. The recommendations from the Governor's Action Team on Energy and Climate Change in its November 1, 2007 "Phase 1" report to the governor, an important first step to achieve that goal. By October 1, 2008, the "Phase 2" report is due and will include recommendations for reducing or sequestering greenhouse gas emissions, identifying opportunities to promote energy-efficient technologies and renewable resources that will enhance economic growth, and the development of adaptation strategies to combat the projected adverse impacts of climate change to society, the economy, and natural systems. These policy recommendations will form the basis for Florida's comprehensive Energy and Climate Change Action Plan. An Adaptation Technical Work Group has been formed to provide input into the Action Team's formulation of adaptation recommendations.

Coastal Erosion After Hurricane Jeanne, FEMA

Confronting the Impacts of Sea-Level Rise

Global warming is causing sea levels to rise due to a combination of thermal expansion of the oceans and rapidly melting glaciers and ice sheets. The average global (eustatic) sea level rose about 6.7 inches over the 20th century.[1] This was 10-times faster than the average rate of sea-level rise during the last 3,000 years (IPCC, 2007a). In the coming decades, the rate of sea-level rise is expected to accelerate. With its vast expanse of coastline, low-lying topography, and growing coastal population, Florida is one of the most vulnerable places in the nation to the impacts of sea-level rise. Relative sea-level rise (which incorporates localized changes in land elevation) in parts of Florida has already outpaced the global average – South Florida, for example, has seen a 9 inch rise since the 1930s (Wanless, Parkinson, and Tedesco, 1994).

The most recent estimates from the 2007 IPCC assessment show an additional 7 to 23 inch rise in global average sea level by the 2090s (IPCC, 2007a). However, scientists are becoming increasingly concerned that the rate of global sea-level rise in the coming decades and beyond will be considerably greater than these projections, as several new studies have determined that the ice sheets of Greenland and parts of Antarctica are melting much more rapidly than previously thought (Otto-Bliesner, et al, 2006; Overpeck, et al., 2006; Rignot and Kanagaratnam, 2006). According to Dr. James Hansen, Director of NASA's Goddard Institute for Space Studies, if greenhouse gas emissions continue to increase on a "business-as-usual" trajectory, we could ultimately see a disintegration of the West Antarctica ice sheets. This has the potential to yield "a sea-level rise on the order of 5 meters this century" (Hansen, 2007). Indeed, sea-level rise of this magnitude would have enormous global consequences.

Even at the lower range of projected sea-level rise for the coming decades, Florida will see significant and costly impacts, including inundation of coastal property and infrastructure, greater vulnerability to storm surges and erosion, and the destruction of vital coastal habitats. According to the Miami-Dade County Climate Change Advisory Task Force (CCATF) in its January 2008 Statement on Sea Level in the Coming Century, "A further 2-foot sea-level rise by the end of the century, as projected in the 2001 IPCC report, would make life in south Florida very difficult for everyone" (Miami-Dade County CCATF, 2008a).

Beaches and Coastal Property

Sea-level rise will increase beach erosion and associated shoreline recession and have a profound impact on Florida's beaches, the beach using public, and the tourism industry. Indeed, beaches are one of the state's most important economic engines, generating tens of billions of dollars in annual revenues (Florida Atlantic University, 2005). A healthy beach/dune system protects upland property from storm damage. Florida's beaches provide critical habitat for endangered sea turtles, shorebirds, invertebrates, forage fish, and other species that are part of the state's invaluable natural heritage.

Unfortunately, Florida's beaches are already disappearing due to a combination of factors, including development and armoring on the beach in the active littoral system, sediment starvation due to inlets and jetties, coastal storms, and sea-level rise. The Florida Department of Environmental Protection (DEP) estimates that nearly half of Florida's 825 miles of beaches are currently "critically eroded" (DEP, 10/26/2007). Much of this erosion is attributable to the state's navigation inlets and the jetties used to stabilize those inlets, which interrupt the natural flow of sand along beaches by causing sand to accumulate in the inlet channel, against the jetties, or within shoals at the mouth and interior of the inlet.

In addition, shoreline development on eroding beaches establishes a line in the sand that property owners often try to defend with seawalls and other armoring structures. Seawall construction reduces a beach's natural resiliency

1 "Eustatic" (also referred to as "global") sea-level rise refers to the changes in ocean volume due to thermal expansion and melting glaciers and ice sheets. At the localized level, the amount of *relative* sea-level rise can vary due to factors (both natural and human-influenced) that determine changes in vertical land elevation, such as land subsidence, sedimentation, and marsh accretion.

to respond to coastal storms by diminishing the beach/dune system's ability to retreat or feed downdrift beaches during storm events (Tait and Griggs, 1990). Armoring may also increase the vulnerability of adjacent unarmored properties to storm damage by reflecting wave energy around the structures. Studies have found that the alteration of sandy beaches by coastal armoring can significantly reduce the diversity and abundance of macroinvertebrates, shorebirds, and other fish and wildlife species that depend on beach habitats (Dugan and Hubbard, 2006). Recent storm events have already increased pressure for seawall development in parts of Florida. For example, after Hurricane Dennis in 2005, Walton County in the Florida Panhandle issued nearly 250 permits to coastal property owners to allow installation of "temporary" armoring structures. Ultimately, this resulted in the installation of several miles of solid seawalls (Gibeaut, 2006).

One of the primary ways in which Florida has addressed beach erosion is through beach re-nourishment, which involves the repeated use of dredged materials to replace lost sand. While such projects can help maintain some of the economic benefits of beaches, including recreational use and protection of coastal property, there is considerable evidence that it diminishes important fish and wildlife habitat by burying shallow reefs, temporarily depressing sea turtle nesting, and reducing densities of invertebrate prey for shorebirds, surf fishes, and crabs (Peterson and Bishop, 2005). Some areas of Florida are already running out of beach-quality sand and the costs of re-nourishment and locating distant sand sources are rising substantially. In all likelihood, pressures for beach re-nourishment and coastal armoring will be exacerbated by sea-level rise given the significant added risk of beach inundation and erosion.

The loss of beaches and coastal property associated with sea-level rise will have enormous economic costs for Florida, let alone incalculable ecological consequences (Schlacher, et al., 2007). A recent analysis of the potential economic costs of sea-level rise and associated storm damage in six Florida counties found that severe storm events and associated damage costs are likely to increase significantly during this century, with coastal property losses likely to double under a sea-level rise scenario of 2 feet by 2080, which is within the range of sea-level rise projected by the IPCC (Harrington and Walton, 2007). In addition, researchers at Tufts University found that a scenario of a 27 inch sea-level rise would make 9 percent of Florida's current land area (4,700 square miles) vulnerable to inundation (Stanton and Ackerman, 2007). They predict that continued sea-level rise and other changes due to climate change could ultimately cost the state $327 billion (in 2006 dollars) by 2100 due to lost tourism revenue, hurricane damages, and at-risk real estate. Furthermore, as the threat of erosion continues to increase, the demand for beach re-nourishment is likely to increase as well – as will its cost to Florida's taxpayers. One early study published by the U.S. EPA estimated that it would cost Florida close to $1.7 billion to replenish sand beaches lost to a 1/2 meter (19.7 inch) rise in sea level and up to $11.8 billion for a 2 meter (78.7 inch) rise in sea level (Leatherman, 1989).

Water Supplies and Water Quality

Inundation and saltwater intrusion into freshwater supplies is a concern for many coastal communities, particularly in South Florida, where water resources are stretched thin by competing needs and the low-lying aquifers are the primary freshwater supply for the region's wells (Twilley, et al., 2001). Extensive water use in some areas, combined with pervasive drought conditions, has already lowered the water table and contributed to saltwater intrusion into local water supplies, a problem that is likely to worsen with sea-level rise.

While studies to date have been limited, a preliminary estimate of the impacts of sea-level rise on the regional water resources of Southeastern Florida suggests that a sea-level rise of 6 inches by 2050 (which is well within the range of projected sea-level rise by mid-century) will likely contribute to increased potential for flooding and a greater need for water-use cutbacks to maintain the aquifer (Trimble, Santee, and Deidrauer, 1998).

In addition to threatening coastal beach property and infrastructure, sea-level rise will have a significant impact on Florida's salt marshes and swamps, mangrove forests, and other coastal and estuarine habitats and the numerous ecological and economic resources they provide. Of particular concern is the fact that many of the state's important coastal habitats have already been damaged or destroyed by extensive dredging, coastal modifications, pollution, and other development. This makes remaining habitat all the more important for fish and wildlife and underscores the importance of conservation and restoration efforts, including the multi-decade, multi-billion dollar Comprehensive Everglades Restoration Plan (CERP). To be successful, however, sea-level rise and other climate changes must be taken into consideration in developing and implementing relevant coastal wetland conservation strategies, as these systems face changes in the coming decades that are far greater than the context accounted for in past restoration planning (Twilley, 2007).

There is evidence that sea-level rise is already affecting coastal habitats in many areas (Krueger and Pittman, 2008). For example, along Florida's Gulf Coast, saltwater intrusion from a combination of sea-level rise and reduced freshwater flows due to extreme drought conditions has contributed to a significant decline in regeneration of cabbage palm, red cedar, and other coastal trees (Desantis, et al., 2007). And in parts of the Everglades, sea-level rise has led to the upland migration of mangrove forests, which have been able to take advantage of changing habitat conditions in areas previously dominated by freshwater marsh (Walker, Smith, and Whelan, 2003). Changes such as these are projected to become even more significant as the rate of sea-level rise accelerates in the coming decades.

Coastal Mud Flats At Low Tide, iStockPhoto

A 2006 study of the potential impacts of sea-level rise at nine of the most important sportfishing areas along Florida's coast found that, with a moderate 15 inch eustatic sea-level rise, nearly 50 percent of critical salt marsh and 84 percent of tidal flats at these sites would be lost, while mangroves are expected to expand inland, increasing in area by 36 percent (Glick, 2006). The area of dry land is projected to decrease by 14 percent, and roughly 30 percent of the areas' ocean beaches and two-thirds of estuarine beaches would disappear. The vast majority of Florida's marine fish and shellfish species depend on salt marshes, tidal flats, and other habitats found in the state's bays and estuaries, so the projected changes to these habitats due to sea-level rise are likely to have a considerable impact on Florida's commercial and recreational fisheries.

In some cases, marshes may be able to accommodate moderate changes in sea level through natural sedimentation and marsh accretion (the build-up of organic and/or inorganic matter). However, studies have shown that the rates of sedimentation and accretion for many of Florida's marshes are failing to keep pace with the rate of sea-level rise. For example, the relative rate of sea-level rise in the Big Bend region has been slightly higher than the global average due to marsh subsidence, which has been at least in part the result of insufficient riverine sediment supply (Cross, et al., 2001). This disparity is expected to worsen as the rate of sea-level rise accelerates with global warming (Morris, et al., 2005). Similarly, the extensive re-plumbing of South Florida has significantly reduced flows of freshwater through the Everglades and into Florida Bay and altered plant productivity, making the system less able to build soils through accretion (Twilley, 2007). One study suggests that the maximum rate of sea-level rise that mangroves can sustain is 9 inches or less over the next century, which is lower than the current rate and considerably lower than the projected rates of sea-level rise under business-as-usual greenhouse gas emissions (Twilley, 1997).

In addition, while some new wetlands are likely to be created in low-lying upland coastal zones as sea-level rises, efforts to minimize land loss and protect roads, buildings, and other structures will likely lead to more armoring of shorelines, precluding the development of new wetlands in those areas (Titus, et al., 1991). Unless major efforts are implemented to enable migration of wetland habitats as sea-level rises, the loss of these habitats will have a significant adverse impact on Florida's ecology and economy. Tidal wetlands help protect coastal water quality and stabilize shallow water and intertidal zones. Many game fish and other species depend on coastal marshes and seagrass beds for spawning, feeding, and protection. Wetland loss would also reduce essential habitat for important prey species, including shrimp, crabs, and smaller fish, which would have ripple effects throughout Florida's marine food web. With thoughtful planning it is possible to allow over time for expected wetland migration.

Recommended Actions to Prepare for Sea-Level Rise

Sea-level rise due to global warming is one of the greatest threats to Florida's coast in the coming years. Fortunately, we have the opportunity to minimize the risks and ensure that Florida's precious coastal resources and the ecological and economic benefits they provide will endure for our children and grandchildren. But there is no time for delay. Many of the decisions we make today – from where and how we build our homes, businesses, and highways, to how much and what kinds of energy we use – will have a significant impact on our resources, land use, and even our climate for many decades to come.

Failure to take sea-level rise into consideration in these decisions will not only place many of Florida's coastal communities at risk, but it would have costly and irreversible consequences for human and natural systems. Certainly many of the federal and state procedures for planning and assessing conditions for coastal and shoreline development fail to incorporate effects of sea-level rise, climate change, and future development associated with a rapidly growing human population. Now is the time for Florida (and relevant federal agencies) to develop a comprehensive strategy to confront sea-level rise in a way that reduces the risks to communities by discouraging building in vulnerable areas, and increases the resiliency and protection of coastal habitats by a) steering away from structural armoring of Florida's shorelines; b) avoiding beach re-nourishment projects where especially harmful for ecosystems, and c) restoring and protecting natural buffers.

Several coastal communities have made an important start. Since 2000, the U.S. EPA has been working with a number of Florida's Regional Planning Councils mapping how sea-level rise would affect the state's coastline in the future, and identify those areas in which communities are most likely to invest in structural protection measures (Treasure Coast Regional Planning Council, 2005). In addition, both Southwest Florida Water Management District Wetland Restoration Program and Miami-Dade County are developing plans to address sea-level rise in their jurisdictions. To be successful, however, these plans must explicitly address coastal ecosystem protections and actions must be coordinated across the state.

Deyle, et al., (2007) identified "uncertainty about sea-level rise scenarios and impacts" as the biggest constraint to planning for sea-level rise. Clearly, state and federal agencies, universities, and other relevant organizations should continue to invest in efforts to assess the vulnerability of Florida's coasts to sea-level rise though improved mapping, including using the latest Light Detection and Ranging (LiDAR) coastal elevation data, ecosystem modeling, and other activities. However, uncertainty about exactly when and how much sea-level rise will occur should not be used as an excuse for inaction. Rather, the very fact that there is significant risk – and the potential for irreversible damages – necessitates precautionary action.

Florida's coastal management and coastal development policies currently do not pro-actively take sea-level rise into consideration. There is no mention of climate change or sea-level rise in Florida's 2007 Strategic Beach Management Plan (DEP, 2007). Similarly, there is an immediate need to reassess the state's Coastal Construction Control Line (CCCL) program, the foundation of Florida's coastal management policies. The current CCCL program was established in 1978 to preserve and protect Florida's beach/dune system from imprudent construction and still provide reasonable use of private property. The design and placement of construction seaward of the CCCL, which corresponds to the landward reach of a 100-year storm surge, is regulated by DEP and authorized by statute. The program does not take sea-level rise scenarios into consideration. In addition, there is no specific dune protection setback ensuring the protection of coastal dunes. Surprisingly, there is also little coordination between the Department of Community Affairs (DCA), DEP, and Regional Planning Councils on climate change issues, including integration of respective agency policies to better protect coastal and marine resources and planning to develop effective adaptation and relocation strategies to protect these resources.

Condo Under Construction and Almost in the Surf Zone, Singer Island. Photo: CCC

Defying long term planning needs in the face of climate change, Florida continues to encourage, allow, and subsidize high risk coastal development in several ways. For example, DEP, in accordance with state law, regularly issues permits for beach-front construction at risk of damage by erosion. While the CCCL regulatory program generally prohibits construction seaward of a line equal to where annual wave events are projected to reach in 30 years, loopholes often render this sensible setback ineffective, such as by allowing development on the frontal dunes of the most erosive beaches in the state (Levina, E., et al. 2007). Exemptions for building seaward of the 30-year erosion line are mandated for single family homes on lots plated before 1985 and are routinely granted if there is an existing line of construction or a pending beach nourishment project. The 30-year erosion line is essentially waived or moved seaward a distance based on the projected funding commitment for continual re-nourishment. Structures are allowed to be built on land known to be washing away based on long term funding for re-nourishment and not on the expected life of the re-nourishment project. In addition, the CCCL permitting program does not account for the potential for extreme erosion associated with hurricanes – such as occurred in 2004 and 2005 – which can result in permitted structures on the beach.

Although the primary focus of the state-financed Citizens Property Insurance Corporation (CPIC) is to provide coverage for wind damage from storms, the general availability of CPIC also results in a subsidy for ill-advised construction in coastal high hazard areas fronting vulnerable and eroding beaches. Insurance coverage is provided regardless of whether development is thousands of feet from the shore or adjacent to the most seaward line of dunes on eroding beaches. In addition, CPIC coverage is provided to builders, investors, and homeowners along the coast regardless of the historical erosion rates, storm history, or frequency of repeat claims.

In specific situations, CPIC coverage may actually be working to undermine federal and state efforts to protect coastal resources, such as those offered by the Coastal Barrier Resources Act (CBRA), which was established in 1982. CBRA denies federal subsidies such as flood insurance to development projects on undeveloped areas on barrier islands prone to erosion and flood damage. Its goals were to minimize loss of life, stop wasteful expenditures of federal funds, and protect coastal resources (Bush, et al., 2004). CPIC coverage is provided for development in CBRA zones irrespective of consistency with the federal prohibition. CPIC also fails to consider specific state initiatives to protect coastal resources. For example, the CCCL is periodically reevaluated after storm events to ensure the regulatory line is functioning as intended to protect property and the beach/dune system. When the CCCL is deemed inadequate due to coastal erosion it is reset landward. This process can take several years. Between the time the state determines the line to be inadequate and the time it is reestablished, homes may be constructed and sited improperly. CPIC coverage is not withheld awaiting reestablishment of the line, thereby supporting inappropriate coastal development. It is also questionable whether coverage should be provided for rebuilding seaward of the 30 year erosion projection line.

These policies not only place buildings and infrastructure in harms way but, in an era of increased coastal erosion and rising seas, threaten the functioning of the beach/dune system and coastal wetlands and increase their vulnerability to coastal storms and high tides. This, in turn, increases demand for more beach nourishment and more bulkheads and seawalls (Titus, 2000). Such a scenario points to a grim future for one of Florida's most valuable natural resources, its coastal system.

Similarly, many federal agencies have thus far failed to incorporate effects of accelerating sea-level rise and reasonably foreseeable effects of climate change into their procedures, such as incorporating likely future conditions into mapping of floodplains, storm surge zones, or flood elevations affected by increasing impervious development in watersheds in the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (NFIP) and the planning of flood damage reduction projects by the Army Corps of Engineers (ACE). Current procedures are based almost entirely on looking backwards at past records only, rather than incorporating current climate science. Such updating is needed across the nation, as well as here in Florida.

Failure to proactively address these concerns would be increasingly costly. On a national level, flood damages currently cost an alarming $6 billion per year – triple what they were in the early 20th century (in adjusted dollars). A significant portion of these losses are from properties with repetitive flooding histories. In 1995, Florida ranked sixth among states in NFIP repetitive-loss properties (those with at least two flood insurance claims paid within a 10-year period since 1978). At the time, Florida had 3,087 such properties, having cost the NFIP $95.5 million in claims payments (Conrad, et al., 1998). As of February 29, 2008, Florida ranked third in the nation, behind Louisiana and Texas, with 14,888 (non-mitigated) repetitive loss properties and total NFIP payments of $1.15 billion (FEMA, 2008). The majority (14,334) are located in the state's coastal counties, with payments there totaling more than $1.12 billion (see Table 1). Currently, the NFIP finds itself in a virtually insurmountable debt to the U.S. Treasury of more than $17 billion, and interest payments of more than $700 million annually. Increased attention must be paid to substantially reducing the numbers and risks associated with flood prone properties, including making significantly greater investments in meaningful mitigation strategies.

[Table 1] Florida Coastal County Repetitive Loss Totals (Non-Mitigated Properties) as of February 29, 2008

County	Total Cumulative Losses
Bay County	51,328,481
Brevard County	4,628,864
Broward County	20,641,299
Charlotte County	4,457,875
Citrus County	20,111,500
Collier County	2,831,377
Dixie County	3,098,573
Duval County	13,796,212
Escambia County	256,321,525
Flagler County	617,407
Franklin County	6,124,677
Gulf County	3,494,990
Hernando County	5,528,585
Hillsborough County	21,396,674
Indian River County	21,363,484
Lee County	30,281,034
Levy County	3,798,260
Manatee County	13,558,311
Martin County	16,052,691
Miami-Dade County	156,195,550
Monroe County	58,372,730
Nassau County	617,501
Okaloosa County	121,774,398
Palm Beach County	14,924,802
Pasco County	28,641,530
Pinellas County	63,207,524
Santa Rosa County	101,798,005
Sarasota County	14,129,084
St. Johns County	1,748,256
St. Lucie County	27,310,443
Taylor County	1,050,479
Wakulla County	8,072,996
Walton County	26,007,241
TOTAL	**$1,123,282,358**

Source: FEMA

The State of Florida and the federal government must take steps to implement ecologically and economically sound adaptive policies and strategies that discourage development in vulnerable areas and support efforts to site structures farther landward of eroding shorelines. This is essential not only to help reduce the serious risks to human safety and well being of communities, but also to ensure the preservation of beaches, dunes, and other natural coastal habitats that are so important to our economy and quality of life. A number of strategies are possible, including rolling easements, targeted coastal land acquisition, tax incentives for landward relocation of development, transfer of development rights, conservation easements, buyouts, stricter setbacks with various strategies to compensate for takings claims, restrictions on rebuilding after storm destruction, meaningful dune protection setbacks, improved comprehensive planning, and other possible policies. The following recommended actions would provide Florida with the much-needed opportunities and guidance to capitalize on these important measures.

State/Local Government Actions

- *The state should require local coastal governments to consider sea-level rise when amending their comprehensive plans for land use, open space, wetland protection, public infrastructure siting and maintenance, and other relevant activities. This should include expanding relevant local comprehensive planning horizons beyond the current 5-10 year period.*
- *The state should assess, restrict, and/or reduce state funding, tax breaks, and other incentives for private development in coastal areas at high risk from erosion and storm surges.*
- *The state should undertake a comprehensive reevaluation of the CCCL program to ensure that it is accomplishing its intended goals of protection of life, property, and the beach/dune system. The reevaluation should consider, among other things: (1) the adequacy of existing coastal setbacks and post-storm redevelopment policies in light of projected sea-level rise scenarios, and (2) the need for expediting reestablishment of the CCCL when, due to coastal erosion and storm surges, the line no longer provides adequate regulatory control over shoreline development.*
- *CPIC coverage should be consistent with the goals of federal and state policies aimed at protecting coastal resources. CPIC coverage should be evaluated to determine if changes are warranted and whether coverage for new development should be restricted in CBRA zones and in areas seaward of the CCCL when DEP has determined the line is no longer effective and needs to be reset landward.*
- *The Strategic Beach Management Plan should incorporate a range of sea-level rise scenarios over at least a 50 year time horizon.*
- *DEP, DCA, and the state's Regional Planning Councils should jointly develop, assess, and recommend for local governments a suite of planning tools and climate change adaptation strategies to maximize opportunities to protect the beach/dune system, coastal wetlands, and other coastal resources in an era of rising seas. These tools should include strategies to encourage the landward siting and relocation of structures and public facilities in areas adjacent to receding shorelines through acquisition, rolling easements, transfer of development rights, stronger setbacks, and tax incentives.*
- *DEP should be funded to support the design and implementation of inlet management plans for all of the state's modified inlets and undertake all reasonable efforts to maximize inlet sand bypassing.*
- *DEP and other relevant agencies should develop state wetlands conservation and restoration plans that promote designation of wetland migration corridors for wetland migration as sea levels rise, thereby protecting the valuable benefits they provide by buffering coasts against storms and erosion, improving water quality, and supporting fish and wildlife.*
- *DEP, Water Management Districts and local and regional planners should evaluate and prepare for relocation and/or protection of drinking water well fields and ground water recharge areas from salt water intrusion.*
- *The Florida Department of Emergency Management (DEM) should incorporate sea-level rise and increasing storm surge impacts into its efforts to remap potential hazard areas in coastal zones. Revised hazard areas should better reflect the added risks to communities associated with climate change and allow reevaluation of the suitability for development in these areas.*
- *The state Legislature should place a priority on coastal land acquisition through the Florida Forever program, a separate dedicated funding source, and/or through other means. Greater incentives should be provided to local governments and private organizations to acquire and manage ecologically important coastal lands, including*

upland buffers in vulnerable areas. Acquisition efforts should be strategically targeted in order to protect coastal resources, reduce insured risk, and reduce the impacts of climate change on both ecosystems and communities.

- *The Florida Division of Community Planning (DCP) should explore using the Florida's Areas of Critical State Concern (ACSC) Program as a way to provide special assistance in planning and redevelopment for areas of the state at high risk of change due to sea-level rise.*
- *The Florida Fish and Wildlife Conservation Commission (FWCC) should incorporate sea-level rise into the coastal habitat restoration and protection strategies of the Florida Wildlife Legacy Initiative.*

Federal/Regional Government Actions

- *Congress should amend the Coastal Zone Management Act (CZMA) to require relevant state agencies to consider sea-level rise in coastal management plans in order to qualify for federal funding assistance; prohibit federal subsidization of infrastructure development and coastal armoring in areas subject to sea-level rise; and encourage public and private land acquisition of coastal habitats and upland buffers.*
- *Congress should establish policies to restrict federal flood insurance (via NFIP) for new construction and rebuilding in high hazard coastal areas. Congress should also provide increased funding and technical support for hazard mitigation by states, communities, and building owners through floodplain management; establishment of greenways, open space, and building setbacks; and use of voluntary buyouts and relocations of high risk properties, higher building elevations, flood proofing, and other techniques. Congress should oppose efforts to expand federal subsidies for wind insurance and natural catastrophe insurance in coastal high hazard areas subject to storm surges, sea-level rise, and eroding shorelines.*
- *Congress 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 land conservation, such as by allowing tax exempt financing for acquisition of properties in the hazard areas.*
- *The Army Corps of Engineers should incorporate sea-level rise projections and other climate change impacts into the CERP to ensure that important ecological functions of the system will endure over the long-term.*
- *Congress should amend the Interstate Land Sales Act to require disclosure of possible consequences of buying or building in coastal hazard areas. Congress should also stimulate full disclosure by removing the "private offering" exemption in Section 4(2) of the Securities Act of 1933 for proposed private investment and development in units of the Coastal Barrier Resources System and in "V Zones" (the most hazardous flood area) identified by NFIP.*
- *Congress should resist efforts to exempt areas or roll back protections for coastal barriers that are included in CBRA. Coastal barriers designated under the act are ineligible for direct or indirect federal financial assistance that might support development.*

Confronting the Impacts of Extreme Weather Events

Global warming is disrupting the planet's climate system, causing widespread changes in regional temperatures, precipitation, and wind patterns (IPCC 2007a). In particular, these changes are manifesting themselves as an increase in the frequency and intensity of "extreme" weather events like heat waves, droughts, floods, and severe storms. According to the IPCC, since 1950, the number of heat waves has increased around the world, as has the extent of regions affected by droughts due to warmer conditions and increased evaporation (IPCC 2007a). Global warming is also contributing to an increase in the frequency and number of very heavy precipitation events and flooding in many areas, a trend that is attributed to higher levels of moisture in the atmosphere (Diffenbaugh, 2005; Groisman, 2004; Trenberth 2003).

Climate models project a continued increase in average regional air temperatures in Florida in the coming decades, including more frequent and severe heat waves, which can exacerbate drought conditions (IPCC 2007a). Current models are less certain in identifying how global warming will affect changes in average precipitation patterns on a local and regional level. For example, two of the more prominent climate models – the Hadley Centre Model and the Canadian Climate Centre Model – differ in their projections for overall precipitation changes in Florida. The Hadley model projects a decrease in average annual rainfall amounts for the state, while the Canadian model projects an increase in rainfall, especially in South Florida (Twilley, et al., 2001). Both models do agree, however, that Florida will see greater precipitation extremes, including more intense rainfall events and more droughts (Twilley, et al., 2001).

A Storm Coming Over Miami, iStockPhoto

Several studies also have found a correlation between warmer average ocean temperatures associated with global warming and an increase in the intensity of tropical storms and hurricanes (Trenberth, 2007; Webster, et al., 2005; Emanuel, 2005). Based on this evidence, a number of scientists believe that the trend toward more-intense storms will continue in the coming decades as our oceans warm further (Trenberth, 2007; Oouchi, et al., 2006; Knutson and Tuleya, 2004; Walsh, Nguyen, and McGregor, 2004). However, there are many factors that contribute to both the frequency and intensity of hurricanes, and some uncertainty remains about how these storms will be affected by global warming in the future (Pielke, et al., 2005). Regardless of whether or not global warming will have a direct impact on hurricane frequency and intensity, there is little question that these storms will become more destructive in the future due to a combination of increased coastal development as well as higher storm surges exacerbated by sea-level rise (Anthes, et al., 2006). [2]

Over the last decade, extreme weather has been prevalent in Florida, which offers a compelling example of what the state will need to prepare for in the decades to come. The hurricane seasons of 2004 and 2005 were enormously destructive and costly to the state, revealing the potential toll of more-intense storms due to global warming. Beyond the unfathomable human and ecological toll, insured losses in Florida over the period totaled more than $35 billion (Florida Office of Insurance Regulation, 2006).

A general trend toward heavier rainfall events (whether or not associated with tropical storms) will likely contribute to a decline in coastal water quality due to enhanced stormwater runoff. This is a problem that has already been exacerbated by the destruction of wetlands, forests, and other natural buffers (which help store water and trap pollutants and sediments) and expansion of impervious surfaces associated with urban development and roads. One of the potential impacts of additional runoff is an increase in the duration and/or extent of coastal hypoxia events caused by eutrophication (excess nitrogen and other nutrients in coastal waters from sources such as agricultural fertilizers, sewage discharges, and septic tanks) (Justic, Rabalais, and Turner, 2003). This nutrient loading leads to excessive algae growth that contributes to a depletion of oxygen in affected waters, a condition called hypoxia. Similarly, anoxia is a condition in which all oxygen is depleted, which can lead to "dead zones" – areas in which most marine organisms cannot survive (Joyce, 2000).

In addition, several record-breaking droughts have plagued Florida and other parts of the Southeast in recent years (including events in 2001-2002 and again in 2006-2007). These droughts have placed considerable strain on freshwater resources throughout the region. If global warming contributes to worsening drought conditions, as projected, it will become increasingly difficult to provide enough water resources to meet the needs of fish, wildlife, and a growing human population without a longer-term, more coordinated approach to water resource management.

While neither hypoxia nor anoxia are new phenomena, their prevalence has become much more widespread in recent decades, which scientists attribute in part to global warming (Boesch, 2007; Dybas, 2005; Kennedy, et al., 2002). This is because heavier precipitation flushes greater amounts of nutrients and other pollutants into coastal waters. In addition, heavy runoff decreases water mixing in estuaries as less dense fresher water rides over the top of the denser saltier water, inhibiting the mixing of water and the replenishment of oxygen in deep waters. Reduced water quality associated with excess stormwater runoff has already plagued Florida's coastal waters, contributing to declines in seagrass coverage, mortality of reef-building corals, and other serious environmental problems (Tomasko, et al., 2005; Ginsburg, Gischler, and Kiene, 2001).

---

2 If global warming does contribute to more intense hurricanes, they will likely bring more rainfall and contribute to flooding and stormwater runoff (Knutson and Tuleya, 2004). This underscores the importance of preparing for greater extremes in flood and stormwater management highlighted in this section. Recommendations to prepare for the consequences of higher storm surges are addressed in the section on sea-level rise.

Recommended Actions to Deal with Extreme Weather Events

As Florida faces greater extremes in precipitation events, including heavier rainfall and the possibility of more-intense coastal storms, improving stormwater management will be critical to meeting important goals to reduce eutrophication and other pollution problems in Florida's coastal waters as well as reduce the risks from localized flooding. For both new developments and redevelopment projects, for example, greater emphasis should be placed on preventive measures employed through land-use planning, such as placing limits on areas of impervious surfaces, and requiring restoration and protection of natural riparian buffers. Such "Low Impact Development" (LID, sometimes also referred to as "green infrastructure") measures are coming into widespread use in states and municipalities around the country, and are encouraged by U.S. EPA as a cost-effective stormwater management approach (U.S. EPA, 2007).

LID generally refers to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site where it is generated, rather than traditional hardscape collection, conveyance, and storage structures. LID approaches currently in use include greenroofs, trees and tree boxes, rain gardens, vegetated swales, pocket wetlands, infiltration planters, porous and permeable pavements, vegetated median strips, reforestation/revegetation, and protection and enhancement of riparian buffers and floodplains. These methods are most effective when supplemented with other decentralized storage and infiltration approaches, such as the use of permeable pavement, and rain barrels and cisterns to capture and re-use rainfall for watering plants or flushing toilets.

Even where engineering solutions to stormwater management are warranted, such as retrofitting culverts, retention ponds, and storm drains, it will be prudent to establish runoff-reduction goals that account for greater extremes than are reflected in historic trends and consider expanding the capacity of these systems now rather than being faced with having to re-invest in further retrofits in the coming decades. Today, Florida's stormwater management strategies largely rely on historical rainfall trends as a guide for determining their likely effectiveness, which could result in the development of infrastructure and approaches that are inadequate to deal with the heavier rainfall events associated with global warming (Harper and Baker, 2007).

Florida must also work with other states in the region to better manage water resources during droughts. The challenges of water resource management in the region have recently been brought to light by the ongoing battle between Florida, Alabama, and Georgia over water flowing from the Chattahoochee and Flint Rivers into the Apalachicola River and, ultimately, Apalachicola Bay. Water diversions for urban consumption, flood control, and other activities upstream have significantly reduced the amount of freshwater entering the bay, which has led to a considerable decline in coastal water quality. A decrease in available water resources due to global warming will exacerbate the situation.

On the whole, Florida still wastes considerable fresh water resources given the lack of more rigorous conservation and reuse opportunities. Ocean outfalls, deep well injection, and lack of advanced treatment and reuse of wastewater and stormwater result in billions of gallons of fresh water wasted daily in Florida. Among other things, Florida should place greater emphasis on implementing measures to increase water-use efficiency among major users such as cities and farms, as well as encourage use of seasonal and long-term projections for riverflows in water management decisions. This will not only provide needed water for drinking and other human uses, but it will enable protection of minimum water levels and flows for ecosystems and wildlife.

State/Local Government Actions

- *DEP should upgrade stormwater regulations, taking the likelihood of more frequent heavy rainfall events into consideration. Emphasis should be placed on natural buffers and requiring adequate long-term capacity and infrastructure for stormwater and sewage (taking projected climate change into consideration) prior to issuing new development permits. Policies should also focus on implementing LID methods, both for new developments and retrofits in existing developed areas.*
- *DEP should enhance protection and restoration of wetlands and riparian floodplains to help remove nutrients and reduce eutrophication and hypoxia, both of which are likely to be made worse as a result of global warming. Homeowners should be encouraged to protect and restore riparian vegetation along key watersheds to increase absorption of stormwater.*
- *DEP should evaluate/revise the Florida Water Plan (and regional water management plans) to explicitly address climate change. State and local water managers should: move away from relying on historic trends to determine future water availability; place significantly greater emphasis on reducing demand (increasing efficiency in water delivery and water use); fund strategies to make better use of reclaimed water, including through decentralized LID approaches; and expand efforts to implement recommendations established under the Florida Water Conservation Initiative.*
- *DEP should redouble efforts to reduce nutrient loading and set numeric criteria for nutrients. This should include: requiring "performance-based treatment systems" (new technology that significantly reduce nutrients and other pollutants) in coastal and other sensitive areas or consider piping into nearby existing systems; reducing phosphorous and nitrogen in the Everglades by lowering Total Maximum Daily Loads (TMDLs); building Storage Treatment Areas (STA); and setting a nitrogen standard for CERP.*
- *DEP Water Management Districts and local governments should work together to address wastewater treatment upgrades and to identify reuse opportunities throughout the state.*
- *Local governments should review land use, zoning, building, and related codes to remove or amend provisions that may inadvertently discourage or prevent the use of LID, and to affirmatively promote LID in new development and redevelopment projects.*

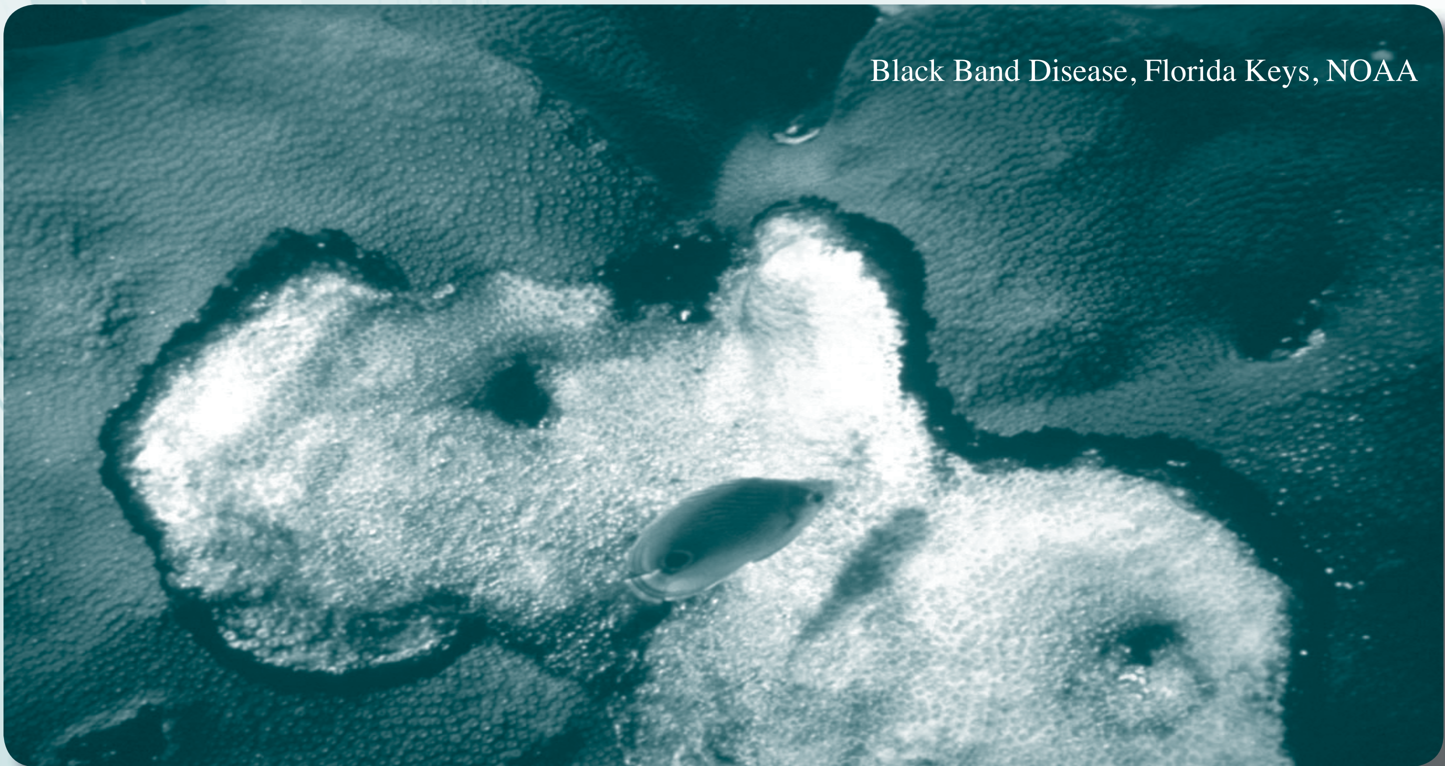
Federal/Regional Government Actions

- *Congress should require all federal water resource-related agencies to incorporate modern climate and sea-level rise projections into their water resources planning procedures and programs.*
- *To reduce eutrophication (and other pollution) associated with heavier rainfall events and runoff, U.S. EPA should revise its stormwater management rules under the Clean Water Act to discourage development in or near coastal and stream riparian buffers, wetlands, and other sensitive areas.*
- *The States of Florida, Georgia, and Alabama should actively engage in a collaborative effort to develop and implement a long-term regional water management plan that incorporates climate change and takes a more coordinated approach to water management, including water conservation and reuse, in order to meet the needs of people and the fish and wildlife they depend on for food, jobs, and recreation.*

Confronting the Impacts of Higher Ocean Temperatures

Average sea surface temperatures have increased over the latter half of the 20th century, providing another important indication of global warming (IPCC 2007a; AchutaRao, et al., 2007). On average, the temperature of the upper 300 meters of the world's oceans has risen about 0.56 degrees Fahrenheit since the 1950s, a trend that scientists have determined is a direct result of human activities (NOAA, 2000; Santer, et al., 2006). The increase has been even greater in the Tropical Atlantic region, where the average sea surface temperature has risen 1 degree Fahrenheit over the past three decades (Barnett, Pierce, and Schnur, 2001). If global warming pollution continues unabated, average ocean temperatures are projected to rise by an additional 2.7 to 5.4 degrees Fahrenheit before the end of the century, with potentially devastating consequences for coastal and marine ecosystems (IPCC 2007a).

The primary impacts of rising sea-surface temperatures in Florida include coral bleaching, exacerbation of marine diseases, and shifts in the ranges and population abundances of fish and other marine species.



Black Band Disease, Florida Keys, NOAA

Coral Bleaching and Diseases

The scientific community largely agrees that increased sea temperatures pose one of the greatest threats of extinction to coral species and coral reefs (IPCC, 2007b). "Bleaching" occurs in stony, calcareous (calcifying and reef-building) corals, soft corals and in some important calcareous macro algae species. Coral reefs are the most biologically diverse ecosystems on earth and provide essential food and habitat to more species than any other ecosystem (Roberts, 2003). In addition, coral reefs provide food, tourism, and recreational opportunities from boating, fishing, and diving.

Coral bleaching is a direct consequence of unusually warm water (Jokiel, 2004). When temperatures exceed the thresholds that they have evolved to tolerate, coral polyps, which are animals, expel their zooxanthellae. The latter are unicellular yellow-brown (dinoflagellate) algae which live symbiotically in the inner lining, or gastrodermis, of reef-building corals. Zooxanthellae give corals their colorful pigment; hence bleaching corals turn pale. Zooxanthellae also provide for their hosts by removing nutrients that attract harmful algae, by providing corals with food in the form of photosynthetic products (sugars), and by providing oxygen. In turn, corals provide protection and access to light for the zooxanthellae. In general, bleaching is a highly traumatic event for most coral species. They can die of malnutrition or suffocate. Often, the bleaching event itself is not fatal but weakens the colony's immune system enough for deadly infections to invade coral tissues (Harvell, 2007).

The number of massive bleaching events around the world has increased considerably since the 1980s, corresponding with a trend of increasingly warmer ocean temperatures combined with pollution and other human-imposed stressors (Wilkinson, 2004). Throughout the Florida Keys and the Caribbean, coral bleaching has contributed to a significant decline in stony coral diversity and cover (Causey, et al., 2005). In 2005, thermal stress to the region's corals due to high sea surface temperatures reached a level greater than the previous 20 years combined, contributing to a mass coral bleaching event that affected as much as 90 percent of coral cover in parts of the region (Donner, Knutson, and Oppenheimer, 2006). As temperatures continue to rise, coral bleaching events are expected to occur much more frequently within the next few decades (West and Salm, 2003). For corals to survive in this era of rapid, human-induced global warming, we must increase the resiliency of coral colonies by reducing other stressors to the greatest possible extent (Westmacott, et al., 2000).

Scientists also agree that global warming will extend "disease seasons." Warmer ocean temperatures are a significant factor in the growing incidence, range, and severity of a number of coral diseases, including black band disease, white band disease, white plague and white pox (Harvell, et al., 1999). While pathogens that cause these diseases occur naturally in coral tissues, studies have found that heat triggers a shift from beneficial bacteria to an overgrowth of opportunistic microbes. For example, recent research on elkhorn (*Acropora palmata*) corals found that surface mucus on healthy corals inhibited growth of potentially invasive microbes - including pathogens that cause white band disease - by up to 10-fold (Ritchie, 2006). The study found that this antibiotic activity was not occurring during a summer bleaching event. Mortality events from white band disease and several other diseases have been significant problems throughout Florida and the Caribbean. In 2006, two species of coral – elkhorn and staghorn (*Acropora cervicornis*) – were listed as threatened under the Endangered Species Act given their recent, widespread decline (Aylesworth and Bruno, 2008). Eleveated sea level, surface temperatures, hurricanes, and disease—all linked to global warming—are considered major threats to these corals. Critical habitat for these corals was proposed in February 2008.

Shifts in Species Ranges and Population Abundances

For most marine species, average ocean temperature on a broad scale is a major factor in determining viable habitat, and preferred temperature ranges can vary considerably among different species (Cheung, Lam, and Pauly, eds., 2008). In fact, optimal temperatures are so important for many fish that commercial and recreational fishermen will often refer to frequently-updated sea surface temperature maps to determine where a particular species or group of species might be at a given time.

Changes in average ocean temperatures can affect factors such as metabolism, reproduction, and predator-prey interactions, which in turn can alter species ranges and population abundances (Roessig, et al., 2004). While highly-mobile species may be able to move to find more favorable conditions, more sedentary species such as corals and mollusks will be forced to bear the changes where they occur. In the northern Gulf of Mexico, for example, much of the popular fishing occurs in summer months from May to October, when many species that prefer warmer waters migrate north. Higher average ocean temperatures due to global warming may expand opportunities for fishing for some species such as snook and tarpon, assuming other essential habitat factors such as salinity levels and food sources are also favorable (Sargeant, 2006). On the other hand, there is considerable concern that warmer waters would facilitate expansion of many opportunistic non-native plant and animal species whose current range may be limited primarily by temperatures (Scavia, et al., 2001). Many non-native species such as the Indo-Pacific lionfish thrive in warmer conditions and already are out-competing native species in Florida's coastal areas (Markham, 2001).

For other species that are already at the upper end of their preferred temperature range, however, warmer average water temperatures may be detrimental, particularly in the northern Gulf of Mexico, where opportunities for those species to retreat farther north in search of cooler waters is physically limited by the coastline. A study of potential effects of higher water temperatures in Apalachicola Bay due to global warming suggests that several important fishery species, including crabs, shrimp, oysters, and flounder, might not be able to survive in the estuary before the end of this century because water temperatures would exceed their thermal tolerance for an extended period of time (Livingston, 1989). Larval and juvenile blue crabs, which have a relatively low tolerance for high temperatures, could see close to 100 percent mortality in the estuary, while spotted seatrout, oyster larvae, panfish, and flounder could see 60 to 90 percent mortality.

Similarly, northern Florida is on the southern edge of the habitat range for striped bass, which cannot tolerate high water temperatures (Coutant, 1990). Higher average temperatures in the region due to global warming may eliminate both anadromous and landlocked striped bass from the region altogether. Given the important roles all native species play in their respective ecosystems, it is possible that major changes in species composition due to global warming will significantly alter the nature of our coastal and marine systems.

Higher water temperatures can exacerbate hypoxia events, as well, because warm water holds less dissolved oxygen than cooler water does. For each degree Fahrenheit in temperature increase, water's ability to dissolve oxygen decreases by about one percent (Najjar, et al., 2000). Higher water temperatures also accelerate the bacterial decay of organic matter present in the water, thereby consuming more oxygen and intensifying hypoxia. High water temperatures and resulting loss of oxygen have been identified as a leading cause of fish kills among coastal states (Lowe, et al., 1991).

Recommended Actions to Reduce the Impacts of Higher Ocean Temperatures

Lessening the impacts of higher ocean temperatures due to global warming will require strategies that increase the overall resiliency of ecosystems. It is necessary to reduce the negative impacts of a broad range of human-induced stressors on coastal and marine ecosystems in an effort to help them resist and/or recover from disturbances such as coral bleaching, disease outbreaks, or anoxia events (Grimsditch and Salm, 2005). Placing significantly greater emphasis on habitat protection and ecosystem-based management (EBM) approaches to managing fisheries, coral reefs, and other coastal resources will set an important foundation on which to cope with the multitude of stressors affecting them.

In particular, fish and wildlife managers and other relevant decision makers should focus on protecting the diversity of species and habitat types that characterize the state and region's ecological systems (Worm, 2006), as well as restoring or preserving habitat connectivity (Nyström and Folke, 2001). For example, restoring or maintaining the presence of algae-grazing species of fish and invertebrates can help limit the overgrowth of harmful, opportunistic algae on reefs damaged by coral bleaching (Nyström, Folke, and Moberg, 2000). In addition, improving connectivity both within and between coral reefs can facilitate distribution of larvae and help maintain genetic diversity among corals (Nyström and Folke, 2001). These factors should be an important consideration in the establishment and management of marine protected areas (MPAs), no-take reserves, and other coastal and marine conservation strategies. Furthermore, it will be important for researchers to continue to closely monitor coastal water temperatures and develop strategic and nimble management responses to deal with extreme events such as mass coral bleaching and disease outbreaks (Marshall and Shuttenberg, 2006).

State/Local Government Actions

- *DEP should amend the Southeast Florida Coral Reef Initiative Local Action Strategy to consider the added stress on coral reefs due to global warming and develop an effective, coordinated management strategy to increase the protection of the region's coral reef ecosystem.*
- *DEP should evaluate and monitor the effectiveness of the state's collective coastal and aquatic managed area and coastal zone management programs in supporting biological diversity among fish and wildlife species and should develop strategies to strengthen these programs.*
- *DEP should discontinue the process of permitting the use of ocean outfalls that discharge polluted wastewater into coastal areas containing coral reefs and require advanced wastewater treatment including nutrient removal and reuse of fresh water supplies.*
- *FWCC should promote the rebuilding of depleted coastal and ocean fish populations since depleted populations will have a harder time dealing with additional stresses posed by climate change and warming waters.*
- *FWCC and other relevant agencies should expand research and monitoring of coral reef ecosystems, including ongoing assessments of factors such as water temperatures and coral bleaching, incidence and range of coral diseases, damage and recovery from storms, and assessment of water quality, including the calcium carbonate saturation state and its effects on reefs over time.*

Federal/Regional Government Actions

- *Congress should enact climate adaptation legislation that would provide funding as well as require federal and state agencies to protect and strengthen the health of coastal and ocean ecosystems [see Box 2 on page 30].*
- *Congress should call for and support a National Academy of Sciences study, looking at the implications of climate change on fisheries management. The study should broadly evaluate management methodologies to mitigate impacts of climate change on the nation's fisheries resources. Following guidelines recommended in the study, the National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries Service (NMFS), in collaboration with FWCC and other relevant state agencies, should develop specific regional climate change adaptation/mitigation strategies to enhance adaptive capacity.*
- *Federal agencies should apply existing and new adaptive ecosystem management protocols with a focus on global warming impacts and measurable actions to ensure no net loss of reef habitats and key estuarine habitats. FWCC and the South Atlantic Fishery Management Council (SAFMC) should work together to implement action items pending in the SAFMC Fishery Ecosystem Plan and existing Essential Fish Habitat protocols.*
- *NMFS should fully consider factors that will enhance the resiliency of listed elkhorn and staghorn corals in its designation of critical habitat for the species, including ensuring adequate habitat connectivity and a healthy, diverse supporting ecosystem.*

[Box 2]

Funding Adaptation: Tapping New Sources

As this report has shown, ensuring that Florida's precious coastal and marine systems and the many benefits they provide us will endure for our children and grandchildren will require a concerted strategy to address the multiple stressors they face, including global warming. Certainly, Florida has made considerable investments to restore and protect fish and wildlife from ongoing threats, and these efforts need to continue. At the same time, new efforts are required to specifically address the changes that global warming is likely to bring, and these new activities will require new sources of funding.

Like other states, conservation activities in Florida are supported by a combination of special revenues, state general fund appropriations, and federal support. However, funds available to Florida agencies regarding conservation, fisheries, environment, and planning are insufficient to meet the current conservation challenges, much less new challenges posed by global warming. Furthermore, these agencies often face budget uncertainty from year to year. It is not uncommon that the special revenues supposedly dedicated to fish and wildlife conservation are redirected to other unrelated efforts. Such funding uncertainty will constrain agencies from pursuing the important new programs necessary to address global warming.

Accordingly, it is critically important that Florida pursue additional state and federal funding sources to support management strategies and decisions. One important opportunity currently under consideration is the incorporation of dedicated funds to invest in natural resources conservation as part of state, regional, and federal global warming mitigation plans. For example, the leading proposals in Congress for controlling global warming pollution create a new system of permits for major emitters, often referred to as a "cap and trade" system. Under such a proposal, the government would auction off annual permits that allow industry to emit a certain amount of carbon dioxide and other greenhouse gases. At the end of the year, each industrial source would be required to hold permits to cover its emissions for the year. As such a system is put in place, it is critical that a portion of proceeds from the auction of emission permits be set aside to fund strategies for protecting and managing natural resources impacted by global warming.

An example of current (2007-2008) federal legislation that directly addresses the need to invest in conservation of natural resources threatened by climate change is the Climate Security Act (S. 2191), sponsored by Senator Joe Lieberman (I) and Senator John Warner (R). In addition to creating a national cap-and-trade system, this bill provides crucial financial resources to federal, state, and tribal agencies for preventing damage to natural resources from climate change and for restoring ecosystems already damaged by climate change. During the first 19 years of the program, an average of 7 percent of the value of emissions permits would be dedicated to such "adaptation," ranging from roughly $4 billion in 2012 to $17 billion in 2030. The Department of Commerce (which includes NOAA and NMFS) would receive 10 percent of the proceeds for "adaptation activities to protect, maintain, and restore coastal, estuarine, and marine resources, habitats, and ecosystems" [Sec. 4702 (g)]. In addition, 15 percent of the proceeds would go to the U.S. EPA (5%) and Army Corps of Engineers (10%) for adaptation projects involving large-scale freshwater and estuarine ecosystems. Given Florida's extensive and unique coastal and marine resources, a significant portion of this funding would benefit the state.

The Climate Security Act also would provide 35 percent of adaptation program funds to state fish and wildlife agencies, which would result in annual amounts to the Florida Fish and Wildlife Conservation Commission (FWCC) ranging from $54 million in 2012 to $244 million in 2030. The bill also specifies that the state must match these dollars with a 10 percent contribution. It is important that Florida's policy makers be aware of this pending opportunity and plan accordingly. Currently, FWCC has difficulties reaching its match requirement under the State Wildlife Grant program, which is significantly lower than potential revenues under the Climate Security Act. Additional efforts will be needed to generate the funds necessary to support the state's critical conservation priorities.

Confronting the Impacts of Increased Ocean Acidification

About a third of the carbon dioxide (CO_2) emitted into the atmosphere by burning fossil fuels is absorbed by the oceans. This added CO_2, is changing the carbon chemistry of ocean water by making it more acidic (IPCC 2007a). In fact, if CO_2 concentrations in the atmosphere continue to increase at the current rate, then the oceans will become relatively more acidic (will have a lower pH) than they have been in millions of years (Caldeira and Wickett, 2003).

This lower pH is eroding the basic mineral building blocks for the shells and skeletons of calcareous, reef-building organisms such as shellfish and corals, as well as a number of important microorganisms that are a foundation for the marine food web (Kuffner and Tihansky, 2008; Orr, et al., 2005). For corals, lower calcification rates ultimately mean weaker, slower-growing reefs (Kleypas, Buddemeier, and Gattuso, 2001). There is evidence that reduced coral calcification is already happening in some areas. For example, researchers at the Australian Institute of Marine Science (AIMS) have found that there has been a 21 percent decline in the calcification rate of Porites corals in parts of the Great Barrier Reef (Cooper, et al., 2008).

A number of laboratory studies suggest that a doubling of CO_2 in the atmosphere from pre-industrial levels would cause coral reef calcification to decline by 10-50 percent (Kleypas, et al., 2006). The combination of warmer and more acidic waters means that coral ecosystems are among the most threatened marine/coastal habitats now in Florida and the world (Hoegh-Guldberg, 2007).

Yellowtail Snapper, NOAA

Recommended Actions to Address Acidification

Unfortunately, there are currently no known ways to mitigate for ocean acidification, except to cut CO_2 emissions into the atmosphere. Even a relatively small change in ocean pH can have a large impact on carbonate ion concentrations (Buddemeier, Kleypas, and Aronson, 2004). A recent study by the German Advisory Council on Global Change (GACGC) suggests that limiting the change in average ocean pH to no more than 0.2 unit below pre-industrial levels (which was about 8.15, versus 8.05 today) will minimize the risk of ecological damage to the oceans' ecosystems (GACGC, 2006). This pH change corresponds to stabilizing atmospheric CO_2 concentrations at about 450 ppm.

State/Local Government Actions

- *Florida should adopt a stringent CO_2 reduction goal to achieve the necessary 80 percent reduction target below current levels by 2050.*
- *Federal and state agencies should make monitoring of ocean pH and calcification rates a part of the coral monitoring plans in the Tortugas Ecological Reserve, the Florida Keys National Marine Sanctuary, Biscayne National Park, and Oculina Bank Habitat Area of Particular Concern.*
- *DEP should enhance state monitoring of biogenic reefs such as oyster reefs as well as valuable shellfish such as scallops for calcification problems.*
- *Relevant state (and federal) agencies should invest in studies to better understand the ecological impacts of ocean acidification.*

Federal/Regional Government Actions

- *Congress and the administration must place mandatory limits on the nation's global warming pollution to ensure we meet the necessary target of an 80 percent reduction from current levels by 2050.*

Sunrise After A Storm, TJ Marshall

Conclusion

Florida faces enormous challenges from global warming. The projected impacts on the state's coastal and marine systems alone would have devastating consequences for the state's economy and quality of life. Fortunately, federal, state, and local governments have an important opportunity to reduce global warming pollution and at the same time help ease the effects that habitat changes will have on fish and wildlife. By implementing the recommendations outlined in this report, we can help change the forecast for Florida's coastal and ocean resources and ensure that the economic opportunities, ecological benefits, and outdoor traditions they provide will endure for generations to come. Indeed, Florida has an opportunity to become a national leader in both climate change mitigation and adaptation and, in the process, build a strong and vibrant economy.

As many studies have shown, moving toward a low-carbon economy (i.e., mitigating global warming) not only will significantly reduce the impacts of global warming and their costs to society, but it will actually create new jobs and stimulate economic growth (UNEP, 2008; Gordon and Hays, 2008; Renner, Sweeney, and Kubit, 2007). Similarly, by taking proactive measures to ameliorate the impacts of global warming that are already underway (i.e., implementing adaptation strategies), Florida can minimize their costs and in the process become an important model for conservation in the 21st century (Stern, 2005). For example, there is enormous potential for the state's highly regarded universities and research institutions to capitalize on the growing need for scientific analyses, engineering and technological innovations, improvements in land-use planning and resource management practices, and other information to support the important decisions that government officials, businesses, natural resource managers, and citizens will need to make to cope with the impacts of global warming.

References

AchutaRao, K.M., et al. 2007. "Simulated and Observed Variability in Ocean Temperature and Heat Content." *Proceedings of the National Academy of Sciences* 104: 10768-10773.

Anthes, R.A., et al. 2006. "Hurricanes and Global Warming: Potential Linkages and Consequences." *Bulletin of the American Meteorological Society* 87: 623-628.

Aronson, R.B. and Precht, W. 2001. "White-band Disease and the Changing Face of Caribbean Coral Reefs." *Hydrobiologia* 460: 25-38.

Aylesworth, L. and Bruno, J. 2008. "Corals as Endangered Species." In: *Encyclopedia of Earth* (C.J. Cleveland, ed.) (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment).

Barnett, T.P., Pierce, D.W., and Schnur, R. 2001. "Detection of Anthropogenic Climate Change in the World's Oceans." *Science* 292: 270-274.

Boesch, et al., 2007. *Coastal Dead Zones and Global Climate Change: Ramifications of Climate Change for Chesapeake Bay Hypoxia* (Arlington, VA: Pew Center on Global Climate Change).

Bollman, N. 2007. *Florida's Resilient Coasts: a State Policy Framework for Adaptation to Climate Change – Discussion Draft* (Fort Lauderdale, FL: Center for Urban and Environmental Solutions, Florida Atlantic University).

Brook, E.J. 2005. "Atmospheric Science: Tiny Bubbles Tell All." *Science* 310: 1285-1287.

Buddemeier, R.W., Kleypas, J.A., and Aronson, R.B. 2004. *Coral Reefs and Global Climate Change: Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems* (Arlington, VA: Pew Center on Global Climate Change).

Burkett, V., et al. 2001. "Chapter 5: The Potential Consequences of Climate Variability and Change for the Southeastern United States," in National Assessment Synthesis Team, ed., *Climate Change Impacts on the United States: Foundation* (Cambridge University Press): 137-164.

Bush, D. M., et al. 2004. *Living With Florida's Atlantic Beaches* (Durham, N.C.: Duke University Press).

Caldeira, K. and Wickett, M.E. 2003. "Oceanography: Anthropogenic Carbon and Ocean pH." *Nature* 425: 365.

Causey, B.D., et al. 2005. "Status of Coral Reefs in Florida," in J.E. Weddell, ed., *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005* (Silver Spring, MD: National Oceanic and Atmospheric Administration): 101-118.

Cheung, W.W.L., Lam, V.W.Y., and Pauly, D. (eds.). 2008. *Modelling Present and Climate-Shifted Distribution of Marine Fishes and Invertebrates* (Vancouver, B.C.: Fisheries Centre, University of British Columbia).

Conrad, D.R., McNitt, B., and Stout, M. 1998. *Higher Ground: A Report on Voluntary Buyouts in the Nation's Floodplains, A Common Ground Solution Serving People at Risk, Taxpayers, and the Environment* (Washington, D.C.: National Wildlife Federation).

Cooper, T., et al. 2008. "Declining Coral Calcification in Massive *Porites* in Two Nearshore Regions of the Northern Great Barrier Reef." *Global Change Biology* 14: 529-538.

Coutant, C.C. 1990. "Temperature-Oxygen Habitat for Freshwater and Coastal Striped Bass in a Changing Climate." *Transactions of the American Fisheries Society* 119: 240-253.

Cross, B.J. et al. 2001. "Quantifying Vertical Accretion and Elevation Vs. Sea Level in Salt Marshes Along the Northwest Coast of Florida." *Geological Society of America Southeastern Section – 50th Annual Meeting, April 5-6, 2001*.

Desantis, L.R.G., et al. 2007. "Sea-Level Rise and Drought Interactions Accelerate Forest Decline on the Gulf Coast of Florida, USA." *Global Change Biology* 13: 2349-2360.

Deyle, R.E., Bailey, K.C., and Matheny, A. 2007. *Adaptive Response Planning to Sea-level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning* (Tallahassee, FL: Florida State University, Department of Urban and Regional Planning).

Diffenbaugh, N.S., et al. 2005. “Fine-scale Processes to Regulate the Response of Extreme Events to Global Climate Change.” *Proceedings of the National Academy of Sciences* 102: 15774-15778.

Donner, S.D., Knutson, T.R., and Oppenheimer, M. 2006. “Model-Based Assessment of the Role of Human-Induced Climate Change in the 2005 Caribbean Coral Bleaching Event.” *Proceedings of the National Academy of Sciences* 104: 5483-5488.

Dugan, J.E. and Hubbard, D.M. 2006. “Ecological Responses to Coastal Armoring on Exposed Sandy Beaches.” *Shore and Beach* 74: 10-16.

Earthjustice. 2006. *The Lake Okeechobee Pollution Crisis and the St. Lucie River and Estuary* (Tallahassee, FL).

Easterling, D.R., et al. 2000. “Climate Extremes: Observations, Modeling, and Impacts,” *Science* 289: 2068-2074.

Emanuel, K. 2005. “Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years.” *Nature* 436: 686-688.

Federal Emergency Management Agency (FEMA). 2008. “Repetitive Loss State Summary Data as of 12/31/07.”

Florida Atlantic University. 2005. *Economics of Beach Tourism in Florida* (Tallahassee, FL: Florida Department of Environmental Protection).

Florida Department of Environmental Protection. “Beach Erosion Control Program” http://www.dep.state.fl.us/beaches/programs/bcherosn.htm (Accessed 10/26/2007).

Florida Department of Environmental Protection, 2007. *State of Florida Beach Management Plan* (Draft June 2007) (Tallahassee, FL).

Florida Department of Insurance Regulation. 2006. *Hurricane Summary Data CY 2004 and CY 2005* (Tallahassee, FL: Florida Department of Financial Services/Financial Services Commission).

German Advisory Council on Global Change. 2006. *The Future Oceans – Warming Up, Rising High, Turning Sour* (Berlin, Germany).

Gibeaut, J. 2006. “Up Against the Seawall: After Last Year’s Hurricanes, a New Storm Over Property Rights and Beach Protection Engulfs Florida’s Coast.” *ABA Journal* July 2006.

Ginsburg, R.N., Gischler, E., and Kiene, W.E. 2001. “Partial Mortality of Massive Reef-Building Corals: An Index of Patch Reef Condition, Florida Reef Tract.” *Bulletin of Marine Science* 69: 1149-1173.

Glick, P. 2006. *An Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida* (Reston, VA: National Wildlife Federation and Tallahassee, FL: Florida Wildlife Federation).

Gordon, K. and Hays, J. 2008. *Green-Collar Jobs in America’s Cities: Building Pathways Out of Poverty and Careers in the Clean Energy Economy* (San Francisco, CA: Apollo Alliance).

Governor’s Action Team on Energy and Climate Change. 2007. *A Report to Governor Charlie Crist. Phase 1 Report: Florida’s Energy and Climate Action Plan Pursuant to Executive Order 07-128, November 1, 2007.*

Grimsditch, G.D., and Salm, R.V. 2005. *Coral Reef Resilience and Resistance to Bleaching* (Gland, Switzerland: The World Conservation Union).

Groisman, P.Y. et al. 2004. “Contemporary Changes of the Hydrological Cycle Over the Contiguous United States: Trends Derived from in Situ.” *Journal of Hydrometeorology* 5: 64-85.

Hansen, J.E. 2007. “Scientific Reticence and Sea Level Rise.” *Environmental Research Letters* 2: 1-6.

Harper, H.H., and Baker, D.M. 2007. *Evaluation of Current Stormwater Design Criteria within the State of Florida: Final Report Prepared for the Florida Department of Environmental Protection* (Orlando, FL: Environmental Research & Design, Inc.).

Harrington, J. and Walton, T.L. Jr., 2007. *Climate Change in Coastal Areas in Florida: Sea-level rise Estimation and Economic Analysis to Year 2080* (Tallahassee, FL: Florida State University).

Harwell, M., Gholz, H., and Rose, J. 2001. *Confronting Cimate Change in the Gulf Coast Region: Florida* (Union of Concerned Scientists and the Ecological Society of America).

Harvell, C.D., et al. 2007 "Coral Disease, Environmental Drivers, and the Balance Between Coral and Microbial Associates." *Oceanography* 20: 172-195.

Harvell, C.D., et al. 1999. "Emerging Marine Diseases – Climate Links and Anthropogenic Factors." *Ecology* 285: 1505-1510.

Harwell, M., Gholz, H., and Rose, J. 2001. *Confronting Cimate Change in the Gulf Coast Region: Florida* (Union of Concerned Scientists and the Ecological Society of America).

Hoegh-Guldberg, O., et al. 2007. "Coral Reefs Under Rapid Climate Change and Ocean Acidification." *Science* 14: 1737-1742.

Hoegh-Guldberg, O. 1999 "Climate Change, Coral Bleaching and the Future of the World's Coral Reefs," *Marine and Freshwater Research* 50: 839-866.

Holland, G.J. and Webster, P.J. 2007. "Heightened Tropical Cyclone Activity in the North Atlantic: Natural Variability or Climate Trend?" Philosophical Transactions of the Royal Society A 365: 2695-2716.

IPCC, 2007a. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [S.D. Solomon, et al., eds.] (Cambridge, U.K: Cambridge University Press).

IPCC, 2007b. *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution to Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [M.L. Parry, et al., eds.] (Cambridge, U.K.: Cambridge University Press).

IPCC, 2007c. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, et al., eds.] (Cambridge, U.K.: Cambridge University Press).

IPCC, 2001. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, U.K.: Cambridge University Press).

Jokiel. P.L. 2004. "Temperature Stress and Coral Bleaching," pp. 401-428 in E. Rosenberg and Y. Loya, eds., *Coral Health and Diseases* (Berlin, Germany: Springer).

Joyce, S. "The Dead Zones: Oxygen-Starved Coastal Waters." *Environmental Health Perspectives* 108: A120-A125.

Kleypas, J.A., et al. *Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research*, report of a workshop held 18-20 April 2005, St. Petersberg, FL., sponsored by NSF, NOAA, and the U.S. Geological Survey.

Kleypas, J.A., Buddemeier, R.W., and Gattuso, J.-P. 2001. "The Future of Coral Reefs in an Age of Global Change." *International Journal of Earth Sciences* 90: 426-437.

Kleypas, J.A., et al. 1999. "Geochemical Consequences of Increased Atmospheric Carbon Dioxide on Coral Reefs," *Science* 284: 118-120.

Knutson, T.R. and Tuleya, R.E. 2004. "Impact of CO_2 –Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization," *Journal of Climate* 17: 3477-3495.

Krueger, C. and Pittman, C. 2008. "As Sea Water Rises, the Toll to Florida is Logged." *St. Petersburg Times*, Friday, March 28, 2008.

Kuffner, I. and Tihansky, A. 2008. *Coral Reef Builders Vulnerable to Ocean Acidification* (Reston, VA: U.S. Geological Survey).

Langdon, C., et al. 2000. "Effect of Calcium Carbonate Saturation State on the Calcification Rate of an Experimental Coral Reef." *Global Biogeochemical Cycles* 14: 639-654.

Leatherman, S.P. 1989. *National Assessment of Beach Nourishment Requirements Associated with Accelerated Sea-Level Rise* (Washington, D.C.: U.S. EPA Office of Policy, Planning, and Evaluation).

Levina, E., et al. 2007. *Policy Frameworks for Adaptation to Climate Change in Coastal Zones: The Case of the Gulf of Mexico* (Paris, France: Organisation for Economic Co-operation and Development and the International Energy Agency).

Livingston, R.J. 1989. "Projected Changes in Estuarine Conditions Based on Models of Long-Term Atmospheric Alteration." Volume E – Aquatic Resources, in J.B. Smith and D. Tirpak, eds., The Potential Effects of Global Climate Change on the United States (Washington, D.C.: U.S. EPA).

Lowe, A.J., et al. 1991. Fish Kills in Coastal Waters: 1980-1989 (Rockville, MD: National Ocean Service, National Oceanic and Atmospheric Administration).

Markham, A. 2001. Trouble in Paradise: The Impacts of Climate Change on Biodiversity and Ecosystems in Florida (Washington, D.C.: World Wildlife Fund).

Marshall, P. and Schuttenberg, H. 2006. A Reef Manager's Guide to Coral Bleaching (Townsville, Australia: Great Barrier Reef Marine Park Authority).

Miami-Dade County Climate Change Advisory Task Force (CCATF). 2008a. Statement on Sea Level in the Coming Century (Miami, FL: Miami-Dade County).

Miami-Dade County CCATF. 2008b. Second Report and Initial Recommendations: Presented to the Miami-Dade Board of County Commissioners (Miami, FL: Climate Change Advisory Task Force).

Morris, J.T. et al. 2002. "Responses of Coastal Wetlands to Rising Sea Level," Ecology 83: 2869-77.

Najjar, R.G., et al. 2000. "The Potential Impacts of Climate Change on the Mid-Atlantic Coastal Region." Climate Research 14: 219-33.

NOAA, 2000. "World Ocean has Warmed Significantly Over Past 40 Years." NOAA News Online, March 23, 2000 http://www.noaanews.noaa.gov/stories/s399.htm (accessed March 24, 2008).

Nyström, M. and Folke, C. 2001. "Spatial Resilience of Coral Reefs." Ecosystems 4: 406-17.

Nyström, M., Folke, C., and Moberg, F. 2000. "Coral Reef Disturbance and Resilience in a Human-dominated Environment." Trends in Ecology and Evolution 15: 413-417.

O'Neill, B.C., and Oppenheimer, M. 2002. "Dangerous Climate Impacts and the Kyoto Protocol." Science 296: 1971-1972.

Oouchi, K., et al. 2006. "Tropical Cyclone Climatology in a Global Warming Climate As Simulated in a 20km-mesh Global Atmospheric Model: Frequency and Wind Intensity Analysis." Journal of the Meteorological Society of Japan 84: 259-276.

Orr, J.C., et al. 2005. "Anthropogenic Ocean Acidification Over the Twenty-first Century and its Impact on Calcifying Organisms." Nature 437: 681-686.

Otto-Bliesner, B.L., et al. 2006. "Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation," Science 311: 1751-3.

Overpeck, J.T. et al. 2006. "Paleoclimatic Evidence for Future Ice-sheet Instability and Rapid Sea-level Rise." Science 311: 147-50.

Pearson, P.N. and Palmer, M.R. 2000. "Atmospheric Carbon Dioxide Concentrations over the Past 60 Million Years." Nature 406: 695-699.

Peng, T.H., et al. 1998. "Quantification of Decadal Anthropogenic CO2 Uptake in the Ocean Based on Dissolved Inorganic Carbon Measurements." Nature 396: 560-563.

Peterson, C.H. and Bishop, M.J. 2005. "Assessing the Environmental Impacts of Beach Nourishment." BioScience 55: 887-896.

Pielke, R.A., et al. 2005. "Hurricanes and Global Warming." Bulletin of the American Meteorological Society : 571-575.

Rahmstorf, S. 2007. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise." *Science* 315: 368-370.

Renner, M., Sweeney, S., and Kubit, J. 2007. *Green Jobs: Towards Sustainable Work in a Low-Carbon World* (Nairobi, Kenya: United Nations Environment Programme; Geneva, Switzerland: International Labour Organisation; and Brussels, Belgium: International Trade Union Confederation).

Rignot, E. and Kanagaratnam, P. 2006. "Changes in the Velocity Structure of the Greenland Ice Sheet." *Science* 311: 986-990.

Ritchie, K.B. 2006. "Regulation of Microbial Populations by Coral Surface Mucus and Mucus-Associated Bacteria." *Marine Ecology Progress Series* 322: 1-14.

Roberts, E. 2003. "Scientists Warn of Coral Reef Damage from Climate Change." *Marine Scientist* 2: 21-23.

Roessig, J.M., et al. 2004. "Effects of Global Climate Change on Marine and Estuarine Fishes and Fisheries." *Reviews in Fish Biology and Fisheries* 14: 251-275.

Santer, B.D., et al. 2006. "Forced and Unforced Ocean Temperature Changes in Atlantic and Pacific Tropical Cyclogenesis Regions." *Proceedings of the National Academy of Sciences* 103: 13905-13910.

Sargeant, F. 2006. "Global Warming Might Help Some Fish Species, Harm Others." *Ichthyology at the Florida Museum of Natural History: In the News, July 12, 2006* http://flmnh.ufl.edu/fish/InNews/warming2006.html (accessed 1/14/2008).

Scavia, D., et al. 2001. *Climate Change Impacts on U.S. Coastal and Marine Ecosystems* (Washington, D.C.: U.S. Global Change Research Group).

Schlacher, T.A., et al. 2007. "Sandy Beaches at the Brink." *Diversity & Distributions* 13: 556-60.

Science and Technology Committee, Miami-Dade County Climate Change Task Force. *Statement on Sea Level in the Coming Century, January 7, 2008*.

Snover, A.K., et al. 2007. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (Oakland, CA: ICLEI – Local Governments for Sustainability).

Stanton, E.A. and Ackerman, F. 2007. *Florida and Climate Change: The Costs of Inaction* (Medford, MA: Tufts University, Global Development and Environment Institute).

Stern, N., et al., 2006. *Stern Review: The Economics of Climate Change* (London: HM Treasury).

Tait, J.F. and Griggs, G.B. 1990. "Beach Response to the Presence of a Seawall: a Comparison of Field Observations." *Shore and Beach* 58: 11-28.

Titus, J.G. 2000. "Does the U.S. Government Realize that the Sea is Rising? How to Restructure Federal Programs so that Wetlands and Beaches Survive." *Golden Gate University Law Review* 30: 717-778.

Titus, J.G., et al. 1991. "Greenhouse Effect and Sea-Level Rise: The Cost of Holding Back the Sea." *Coastal Management* 19: 171-204.

Tomasko, D.A., et al. 2005. "Spatial and Temporal Variation in Seagrass Coverage in Southwest Florida: Assessing the Relative Effects of Anthropogenic Nutrient Load Reductions and Rainfall in Four Contiguous Estuaries." *Marine Pollution Bulletin* 50: 797-805.

Trenberth, K.E. 2007. "Warmer Oceans, Stronger Hurricanes." *Scientific American* 297.

Treasure Coast Regional Planning Council. 2005. *Sea-level rise in the Treasure Coast Region* (Submitted to the Southwest Florida Regional Planning Council, December 5, 2005).

Trenberth, K.E. 2007. "Warmer Oceans, Stronger Hurricanes." *Scientific American* 297: 44-51.

Trenberth, K.E. and Shea, D.J. 2006. "Atlantic Hurricanes and Natural Variability in 2005." *Geophysical Research Letters* 33: 233-244.

Trenberth, K.E. et al. 2003 "The Changing Character of Precipitation." *Bulletin of the American Meteorological Society* 84: 1205-1217.

Trimble, P.J., Santee, E.R., and Deidrauer, C.J. 1998. "Preliminary Estimate of Impacts of Sea-level rise on the Regional Water Resources of Southeastern Florida." *Proceedings of the International Coastal Symposium. Journal of Coastal Research, Special Issue*: 252-255, Presented at the May 1998 International Coastal Symposium in Palm Beach, FL.

Twilley, R.R. 2007. *Coastal Wetlands and Global Climate Change: Gulf Coast Wetland Sustainability in a Changing Climate* (Arlington, VA: Pew Center on Global Climate Change).

Twilley, R.R., et al. 2001. *Confronting Climate Change in the Gulf Coast Region* (Washington, D.C: Union of Concerned Scientists and the Ecological Society of America).

Twilley, R.R. 1997. "Mangrove Wetlands," in Messina, M. and Connor, W., eds. *Southern Forested Wetlands: Ecology and Management* (Boca Raton, FL: CRC Press): 445-473.

United Nations Environment Programme (UNEP). 2008. *UNEP Background Paper on Green Jobs.*

U.S. EPA. 2007. *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* (Washington, D.C.: EPA 841-F-07-006).

U.S. EPA. 1997. *Climate Change and Florida* (Washington, D.C.: EPA-230-F-97-088i).

Walker, C., Smith, T.J., III, and Whelan, K.R.T. 2003. "Short Term Dynamics of Vegetation Change Across a Mangrove - Marsh Ecotone in the Southwest Coastal Everglades: Storms, Sea Level, Fires and Freezes." *Joint Conference on the Science and Restoration of the Greater Everglades and Florida Keys, Program with Abstracts*: 571-573.

Walsh, K.J.E., Nguyen, K.C., and McGregor, J.L. 2004. "Fine-resolution Regional Climate Model Simulations of the Impact of Climate Change on Tropical Cyclones Near Australia." *Climate Dynamics* 22: 47-56.

Wanless, H.R., Parkinson, R., and Tedesco, L.P. 1994. "Sea Level Control on Stability of Everglades Wetlands," in Davis, S.M. and Ogden, J.C. (eds.) *Everglades: The Ecosystem and its Restoration* (Del Ray Beach, FL: St. Lucie Press): 199-222.

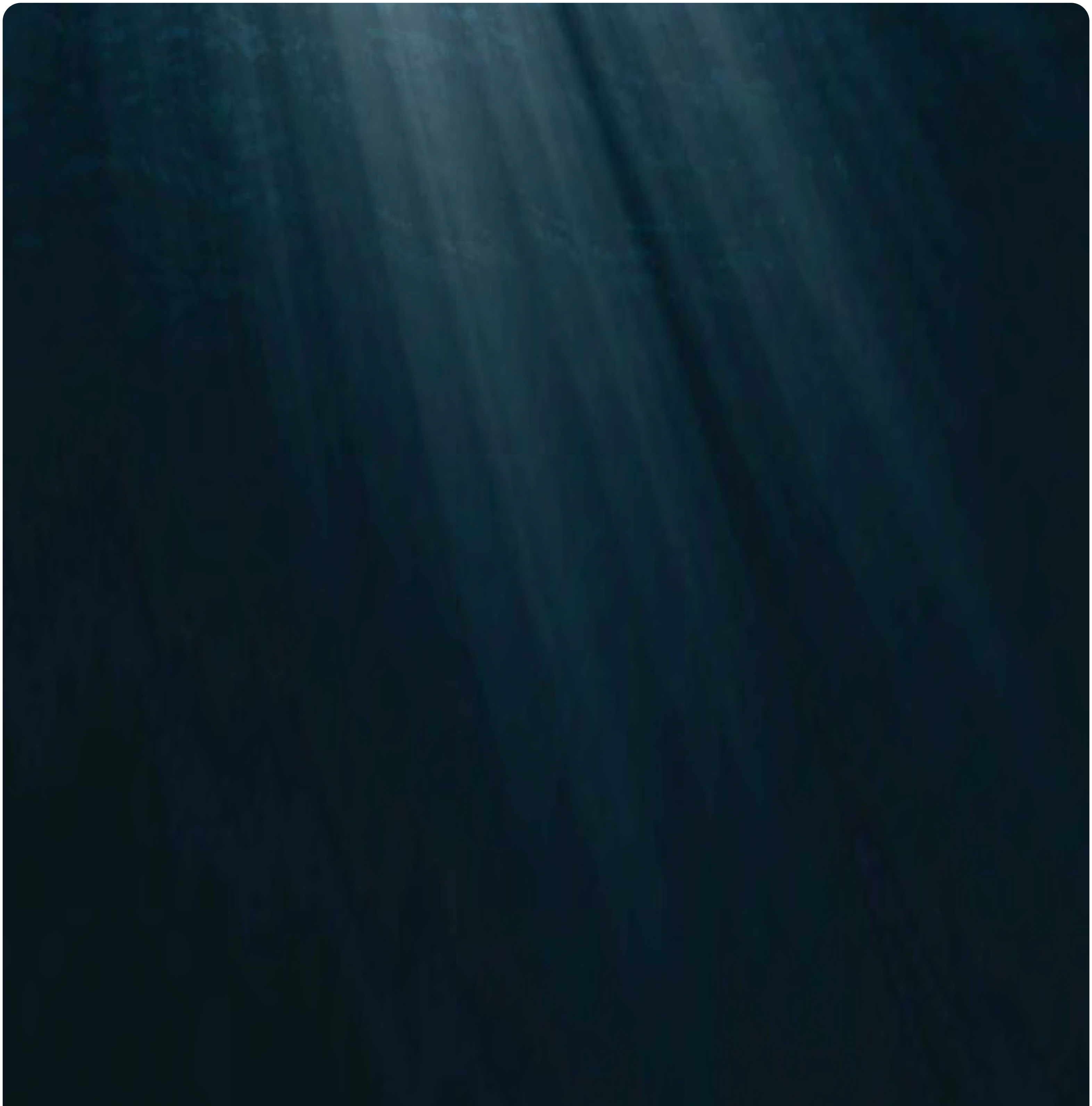
Webster, P.J., et al. 2005. "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment." Science 309: 1844-1846.

West, J.M. and Salm, R.V. 2003. "Resistance and Resilience to Coral Bleaching: Implications for Coral Reef Conservation and Management." *Conservation Biology* 17: 956-967.

Westmacott, S., et al. 2000. *Management of Bleached and Severely Damaged Coral Reefs* (Gland, Switzerland: The World Conservation Union).

Wilkinson, C. (ed.). 2004. *Status of Coral Reefs of the World:* 2004 (Townsville, Queensland AU: Global Coral Reef Monitoring Network and Australian Institute of Marine Science).

Worm, B., et al. 2006. "Impacts of Biodiversity Loss on Ocean Ecosystem Services." *Science* 314: 787-790.



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

Florida Coastal and Ocean Coalition

www.flcoastalandocean.org/PreparingforaSeaChange
info@flcoastalandocean.org