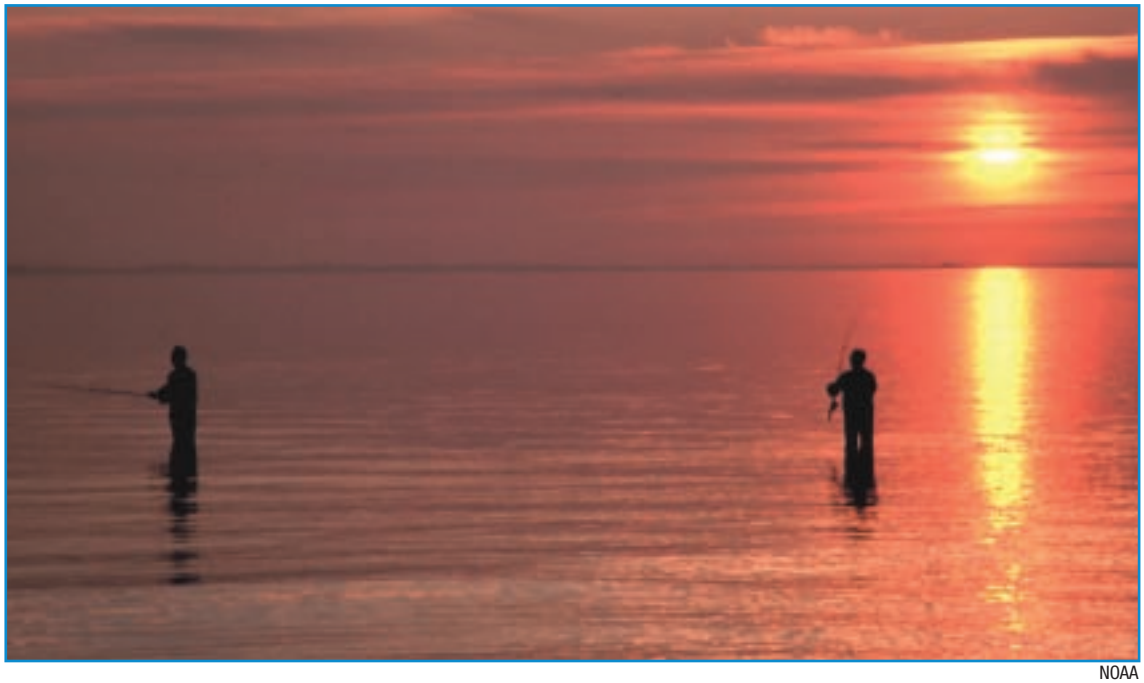
AN UNFAVORABLE TIDE

Global Warming, Coastal Habitats and Sportfishing in Florida



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NATIONAL WILDLIFE FEDERATION

FLORIDA WILDLIFE FEDERATION

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The National Wildlife Federation is America's conservation organization protecting wildlife for our children's future.

The mission of the Florida Wildlife Federation is to promote, through education and advocacy, the conservation, restoration, and sound management of Florida's fish and wildlife and their habitats. The Florida Wildlife Federation also encourages the public's appreciation of Florida's environment through sustainable, resource-based outdoor recreation.

An Unfavorable Tide—Global Warming, Coastal Habitats and Sportfishing in Florida

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Front Cover Illustration: Stephen Left

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Foreword

The following report, *An Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida*, represents a second heroic effort by the National Wildlife Federation (NWF) and the Florida Wildlife Federation (FWF) to educate sportsmen about what climate change may mean for fish, wildlife, as well as the recreational opportunities and industries that depend upon susceptible ecosystems. The first report educated waterfowlers about the potential impacts to populations of ducks and geese, as the prairie pothole region in the Northern Great Plains becomes drier and as coastal freshwater marshes become salty. NWF and FWF produced *An Unfavorable Tide* for the benefit of Florida's anglers, and their children, grandchildren and great grandchildren.


VISIT FLORIDA

Wherever you fish in Florida, this report literally hits home. Nine of the state's greatest fisheries were modeled for 25- , 50- and 100-year impacts of sea-level rise, including Pensacola, Apalachicola, Tampa Bay, Charlotte Harbor, the Ten Thousand Islands, Florida Bay, Biscayne Bay, St. Lucie River, and the Indian River Lagoon. For me, the most shocking model shows that 91 percent of the tidal flats in Florida Bay, where I've spent so many happy hours poling after redfish tailing on fiddler crabs, will be inundated by 2025--99 percent by the turn of the century. It's sad to imagine a day when Snake Bight becomes too deep to sight fish. However, sea-level rise won't necessarily equate to a net loss of wildlife habitats, except where development deprives the coast of its ability to morph. In wilderness areas, such as Everglades National Park, brackish marsh and mangroves will likely migrate inland. So maybe my grandkids will chase reds up around Homestead.

The issue may seem ponderous, and pardon the pun, global warming isn't yet a hot topic at institutions such as the Lorelei Cabana Bar on Islamorada Key, fishing clubs or even among armchair conservationists. Indeed, climate change and symptoms of climate change including sea-level rise seem like vast and intangible issues to most anglers. For the most part, we feel humbly blessed to get out on the water come Saturday. That's why most fishing magazine editors rarely risk souring a magazine or annoying themselves or readers with the subject. Mostly, and with considerable political success, we've focused conservation advocacy and coverage on fisheries management, access and habitat issues that impact family-level fishing in immediate ways.

Indeed, conservation efforts by the fishing community have fomented revolutionary changes. The NWF/FWF report recognizes the 1994 gillnet ban, which brought many species back from the brink. Anglers are also fighting for sustainable beach management, clean water, and Everglades restoration; but climate change is already factoring into these initiatives, whether climate change is discussed or not. Undeniably, we are already experiencing

symptoms of climate change that are made more severe by anthropogenic (human) alterations to coastal systems. These include erosion, saltwater intrusion, hypoxia (low dissolved oxygen due to algal blooms and/or high temperatures), and more powerful hurricanes. But we are responding to them with bandaids such as the often harmful practice known as "beach nourishment;" meanwhile we're engineering Everglades restoration projects that likely aren't large or effective enough to fix the problems. By incorporating climate change into fisheries management and coastal management today, we can better ensure continued catches in the future.

For example, consider the past year's hot-button issue of grouper closures in the Gulf of Mexico. Gulf managers issued an emergency closure on red grouper and they wanted to include gag grouper in the closure. Many anglers are skeptical of the data, so the stocks may or may not be overfished. But it's well established that habitat loss equates to diminishing stocks, and due to sea-level rise, models anticipate a 61-percent loss of salt marsh in Apalachicola Bay by 2100. Salt marshes are essential habitat for juveniles of several grouper species, including gags, and groupers take a relatively long time to mature. Yet during months of covering grouper rebuilding plans, not once did I hear a word about historical habitat loss or habitat restoration, never mind sea-level rise.

Salt marshes are essential habitat for juveniles of several grouper species, including gags, and groupers take a relatively long time to mature. Yet during months of covering grouper rebuilding plans, not once did I hear a word about historical habitat loss or habitat restoration, never mind sea-level rise.

In many areas, meaningful habitat restorations will have to involve the concept of "managed retreat." For example, we need strategies and funding to buy swaths of coastal land, or give developers incentives to leave buffer areas, so that salt marshes and other essential habitats can migrate landward. On the barrier islands, we need development setbacks and rolling easements, to curb the demand for sea walls and the massive dredge-and-fill projects that smother beach invertebrates, sully nearshore waters and damage nearshore reefs. But presently, we are trapped in pioneer-era mentality, and hemmed in by un-clever, rigid and sacrosanct property rights laws, as well as water management regimes, that threaten everything from property values to our next fishing trips. Climate change is the flatulent elephant on the couch that politicians and coastal managers assiduously ignore. Anglers are the state's most successful conservationists, and we cannot expect government to address the matter, if we ignore it.

—TERRY GIBSON, Managing Editor, *Shallow Water Angler*

Executive Summary

Overview

Florida's coasts and the numerous ecological and economic resources they provide are invaluable to the tens of millions of people who live in Florida or visit the state each year. No other state offers more opportunities to boat, dive or fish such a diverse marine environment than Florida. In 2005, anglers spent $3.3 billion on saltwater recreational fishing in the state, supporting nearly 60,000 jobs. Florida has truly earned its reputation as "Fishing Capital of the World." But that reputation is in jeopardy due to global warming.

This report provides the latest information about global warming and how associated sea-level rise and other changes would likely affect Florida's coastal habitats, with a particular emphasis on the recreational saltwater fisheries they support. Model results for nine sites along Florida's coasts project that sea level rise would dramatically alter the extent and composition of important coastal habitats throughout the region if global warming continues unabated. In addition, global warming is expected to lead to an increase in marine diseases, harmful algal blooms, more-extreme rainfall patterns and stronger hurricanes, all of which would have a significant impact on the state's prime fisheries.

Background

The considerable increase in urban development, agriculture, industry and tourism during the past century have brought enormous conservation challenges to Florida – particularly to its freshwater and marine resources. Since the 1940s, Florida has lost nearly one-third of its seagrass beds and more than half of its saltmarsh, mangroves and other wetland habitat, contributing to significant declines in fish and wildlife populations as well as growing concerns about the state's overall ecological health.

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In recent years, investments in improved fisheries management, species protections and habitat restoration have offered considerable hope that the situation may be turning around. Whether those conservation successes will endure, however, will depend on how well Florida is able to promote more-sustainable use of its coastal resources in the face of continued population growth, pressures for development and now, the very real threat of global warming.

Global Warming and Florida

The burning of fossil fuels – mostly oil, natural gas and coal – is the driving force behind global warming. Science has shown a direct relationship between the amount of carbon dioxide and other heat-trapping gases being released into the air due to human activities and the increase in average surface temperatures around the world. Since the start of the Industrial Revolution, the amount of carbon pollution in the Earth's atmosphere has risen to a level greater than any other time in at least the past 650,000 years, and perhaps as long as 20 million years.

AMERICAN SOCIETY FOR PUBLIC ADMINISTRATION

As a result, in less than one century, the Earth's average temperature has risen more than 1 degree Fahrenheit, and it is expected to rise by another 2.5 to 10 degrees F by 2100 if global warming pollution remains unchecked. As the global temperature rises, local climate systems are being altered in ways that directly affect oceans, rivers, lakes, wetlands and other habitats. Rising sea levels, higher sea surface temperatures and shifts in precipitation patterns affecting freshwater runoff would put Florida's coastal and marine habitats at great risk.

Sea-Level Rise and Coastal Habitats

A significant increase in the rate of sea-level rise due to melting glaciers and ice caps and the thermal expansion of the oceans is one of the most direct consequences of global warming, and Florida is on the front line. The global average sea level has already risen about 6 inches over the past century. Based on recent trends, scientists' mid-range projection is that sea level will rise another 15 inches by the year 2100. Along Florida's gradually-sloped shores, this would translate into a horizontal advance of water inland by as much as 250 feet, contributing to coastal erosion, inundation and changes in wetlands and mangroves. Moreover, there are signs that the rate of sea-level rise in the future could actually be considerably greater than current projections, due to a recently discovered increase in the rate at which the ice sheets of Greenland and Antarctica are melting.

Left unchecked, sea level rise would extensively alter habitats critical not only for Florida's coastal fisheries, but for waterfowl, shorebirds, sea turtles, manatees and many other wildlife species. It would also have costly consequences for coastal tourism by contributing to beach erosion and property damage.

The National Wildlife Federation and Florida Wildlife Federation commissioned an independent researcher to study nine areas along Florida's coast (including Pensacola Bay, Apalachicola Bay, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, Florida Bay, Biscayne Bay, St. Lucie Estuary and Indian River Lagoon) to see how the mid-range scenario of a 15-inch rise in average sea level during this century would affect coastal habitats. The study found that nearly 50 percent (9,294 hectares, or 22,956 acres) of critical saltmarsh and 84 percent (67,438 ha) of tidal flats at these sites would be lost. The area of dry land is projected to decrease by 14 percent (70,680 ha), and roughly 30 percent (405 ha) of ocean beaches and two-thirds (2,380 ha) of estuarine beaches would disappear. As sea level rises, the area of

open-ocean and estuarine water is projected to increase by 64 percent and 18 percent, respectively (totaling 107,737 ha), and mangroves are expected to expand in some areas, increasing by 36 percent (37,466 ha). The area of brackish marsh is projected to increase more than 40-fold (29,836 ha), mostly around Apalachicola, taking over much of the current hardwood swamp land.

How sea-level rise would affect habitats in each of the nine study sites varies considerably based on the different habitat types, geological and oceanographic features and the extent of coastal development in the particular area. Along the Gulf Coast and in South Florida, the most vulnerable habitats are saltmarshes and tidal flats. Along the East Coast, the greatest problems are likely to be significant erosion of beaches and inundation of dry land.

Projected Effects of 15-inch Sea-Level Rise for Nine Coastal Areas of Florida by 2100

	SIGNIFICANT HABITAT CHANGES			EXAMPLES OF SPECIES AT RISK
	Losses of Estuarine Habitats/Beaches	Losses of Freshwater/Dry Land Habitats	Increases in Habitats	
PENSACOLA	73% loss of saltmarsh, 67% loss of ocean beach	6% loss of dry land	7-fold increase in brackish marsh	Flounder, gag grouper, redfish, spotted seatrout, tarpon, pompano
APALACHICOLA	61% loss of saltmarsh, 87% loss of estuarine beach	13% loss of hardwood swamp, 76% loss of tidal fresh marsh, 28% loss of dry land (particularly along river basin)	60-fold increase in brackish marsh	Flounder, gag grouper, redfish, spotted seatrout, tarpon
TAMPA BAY	96% loss of tidal flats, 86% loss of saltmarsh	10% loss of dry land	Mangrove area more than doubles	Flounder, permit, redfish, sheepshead, snook, spotted seatrout, tarpon
CHARLOTTE HARBOR	97% loss of tidal flats, 89% loss of saltmarsh, 71% loss of estuarine beach	35% loss of dry land, 36% loss of hardwood swamp	75% increase in mangrove area, 46% increase in estuarine open water	Flounder, gray snapper, permit, redfish, sheepshead, snook, spotted seatrout, tarpon
TEN THOUSAND ISLANDS	76% loss of saltmarsh	44% loss of inland fresh marsh, 31% loss of hardwood swamp, 80% loss of dry land	16% increase in mangrove area, 4-fold increase in ocean beach	Gray snapper, redfish, snook, spotted seatrout, tarpon
FLORIDA BAY	99% loss of tidal flats, 32% loss of saltmarsh, 89% loss of estuarine beach, 76% loss of ocean beach, 3% loss of mangrove	51% loss of dry land	29% increase in open estuarine water	Bonefish, yellowtail snapper, permit, redfish, snook, spotted seatrout, tarpon
BISCAYNE BAY	79% loss of tidal flats, 54% loss of saltmarsh	85% loss of cypress swamp, 33% loss of inland fresh marsh	71% increase in mangrove area, 42% increase in hardwood swamp, 12-fold increase in brackish marsh	Bonefish, yellowtail snapper, permit, redfish, snook, tarpon
ST. LUCIE	80% loss of ocean beach, 99% loss of mangrove area	10% loss of dry land	60% increase in inland fresh marsh, 139% increase in estuarine beach	Flounder, pompano, redfish, snappers, snook, spotted seatrout
INDIAN RIVER LAGOON	49% loss of ocean beach	15% loss of dry land, 11% loss of hardwood swamp	Significant increase saltmarsh, brackish marsh and tidal flats	Flounder, pompano, redfish, snappers, snook, spotted seatrout


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Implications for Fisheries

The vast majority of Florida's marine fish and shellfish species depend on saltmarshes, seagrass beds and other habitats found in the state's bays and estuaries, so the projected changes to these habitats due to sea-level rise would have an enormous impact on Florida's commercial and recreational fisheries. Those species that depend on saltmarshes and seagrass beds for their egg, larval and juvenile life stages are especially vulnerable, since problems that affect many of Florida's fish and shellfish in their early life stages are among the most important determinants of their population abundance down the road. The projected 50 percent loss of saltmarsh habitat, for example, would be a significant reduction in fish nursery habitat. In addition, significant declines in beaches and tidal flats in some areas would reduce habitat for species that rely on those areas to feed.

Translating the potential habitat changes into impacts on specific marine species is difficult, as there are many combined factors at play. However, it is reasonable to develop a general sense of those species that are particularly vulnerable given their relative dependence on the habitats most threatened by sea-level rise. Ten important Florida marine gamefish species at risk include:

- Bonefish
- Flounder
- Gag grouper
- Gray snapper
- Permit
- Pompano
- Redfish
- Snook
- Spotted seatrout
- Tarpon

In many areas, sea-level rise would also reduce essential habitat for important prey species such as shrimp, crabs and smaller fish, causing ripple effects throughout the marine food web. This list is by no means comprehensive, nor is it a "prediction" of what is to come; but it does signify the extent to which sea-level rise could threaten Florida's treasured sportfishing traditions.

Additional Consequences of Global Warming

Complicating matters is the fact that sea-level rise is not the only consequence of global warming in Florida. Other likely consequences include:

- Higher average air and water temperatures are expected to shift the freeze line north, enabling cold-sensitive species such as mangroves and snook to move farther north within the state. On the other hand, species already at the upper-end of their temperature

limit, such Gulf of Mexico sturgeon, American shad and striped bass, may be eliminated from Florida altogether due to global warming.

- Higher temperatures would contribute to an expansion of opportunistic non-native species, including a number of introduced tropical fish and invasive plants such as the Australian pine tree.
- Coral bleaching events associated with higher sea-surface temperatures are expected to become more frequent and severe throughout the Florida Keys, threatening to devastate this important marine ecosystem.
- Harmful algal blooms such as "red tides" have become more extensive in recent years, a trend that scientists also attribute to a combination of higher ocean temperatures and eutrophication (a problem associated with excess nutrient runoff). The incidence and extent of harmful algal blooms will increase if global warming remains unchecked.
- Warmer ocean temperatures have also been a significant factor in the growing incidence, range and severity of a number of other marine diseases (and the emergence of some new diseases) affecting finfish, oysters, shrimp and corals. As with harmful algal blooms, future warming is expected to exacerbate these trends.
- The prevalence of hypoxia (low oxygen) events, a significant cause of major fish kills in the region, is likely to become more widespread due to a combination of altered salinity, eutrophication of coastal waters and the trend toward higher average water temperatures.
- Hurricanes are already becoming more intense and destructive, fueled by warmer ocean temperatures – not good news for the people who live and work along the coasts, let alone for the species and habitats that will find it harder and harder to recover from the storms.

WOLCOTT HENRY

Most importantly, all of the changes caused by global warming would fall on top of the numerous other stressors that threaten Florida's coastal resources. While it is difficult to know exactly what each and all of these problems combined would mean for Florida in the decades to come, there is no question that without meaningful action to address these multiple threats the future of the state's coastal habitats, the fish and wildlife they support and the livelihoods and quality of life of the people who depend on them would be dramatically and irretrievably different from what they are today.

Changing the Forecast for Sportfishing in Florida: A Plan of Action

Fortunately the solutions are at hand, and with a strong voice and determination, people can change the forecast for Florida's coastal systems and preserve the economic opportunities, ecological benefits and outdoor traditions they provide. A meaningful strategy should include the following actions:

1. Minimize the threat of global warming by reducing global warming pollution.

First and foremost, Florida and the nation should be part of the solution to curb global warming altogether by reducing the pollution that is causing it. Few states are likely to be more dramatically affected by global warming than Florida. With so much at stake, Floridians – both residents and seasonal visitors alike – should be demanding that the state take a leadership role in promoting meaningful efforts to minimize the threat today.

MONROE COUNTY, FLORIDA

These efforts should include strengthening local, state and federal policies and programs to reduce dependence on fossil fuels by promoting energy efficiency, renewable energy and cleaner transportation options; encouraging protection and restoration of natural habitats (wetlands, grasslands, forests) that have a net use of carbon dioxide (often called carbon sequestration); setting specific limits on the nation's global warming pollution; and reengaging in international cooperation on global warming. Solutions also must involve smart business strategies that recognize that the natural environment is a capital asset, and that emphasize creative cooperation between the business and environmental communities.

2. Develop and implement more-rigorous fishery and coastal resource management strategies that fully incorporate the likely impacts of global warming on habitats.

State and federal agencies also must pay greater attention to the potential impacts of global warming as they develop and prioritize projects in their respective fishery and coastal resource management plans. An effective strategy to protect coastal habitats and communities alike should include expanding projects to restore coastal systems to more natural conditions by removing structural barriers, restoring natural water flows and replanting native vegetation. It should also include policies and programs to ensure that currently undeveloped coastal areas remain protected. Moreover, coastal managers and developers should take full consideration of the "true" costs of proposed projects, including the likely impacts on ecosystems and the critical services they provide. Finally, it is important to expand the development of tools and enhance monitoring efforts to enable scientists to better understand how global warming is affecting habitats and fish.

Through each of these actions, Florida has an opportunity to prevent the worst-case scenarios from occurring and protect its treasured natural heritage – and its sportfishing legacy – for generations to come.

Introduction

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Florida's Sportfishing Legacy

With its vast expanse of coastline, its wealth of freshwater and marine habitats and nearly 100 different gamefish species, Florida has truly earned its reputation as the "Fishing Capital of the World."[1]

In 2005, residents and visitors spent $3.3 billion on saltwater recreational fishing, supporting nearly 60,000 jobs – six times the number of jobs supported by Florida's commercial fishing industry.[2] Places like Indian River Lagoon, Apalachicola Bay, Tampa Bay and the Florida Keys are year-round destinations for saltwater anglers, and the fishing for prized gamefish such as spotted seatrout, redfish (also called red drum), snook and tarpon is world-renowned.

Florida's Top 20 Saltwater Gamefish

SPECIES	DISTRIBUTION
BARRACUDA	Widely distributed. Usually caught offshore and on the flats of Florida Keys. Year-round in southern waters, move north in warmer months.
BLUEFISH	The largest concentration of the biggest fish is on the Atlantic side. Most numerous in winter and stay close to shore.
BONEFISH	Limited to Biscayne Bay and the Florida Keys. Move into flats to feed when water is between 74 and 86 degrees.
COBIA	Widely distributed offshore and in large bays like Tampa Bay and Charlotte Harbor. Reside year-round in south Florida, migrate north in spring. Like to congregate around structures and can sometimes be caught off piers along the Panhandle.
DOLPHIN	Travel in schools in open water. Live year-round in southeast Florida and the Keys, move north in summer. Found all along the Atlantic coast and sporadi cally along the Gulf.
FLOUNDER	Caught statewide, but bigger fish are from central Florida northward.
GROUPER	Gag and red groupers and jewfish are the most widely-distributed species. Adults are offshore bottom feeders. Younger fish are caught in seagrass beds, around mangroves, and in deeper holes of backwater tidal creeks.
KING MACKEREL	Along the Atlantic, they are caught year-round south of Jupiter Inlet. In the Gulf, they migrate north and summer off the Panhandle. Mostly offshore, although some larger fish may move into nearshore waters and can be caught from ocean piers and surf.

Florida's Top 20 Saltwater Gamefish (CONTINUED)

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SPECIES	DISTRIBUTION
MARLIN	Spend their entire lives at sea. The best marlin fishing is from Palm Beach south to the Keys on the Atlantic Coast, although they may be found off the Panhandle in summer months.
PERMIT	Most prevalent on the flats of Biscayne Bay and the Keys. Also caught off shore in southwest Florida near wrecks.
POMPANO	Common along both coasts, usually close to shore. May be farther north in warmer months.
REDFISH	Redfish (also called red drum and red bass) thrive throughout Florida's coastal and nearshore waters.
SAILFISH	Highly-roaming fish. Found off the Atlantic coast during summer and early fall. Year-round residents in the Keys, may be found near Panhandle in summer. Occasionally caught from piers.
SHARK	Collectively, sharks are widely distributed throughout the state and may be caught in both nearshore and offshore waters. Future populations are of increasing concern.
SHEEPSHEAD	Year-round residents throughout the state. Most commonly along bridge and dock pilings, oyster bars and nearshore reefs. They also visit flats in some areas.
SNAPPER	There are 15 species of snapper in Florida. The top five include gray, lane, red, yellowtail and mutton. Gray snapper are found throughout coastal waters from the mangroves and nearshore seagrass beds to hard bottoms, wrecks and coral reefs offshore. Lane snapper are also widely distributed but more abundant in warm offshore waters in south Florida. Red snapper are most common in deeper, northern offshore waters. The best fishing for yellowtail and mutton snapper is near the Keys.
SNOOK	Primarily inshore fish that don't migrate far from where they spawn. From April to October, adults move to estuaries to spawn offshore. Juveniles and adults tolerate fresh water and may move into coastal canals and creeks. Common from Tampa Bay south on the west coast and from Cape Canaveral south on the East Coast. Very sensitive to cold water.
SPANISH MACKEREL	Commonly found along both coasts of Florida. Highly migratory, spending summers in the north and winters in the south.
SPOTTED SEATROUT	Common in the estuarine and coastal waters of Florida (except from south Lake Worth to Miami and the lower Keys). Prefer estuaries, spawning there and growing up among seagrass beds.
TARPON	Spawn offshore and move into estuaries during the height of the rainy season. High water levels allow them to move far inland – they may get land locked in small ponds and ditches when summer rains and mangroves dry out. They take 10 to 13 years to mature. The best tarpon fishing is along the coast in the southern half of the state.

SOURCE: K. Thoemke, Fishing Florida (Guilford, CT: The Globe Pequot Press, 1995)

Trouble In Paradise

Not surprisingly, the considerable natural beauty and bounty that Florida has to offer are the primary reasons so many people call Florida home – and so many more come to the state each year to visit. With more than 17.4 million residents, Florida is currently the fourth most populated state in the nation. Nearly 4.5 million people have moved to Florida since 1990, and the U.S. Census Bureau projects that the state's population will increase another 25 percent by 2025, most of which is expected to occur in coastal areas.[3] In addition, tens of millions of people visit Florida each year (79.7 million people in 2004 alone), making it one of the most popular tourist destinations in America.[4]


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Unfortunately, the associated expansion of urban development, agricultural, industrial and tourism activities over the years has brought with it enormous conservation challenges, particularly for the state's freshwater and marine resources. Unsustainable fishing practices during the past century have led to considerable declines in the abundance of many of Florida's important fishery species, prompting numerous efforts to better-manage the state's fisheries through establishment of bag and size limits, designated fishing zones, promotion of catch-and-release fishing and other strategies.

Florida's anglers have been leaders in promoting effective conservation, and many of the state's fishery restoration efforts have been highly successful. One of the most important actions to protect the state's fisheries occurred in 1994, when Florida voters passed a constitutional amendment banning the use of gillnets in the state's waters. Another example is the restoration of once-declining populations of redfish, which are now thriving thanks to the implementation of bag and size limits that protect the younger fish and those ready to spawn.[5]

Despite these and other management success stories, however, extensive habitat degradation also has had a significant impact on Florida's fisheries, and there has been a growing awareness that healthy habitat and successful fishing go hand-in-hand. Accordingly, the management of state (nearshore) and federal marine resources has become much more focused on identifying, restoring and protecting Essential Fish Habitat (including Habitat Areas of Particular Concern), based on provisions established under the 1996 reauthorization of the Magnuson-Stevens Act.[6] The identification of Essential Fish Habitat for species in each of their life stages has been a critical element of successful coastal and fishery management plans across the country, as it provides an important framework for identifying what are likely to be the most effective conservation priorities.

Habitats at Risk mean Fish at Risk

Florida has some of North America's most diverse coastal and marine habitat, much of which has been designated as Essential Fish Habitat for the region's numerous managed fishery species.[7] Depending on the region, there may be sandy beaches, barrier islands, oyster beds and reefs. Along parts of Florida's west coast, tidal flats may span for miles, and bays and estuaries may be lined with saltmarshes, transitional (brackish) marshes and expansive seagrass beds. Florida's East Coast also features long barrier islands, inlets and lagoons, and the transition between the coast and ocean is generally more dramatic, with the sea floor dropping off rapidly not far from shore. And in the south, mangroves, seagrasses, coral reefs and rocky islands prevail. Together, these habitats support literally thousands of species of fish and other marine life and offer a plethora of opportunities for sportfishing enthusiasts.

About 90 percent of Florida's most important recreational and commercial fish and shellfish species spend at least part of their lives in seagrass meadows, saltmarshes, mangroves and other estuarine habitats.

According to the National Oceanic and Atmospheric Administration, one of the biggest threats to Florida's marine fishing resources is the destruction of estuaries – the places where rivers and streams meet the ocean.[8] About 90 percent of Florida's most important recreational and commercial fish and shellfish species spend at least part of their lives in seagrass meadows, saltmarshes, mangroves and other estuarine habitats. Estuaries provide critical refuge and food sources for juvenile redfish, gray snapper, gag grouper and snook as well as year round habitat for spotted seatrout, which are among the most sought-after gamefish species in the state. Many smaller fish, mollusks and crustaceans also inhabit estuaries, where they find food and shelter. These species, in turn, provide critical prey for larger fish – as well as bait for anglers.

Flood control projects and the diversion of water for agricultural and urban consumption have altered natural freshwater flows into estuaries and bays and contributed to excessive nutrient concentrations, changes in salinity and related problems throughout the state's coastal waters. A recent, devastating example of this was in 2005, when excessive discharges from Lake Okeechobee to the East and West Coast estuaries resulted in massive fish kills in the St. Lucie and Caloosahatchee rivers. Dredging, construction and other development activities also have caused considerable habitat loss. To date, urban development has been the primary reason for the destruction of nearly one-third of seagrass habitat and more than half of Florida's saltmarsh, mangroves and other wetland habitat since the mid-1940s.[9]

Some of the most devastating problems have occurred in South Florida, where the great Everglades ecosystem has been reduced to half its original size and changes in the timing and extent of freshwater flows into Florida Bay and other parts of the coast have contributed to extensive habitat loss and declining fish and wildlife populations. Other areas have seen their share of changes as well. And now, global warming must be added to the list of threats to Florida's coastal resources.

SOURCE FOR THE CHART ON PAGE13: Florida Department of Environmental Protection, http://www.dep.state.fl.us/coastal/habitats/ and Florida Fish and Wildlife Conservation Commission, Florida's Wildlife Legacy Initiative. Florida's Comprehensive Wildlife Conservation Strategy (Tallahassee, FL, 2005)

Florida's Coastal Habitats

HABITAT TYPE	DESCRIPTION	EXAMPLES OF POPULAR GAMEFISH SPECIES
Saltmarshes (Including Brackish Marsh)	Saltmarshes are coastal wetlands that occur in the zone between low and high tides. The less-salty brackish marsh habitat is usually found between the saltmarsh on the sea side and tidal fresh marsh near the shore. Most of Florida's saltmarshes occur on the Gulf Coast from Apalachicola to Tampa Bay to Cedar Key, and from Daytona Beach northward on the Atlantic Coast. These wetlands help filter pollutants, protect coasts from storms, and provide critical habitat for fish and wildlife.	Many of Florida's most popular recreational marine fish spend at least part of their lives in saltmarshes, including tarpon, snook, gray snapper, spotted seatrout, sheepshead and redfish. Saltmarshes also provide essential habitat for shrimp, crabs and numerous smaller fish that are important food sources for gamefish.
Tidal Flats	Tidal flats are areas of broad, flat land created by tides. They are generally composed of sandy and/or muddy soils and provide important sources of food for birds and other wildlife. They also play an important role in purifying pollutants that come from shore.	Tidal flats are important habitat for crabs, clams and worms, and a number of Florida's popular gamefish species rely on tidal flats to feed, including bonefish, permit, tarpon, snook, pompano, sheepshead, redfish, flounder, and several snapper and shark species.
Seagrass Beds	Seagrass beds consist of plants that live underwater, usually in relatively shallow areas (depending on water clarity). They are most abundant in protected bays and lagoons in South Florida and along the Gulf Coast.	Seagrass beds provide food and nursery habitat for numerous species, including spotted seatrout, redfish, flounder, sheepshead, tarpon, bonefish, snook, and several species of snapper, grouper and shark. They also provide essential habitat for shrimp, crabs and numerous smaller fish.
Mangroves	Mangrove forests comprised of red, white and black mangrove species thrive in the southern part of the state. Florida's mangrove forests provide nurseries and shelter for many fish and wildlife species. They also protect the shoreline from erosion and trap sediments and debris.	Some of the gamefish species that rely on mangrove habitat include tarpon, snook, cobia, redfish, flounder and several species of grouper and snapper.
Coral Reefs	Florida's coral reefs are located in the southern part of the state along the Florida Keys. They are among the most unique and diverse habitats for fish and other marine life.	The most popular reef fishes for anglers are groupers and snappers, although the numerous smaller that congregate around reefs may also attract larger roaming species such as dolphin, king and Spanish mackerel, marlin and sailfish.
Beaches/Surf Zone	Florida's open beaches also provide habitat for popular fishery species, particularly where food availability and water quality is favorable.	Florida pompano is the state's most sought-after surf fish, but anglers may also be able to catch permit, bluefish, cobia, tarpon, Spanish and king mackerel, gray snapper, bonefish, spotted seatrout, redfish, flounder and sharks.
Nearshore Hardbottom Reefs	Nearshore hardbottom reefs are primarily found in shallow waters between barrier islands near the coast and mid-shelf reefs farther out in the ocean. These habitats are comprised of limestone structures and are home to a variety of marine species.	Hardbottom reefs provide important cover and feeding areas for many fish species, including juvenile snappers, grunts, groupers and wrasses.
Freshwater Marshes	Mainly in the southern part of the state, freshwater marshes are comprised primarily of grasses and other grass-like plants. They serve as natural filters and are important habitat for waterfowl and other wildlife.	Freshwater marshes can support a number of freshwater fish species, particularly in deeper areas. Tidal fresh marshes may also provide nursery habitat for freshwater-tolerant coastal species such as snook, spotted seatrout, and tarpon.
Freshwater Swamps	Generally wet, wooded areas that may include cypress trees or hardwoods such as oak. Cypress swamps are the most common freshwater swamp in Florida. Hardwood swamps are mainly in the northern part of the state. Florida's swamps are important habitat for numerous wildlife species, including the Florida panther.	Support a number of freshwater species, particularly in river-fed areas.

NOAA; U.S.DEPARTMENT OF AGRICULTURE

The Threat of Global Warming

The evidence that human activities are causing global warming is stronger than ever. By burning fossil fuels such as coal, oil, and gas in power plants, factories, and cars, humans have been sending tremendous amounts of heat-trapping gases such as carbon dioxide, methane, and nitrous oxide into the air. Additionally, people have reduced the planet's ability to absorb excess carbon through photosynthesis by destroying vast areas of forests, wetlands, and other natural systems. As a result, carbon dioxide and other gases are rapidly building up in the atmosphere, overloading the natural blanket of gases that help maintain the Earth's surface temperature.[10]

Data reveals that the level of carbon dioxide and other heat-trapping gases in the Earth's atmosphere is significantly greater than at any other time in the past 650 thousand years (and perhaps as much as the past 20 million years).[11, 12] These higher greenhouse gas concentrations translate directly into higher global temperatures. Within the past century, the Earth's average temperature has increased more than 1 degree Fahrenheit, and the rate of warming is getting faster. [13, 14]

FEMA

Without significant action to reduce global warming pollution soon, the average global temperature is projected to rise another 2.5 to10 degrees F by 2100. While that may not seem like much, consider that the average global temperature difference between the peak of the last ice age more than 20,000 years ago and today's climate is only 9 degrees F. With global warming, the planet's temperature is expected to change by a similar amount, but this time in just a matter of decades, not thousands of years.

Global warming means far more than hotter weather. As the atmosphere heats up, the planet's climate system is being altered in ways that directly affect forests, oceans, rivers, wetlands and other habitats and the species that depend on them. Average precipitation patterns are changing, and extreme weather emergencies such as droughts and floods are becoming more severe.[15] Sea surface temperatures are rising, contributing to stronger hurricanes around the world.

In addition, thermal expansion of the oceans combined with the melting of glaciers and polar ice caps are causing global sea level to rise at an accelerating pace. Average sea level has already risen 6 inches during the past century, which is about 10 times faster than the rate of sea-level rise over the last 2000 years. If global warming pollution remains unchecked, the rate of sea level rise will continue to accelerate in the coming decades. Based on recent trends,

scientists' middle-of-the-road projection is that sea level will rise another 15 inches by the year 2100.[16] And scientists are becoming increasingly concerned that rate of sea-level rise in the future could be significantly greater than current projections, as several new studies have determined that the vast ice sheets of Antarctica and Greenland are melting much more rapidly than previously thought.[17] If the Greenland ice sheet alone were to melt completely, it would raise global sea levels by more than 20 feet within a few hundred years, putting most of southern Florida underwater.[18]

Rising Sea Levels – An Enemy on All Sides

Given its miles of coastline and low-lying topography, Florida is particularly vulnerable to sea-level rise.[19] Along Florida's gradually-sloped shores, even a 15-inch rise would translate into a horizontal advance of water inland by as much as 250 feet.

The consequences of this much sea level rise for coastal property alone would be enormous, a prospect that already has many of Florida's coastal planners concerned. Since 2000, the U.S. Environmental Protection Agency has been working with a number of Florida's Regional Planning Councils to map 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.[20] The overarching purpose of this effort has been to help regional planners and citizens better understand the implications of sea-level rise for land use in their communities in order to assist in coastal development decisions. Accordingly, these projects have tended to characterize land use types in the given area fairly generally as open water, wetlands, developed land and open/agricultural land. This provides a useful snapshot of what Florida's coasts might look like in the future given existing topographical features. However, it does not address the fundamental connection between the vitality of coastal communities and the health of the state's diverse coastal ecosystems.

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This report is meant to provide an overview of how sea-level rise will affect coastal habitats and highlight what those changes might mean for the recreational fisheries and other important ecological resources that sustain Florida's economy and quality of life.

Sea-level Rise and Coastal Habitats

One of the primary ways in which sea-level rise would affect Florida's coastal habitats is through sea-water inundation, which can increase the salinity of the surface and groundwater. Most coastal plant and animal species are adapted to a certain level of salinity, so prolonged changes in salinity can make habitats more favorable for some species, less for others. Sea-level rise would also contribute to the expansion of open water in some areas – not just along the coasts but inland, where dry land can become saturated by an increase in the height of the water table. Furthermore, sea-level rise would lead to significant beach erosion and cause overwash of barrier islands, which would make coastal infrastructure more vulnerable to storm surges.

Recent studies indicate that sea level rise already has had an impact on Florida's coastal habitats. In the Everglades ecosystem, for example, sea-level rise has contributed to a significant upland migration of mangrove forests, where the trees have been able to take advantage of changing habitat conditions in areas previously dominated by freshwater marsh land.[21] In other parts of the state, such as along Florida's Big Bend region, saltwater intrusion has led to a decline in regeneration of cabbage palm, red cedar and other coastal trees, particularly in areas where development has hindered their ability to migrate inland.[22] In addition to affecting ecosystems, these changes have made Florida's coasts more susceptible to damage from hurricanes.[23]

As the rate of sea-level rise continues to accelerate, it is expected to exceed the rate at which habitats like mangroves and wetlands can migrate in some areas, even where such migration is not otherwise hindered by coastal development. For example, estimates of the critical rate of sea-level rise above which mangrove ecosystems in South Florida would collapse range from 0.5 to 1 inch/decade.[24] In addition, sea-level rise will have a direct impact on the distribution and composition of seagrasses by increasing the depth of water and reducing the level of light that seagrasses need for photosynthesis.[25]

Initially, some of the effects on habitats and species may be considered beneficial, such as if sea-level rise increases the total area of saltmarsh that fish can access. Over the longer term, however, scientists expect the overall impacts to be negative.[26] On the whole, sea-level rise would cause significant changes to the habitats critical not only for the state's coastal fisheries, but for waterfowl, shorebirds, sea turtles, manatees, and many other wildlife species. Sea-level rise would also have costly consequences for coastal tourism by contributing to beach erosion and property damage. This would significantly increase pressure for expensive and highly damaging dredge-and-fill "beach nourishment" projects, which are already causing considerable harm to nearshore hardbottom reefs and other important fish habitat. Moreover, it would cost Florida an estimated $5.8 billion per year to replenish sand beaches lost to a one-meter rise in sea level.[27]

Projected Habitat Changes for Nine Sites in Florida

The National Wildlife Federation and Florida Wildlife Federation engaged sea-level rise modeling expert Jonathan Clough, of Warren Pinnacle Consulting, Inc., to estimate how sea-level rise during this century would affect coastal habitat in nine areas along Florida's coast that are particularly important habitat for the state's gamefish species. These areas include: Pensacola Bay, Apalachicola Bay, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, Florida Bay, Biscayne Bay, St. Lucie Estuary and Indian River Lagoon.

This analysis used the most recent (2001) sea-level rise scenarios of the Intergovernmental Panel on Climate Change (IPCC) in an analytical model called Sea Level Affecting Marshes Model (SLAMM, Version 4.1), which was designed to simulate the dominant processes involved in wetland conversion and shoreline modification under long-term sea-level rise. The model integrates area-specific National Oceanic and Atmospheric Administration tidal data and detailed wetland information from the U.S. Fish & Wildlife Service's National Wetland Inventory with the U.S. Geological Survey's Digital Elevation Model to project habitat changes associated with sea-level rise in greater detail than by just looking at

coastal topography alone. For example, the model can assess how much erosion may occur due to wave action or whether overwash may push sediments onto marshes or mangroves on the lee side of barrier islands. The use of National Wetland Inventory data also identifies areas in which structures such as dikes are currently present.[a]

This overview report highlights the model results for the Intergovernmental Panel on Climate Change's moderate Scenario A1B, which projects the following ranges in sea-level rise:[b]

	Min	Mean	Max
2025	1.1 in.	3.0 in.	5.0 in.
2050	2.5 in.	6.6 in.	11.2 in.
2075	3.9 in.	11.0 in.	19.1 in.
2100	5.1 in.	15.2 in.	27.3 in.

Under the mean range of estimated sea-level rise (6.6 inches by 2050 and 15.2 inches by 2100), the model projects dramatic changes in the extent and composition of coastal habitats throughout the study regions. Looking at all nine sites combined, nearly 50 percent of critical saltmarsh and 84 percent of tidal flats are projected to be lost by 2100, largely due to erosion and inundation by sea water. The area of dry land is projected to decrease by 14 percent over all sites due to erosion, inundation and/or saturation (a process whereby higher sea levels cause the elevation of the nearshore water table to rise, contributing to an expansion of freshwater marsh onto adjacent low-lying dry land).

In addition, roughly 30 percent of ocean beaches and two-thirds of estuarine beaches would disappear (primarily to erosion, but also due to overwash and inundation). As sea level rises, the area of open-ocean and estuarine water is predicted to increase, and mangroves are expected to expand in several areas, increasing by 36 percent. This is particularly the case in areas without structural protections such as sea walls and levees, thereby allowing saltwater to intrude into nearby fresh marsh or swamp land and enable mangroves to take advantage of the higher salinity levels farther inland.

The aggregate figures also show a dramatic increase in brackish marsh (primarily in Apalachicola, where 13 percent of the region's extensive hardwood swamps are expected to be converted to brackish marsh). St. Lucie also sees a large percentage increase in brackish marsh, although at that site, and at most of the other study areas, it remains only a small proportion of total habitat.

[a] More-detailed technical descriptions of the SLAMM 4.1 model and the IPCC scenarios are available in J.S. Clough and R.A. Park, SLAMM 4.1 Technical Documentation, December 2005. A more-detailed summary of the findings highlighted in this report is available in J.S. Clough, Application of SLAMM 4.1 to Nine Sites in Florida, for the National Wildlife Federation, February 16, 2006. Both documents are available upon request from the National Wildlife Federation.

[b] IPCC Scenario A1 assumes a world that includes very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The A1B scenario assumes that energy sources will be balanced across all sources. Under this scenario, the atmospheric concentration of CO2 is projected to reach 750 ppm by the year 2100 (nearly triple pre-industrial levels).

Summary of Projections of Marsh Fate for All Model Sites, 2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.(ha)	Year 2025 (ha)	Year 2050(ha)	Year 2100(ha)	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	496,043	457,931	445,303	425,363	29%	8% loss	10% loss	14% loss
Hardwood Swamp	175,319	177,524	179,543	156,699	10%	1% gain	2% gain	11% loss
Cypress Swamp	2,955	2,840	2,878	2,287	0%	4% loss	3% loss	23% loss
Inland Fresh Marsh	56,129	60,216	63,285	53,505	3%	7% gain	13% gain	5% loss
Tidal Fresh Marsh	1,915	1,877	1,854	1,745	0%	2% loss	3% loss	9% loss
Brackish Marsh	684	13,300	5,458	30,520	0%	1,844% gain	698% gain	4,364% gain
Saltmarsh	19,328	14,176	17,812	10,034	1%	27% loss	8% loss	48% loss
Mangrove	104,384	120.181	123,340	141,814	6%	15% gain	18% gain	36% gain
Estuarine Beach	3,530	2,798	1,396	1,150	0%	21% loss	60% loss	67% loss
Tidal Flat	80,458	19.263	14,559	13,020	5%	76% loss	82% loss	84% loss
Ocean Beach	1,292	1,399	1,093	887	0%	8% gain	15% loss	31% loss
Rocky Intertidal	21	21	21	21	0%	0%	0%	0%
Inland Open Water	15,055	15,113	13,328	12,609	1%	0%	11% loss	16% loss
Riverine Tidal	493	484	301	179	0%	2% loss	39% loss	64% loss
Estuarine Open Water	508,769	575,826	588,933	602,246	29%	13% gain	16% gain	18% gain
Open Ocean	261,355	264,743	268,589	275,615	15%	1% gain	3% gain	5% gain

It is important to note that this analysis is based on a simplifying assumption that there would be no additional increase in the development of dikes, seawalls and other coastal protections around dry land in the future beyond what was captured in the National Wetlands Inventory data used in the model. However, this assumption more likely reflects future conditions in areas with natural coastal buffers such as parkland (e.g., Apalachicola, Ten Thousand Islands and Florida Bay). For the more urbanized areas, the projections for habitat migrations inland are probably overestimated given the considerable likelihood that people would invest in further structural developments and other strategies in an attempt to protect coastal property from the rising seas. Instead, those areas would likely see wetland habitat decline outright, along with the invaluable ecosystems services they provide. Furthermore, this analysis does not include the potential losses to coastal habitats due to the numerous additional stressors they face.

Implications for Florida's Saltwater Recreational Fisheries

The dramatic changes to Florida's coastal habitats due to sea-level rise would have a significant impact on many of the state's most popular recreational saltwater gamefish species. A number of studies have shown a direct relationship between the availability of coastal marshes and other habitats and fishery yields, and fisheries scientists often monitor the conditions of estuaries to help them determine how successful fishery harvests might be in the future.[28]

All coastal habitats are biologically, chemically and physically linked, so problems that affect even one habitat type directly will affect the entire coastal system.[29] For example, estuaries and bays that experience a net loss in coastal saltmarsh habitat are more likely to face declining water quality, because saltmarshes play a critical role in regulating nutrients and filtering pollutants. Algal blooms and other problems associated with excess runoff of nutrients such as nitrogen and phosphorus in coastal waters can cause significant harm to seagrass beds and contribute to hypoxia (low oxygen) events.[30]


SOUTH FLORIDA WATER MANAGEMENT DISTRICT

How coastal habitats change will also depend on the timing and overall extent of sea-level rise. Initially, sea-level rise may lead to more fragmentation of marshes in some areas, which would enable some species to gain greater access to the habitat. This may be in part why some fisheries in the northern Gulf of Mexico have not shown significant declines despite the considerable marsh loss that has occurred in the region in recent decades.[31] However, evidence suggests that this would be a temporary phenomenon, as rapid sea-level rise and other factors contributing to coastal marsh loss ultimately cause the habitats to disappear altogether.

Researchers have found, for example, that there is a strong positive correlation between shrimp abundance in the Gulf of Mexico and the area of estuarine vegetation along the coast from Louisiana to Florida.[32] Analysis of sea-level rise for parts of the Gulf Coast suggests that, after an initial but temporary increase in brown shrimp catch, there would be a significant (up to 45%) decline in annual shrimp catch as sea level rises beyond 4 inches, which could occur as early as 2025.[33]

Even in places that would see an expansion of some habitat types, the overall composition of the ecosystems of which they are a part would change considerably. Some species would benefit, others will not. Inundation due to sea-level rise may enable mangroves in some areas to expand farther inland, providing mangrove-ranging species with additional habitat for nurseries and shelter. However, that same process of inundation may alter the salinity of the associated estuary to such an extent that it may no longer be favorable for important food sources such as young shrimp and fish that had once thrived in nearby saltmarshes or seagrass beds.

In addition, any expansion in the area of some habitat types means a reduction in others. The inland migration of mangroves is projected to displace saltmarshes, freshwater marshes, swamps and dry land, putting a squeeze on species that depend on those habitats – including vulnerable populations such as the Florida panther, American crocodile and dusky seaside sparrow.

Given the complexity of Florida's natural systems and the multitude of factors affecting them, it is impossible to know exactly what the changes due to sea-level rise would mean for Florida's fisheries in the decades to come. Yet, there is no question that the future of Florida's coastal habitats, the fish and wildlife they support and the livelihoods and quality of life of the people who depend on them would be dramatically and irretrievably different from what they are today if global warming remains unchecked.

Gamefish Species at Risk

The saltwater gamefish species that depend on coastal saltmarshes and seagrass beds for their egg, larval and juvenile life stages are particularly vulnerable to the loss of these coastal habitats due to sea-level rise, as problems that affect many of Florida's fish and shellfish species in these early life stages are among the most important determinants of their population abundance down the road. In addition, the projected loss of considerable areas of beaches and tidal flats would threaten a number of species that rely on those areas to feed.

NOAA

Translating the potential habitat changes into impacts on specific marine species is difficult, as there are many combined factors at play. However, it is reasonable to develop a general sense of those species that are particularly vulnerable given their relative dependence on the habitats most threatened by sea-level rise. Ten important Florida gamefish species that are at risk include: bonefish, flounder, gag grouper, gray snapper, permit, pompano, redfish, snook, spotted seatrout and tarpon.

In many areas, sea-level rise would also reduce essential habitat for important prey species such as shrimp, crabs and smaller fish, which would have ripple effects throughout the marine food web. This list is by no means comprehensive, nor is it a "prediction" of what is to come; but it does signify the extent to which sea-level rise could affect Florida's treasured sportfishing traditions.

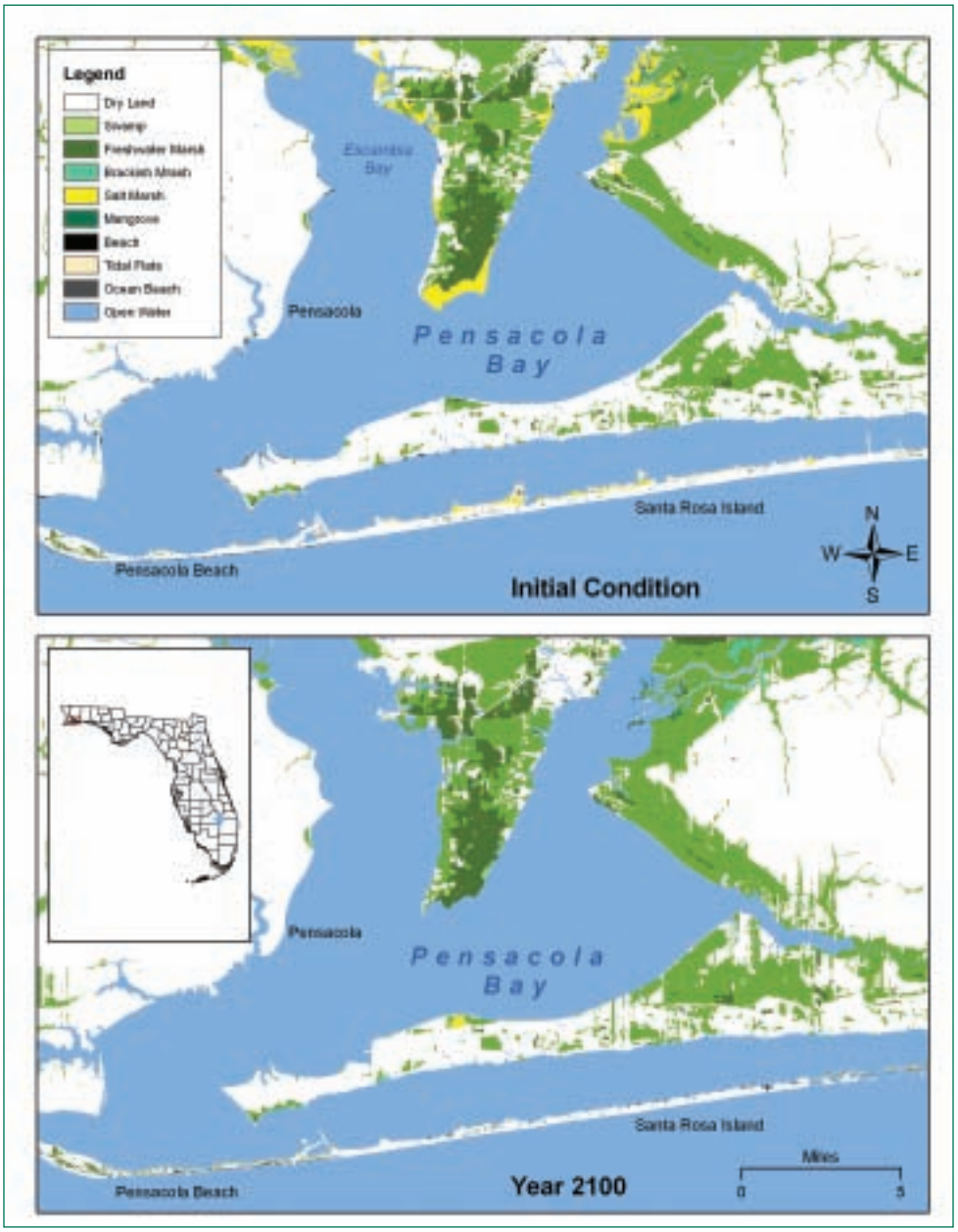
Results by Location

The effects of sea-level rise on habitats and species in each of the study areas varies considerably based on the different habitat types, oceanographic and geological features and extent of coastal development in the particular area. Based on this study's projections, the most vulnerable habitats along the Gulf Coast and in South Florida are saltmarshes and tidal flats. Along the East Coast, the greatest problems include significant erosion of beaches and inundation of dry land.

PENSACOLA

The Pensacola Bay system in the western Florida Panhandle is one of the state's largest watersheds, and much of the area has been designated as an Aquatic Preserve by the Florida Department of Environmental Protection.[34] The Bay and its nearby waters are rich in seagrass beds and oyster bars, and there are numerous artificial and natural reefs offshore. Fishing occurs year-round, but it is particularly popular in summer months when warm water-preferring southern species migrate north. Popular species include redfish, spotted seatrout, tarpon, bluefish, pompano, Spanish mackerel, flounder and some groupers and snappers.[35] In 2005, retail sales associated with saltwater recreational fishing in Escambia and Santa Rosa counties totaled $125.5 million, supporting more than 2,200 jobs.[36]

Polluted runoff has been one of the most serious problems affecting the Pensacola Bay, although dredging and other activities associated with coastal development in the region also have affected habitats and fisheries. Since the mid-1970s, once-extensive seagrass beds have been all but eliminated in parts of the region, contributing to a dramatic decline in commercial shrimp and scallop harvests.[37]



Sea-level rise in the coming decades is projected to reduce saltmarsh habitat in Pensacola Bay by 30% by 2050 and 70% by 2100, making remaining seagrass beds much more vulnerable to polluted runoff and increasing the risk of hypoxic waters and harmful algal blooms. The loss of these habitats would have a significant impact on a number of the area's most important gamefish species, including redfish, spotted seatrout, tarpon, gag grouper and flounder. Some of the area's coastal infrastructure is at risk as well. While the relatively steep slopes of dry land around Pensacola result in a relatively low loss rate for dry land (5 to 6 percent), some migration of the barrier islands is predicted with a two-thirds loss of ocean beach, which would limit opportunities to fish for popular surf species such as pompano.

Projections of Marsh Fate for Pensacola,
2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	64,476	62,055	61,057	60,580	42%	4% loss	5% loss	6% loss
Hardwood Swamp	16,697	16,892	17,591	17,240	11%	1% gain	5% gain	3% gain
Cypress Swamp	128	124	122	122	0%	3% loss	4% loss	5% loss
Inland Fresh Marsh	2,814	2,937	2,942	2,931	2%	4% gain	5% gain	4% gain
Tidal Fresh Marsh	19	19	19	19	0%	0%	0%	0%
Brackish Marsh	70	1,779	365	536	0%	2,441% gain	423% gain	668% gain
Saltmarsh	2,785	1,399	1,915	753	2%	50% loss	31% loss	73% loss
Estuarine Beach	59	295	54	38	0%	400% gain	9% loss	36% loss
Tidal Flat	470	1,468	2,429	449	0%	212% gain	417% gain	4% loss
Ocean Beach	45	82	16	15	0%	82% gain	65% loss	67% loss
Inland Open Water	917	910	785	761	1%	1% loss	14% loss	17% loss
Estuarine Open Water	46,256	46,736	47,287	50,986	30%	1% gain	2% gain	10% gain
Open Ocean	17,471	17,513	17,625	17,778	11%	0%	1% gain	2% gain

"Global warming is reality, and sea level is rising. With each increment of rise, thousands of acres of Florida's coastal marshes and wetlands are permanently lost. Efforts to stem this loss with renourished beaches, bulldozed berms and coastal armoring are doomed to failure. It is high time federal, state and local government officials face this fact. It is also time to recognize that losing coastal wetlands makes saving non-coastal wetlands that much more important. Unfortunately, isolated wetlands of the sixteen counties of Northwest Florida do not enjoy the same protections afforded similar wetlands in other parts of the state. Ten years ago, when the Florida legislature tasked the state's water management districts to protect isolated wetlands, the Northwest district was given a "temporary" exemption. That exemption continues today. It is essential that this exemption be lifted now and our Northwest Florida Water Management District be given the same authority to protect wetlands that all other districts have exercised for years."

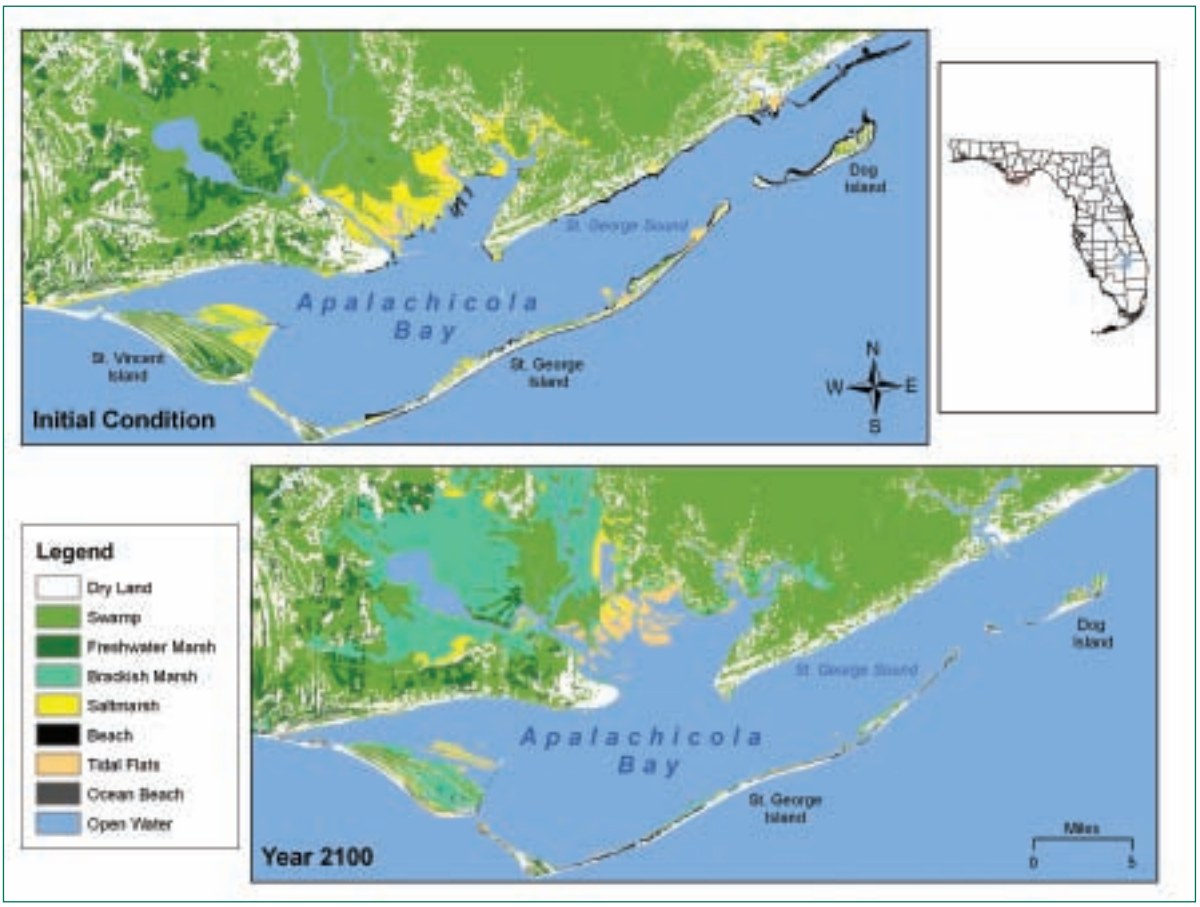
BOB REID
CHAIR, FLORIDA WILDLIFE FEDERATION
NICEVILLE

APALACHICOLA

Apalachicola Bay is home to one of the largest and most renowned commercial oyster fisheries in the world, and it is an important area for brown shrimp, scallops and blue crabs as well. Anglers flock to the region to fish for spotted seatrout, redfish, tarpon, Spanish mackerel, sheepshead, dolphin, cobia, flounder, and several grouper and snapper species.[38] In 2005, retail sales associated with saltwater recreational fishing in Gulf and Franklin counties totaled $108 million, supporting nearly 2,000 jobs.[39]

Much of the Apalachicola coastal region has been set aside as protected, which has helped maintain the area's fish and wildlife populations. However, an unresolved water dispute with Georgia over minimum flows and levels, substantial water diversions and polluted runoff associated with urban development and agricultural activities inland have caused significant water quality problems in Apalachicola Bay and surrounding waters, and those problems are expected to become worse as the region's human population continues to grow. With the added stressors associated with sea-level rise, reductions in water quality and changes in habitat due to these multiple threats could have serious consequences for the area's fisheries.

Sea-level rise is projected to cause a 61-percent decline in important saltmarsh habitat in Apalachicola Bay by 2100, making coastal waters and seagrass beds more vulnerable to polluted runoff. Inundation also is expected to cause a significant decline in hardwood swamp area, particularly along the Apalachicola River, where swamp elevations are low relative to sea level. An estimated 13 to 16 percent of these swamps are expected to convert to brackish marsh, which had been virtually non-existent at this site. Some tidal and inland freshwater marsh is



projected to become inundated and converted to brackish marsh as well. In addition, inundation and saturation are projected to convert more than a quarter of the dry land on this site, primarily along the river basin; and overwash is expected to have a significant effect on the barrier islands to the south of this site.

Species that would face the greatest impact from saltmarsh and seagrass loss in Apalachicola include the oyster, flounder, spotted seatrout, redfish, tarpon and young gag grouper. The region's brown shrimp and blue crabs also are vulnerable to declines in essential habitat, which could reduce available food sources for many of the region's gamefish species.

Projections of Marsh Fate for Apalachicola, 2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	34,921	29,879	28,015	25,218	12%	14% loss	20% loss	28% loss
Hardwood Swamp	126,599	127,402	128,183	110,640	43%	1% gain	1% gain	13% loss
Cypress Swamp	64	62	62	38	0%	3% loss	3% loss	41% loss
Inland Fresh Marsh	9,318	9,742	9,874	6,787	3%	5% gain	6% gain	27% loss
Tidal Fresh Marsh	159	132	125	38	0%	17% loss	22% loss	76% loss
Brackish Marsh	349	3,921	1,496	22,193	0%	1,023% gain	329% gain	6,264% gain
Saltmarsh	7,164	5,330	5,603	2,828	2%	26% loss	22% loss	61% loss
Estuarine Beach	1,739	945	270	222	1%	46% loss	84% loss	87% loss
Tidal Flat	531	2,683	5,553	3,787	0%	405% gain	945% gain	613% gain
Ocean Beach	1.4	24	19	131	0%	2,300% gain	1,232% gain	8,978% gain
Rocky Intertidal	18	18	18	18	0%	0%	0%	0%
Inland Open Water	3,033	3,020	2,197	1,937	1%	0%	28% loss	36% loss
Riverine Tidal	396	393	222	103	0%	1% loss	44% loss	74% loss
Estuarine Open Water	56,051	56,465	57,924	64,640	19%	1% gain	3% gain	15% gain
Open Ocean	51,387	51,716	52,169	53,150	18%	1% gain	2% gain	3% gain

"The health of the Apalachicola River and the Apalachicola Bay and Estuary is vital not only to Robinson Brothers fishing guides and our fishing clients but to our entire Panhandle. Our local economy is based on the mix of salt and fresh water that surrounds us and truly depends on how well we are able to preserve the delicate balance of the nursery the estuary supports. This report underscores the need to aggressively combat global warming and to aggressively prepare for future sea-level rise."

KATHY ROBINSON
ROBINSON BROTHERS GUIDE SERVICE, LLC
APALACHICOLA

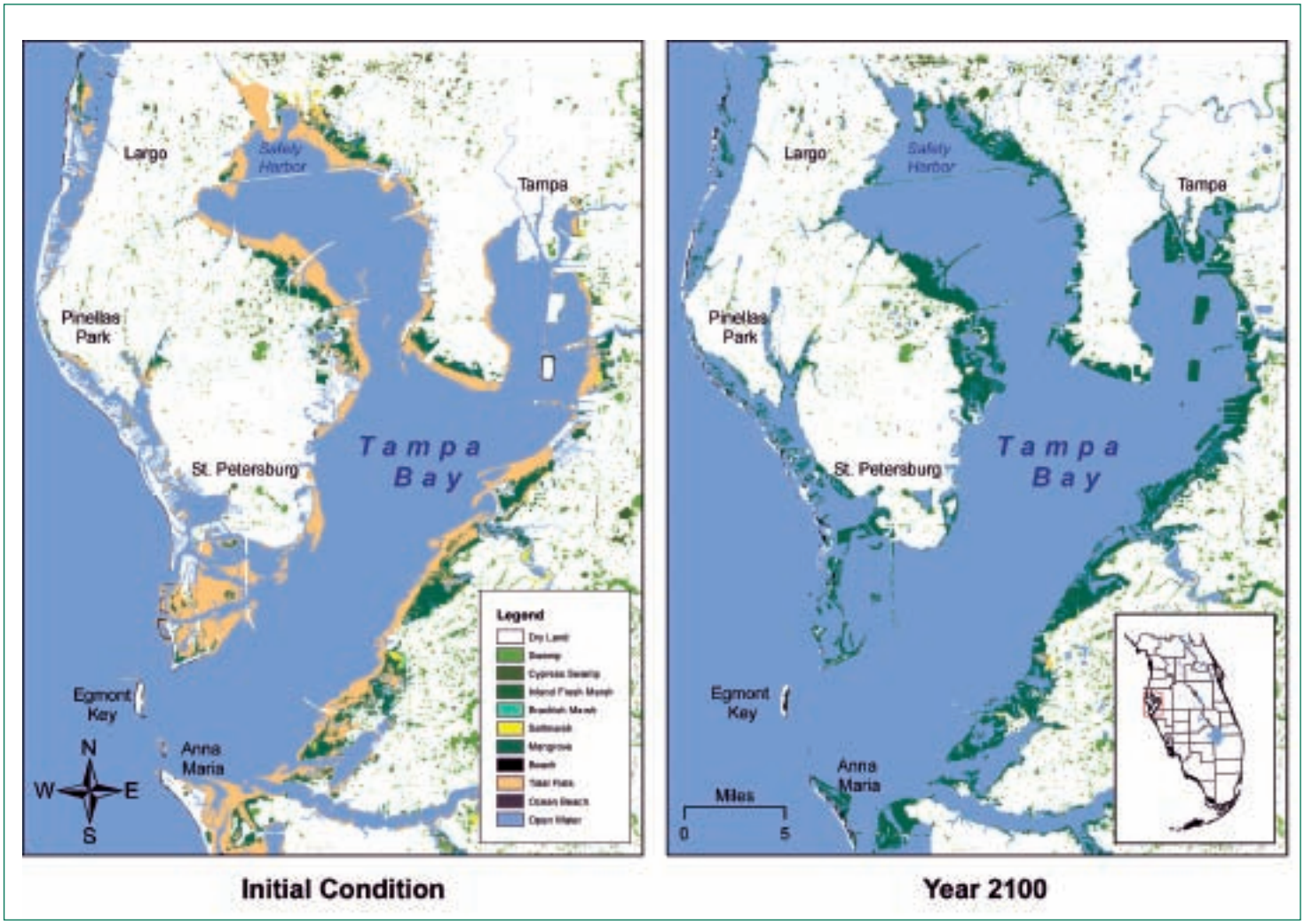
NOAA

TAMPA BAY

With more than 100 public boat launches, waterfront parks and bridges, the Tampa Bay region is an enormously popular area for saltwater anglers.[40] Some of the most sought-after sportfish in the waters around Tampa Bay include spotted seatrout, redfish, snook, flounder, Spanish mackerel, cobia, tarpon, pompano, permit and sheepshead. In 2005, retail sales associated with saltwater recreational fishing in Hillsborough, Manatee and Pinellas counties totaled $393 million, supporting more than 7,000 jobs.[41]

The greatest threat to both upland and coastal habitats in the Tampa Bay region during the 20th century has been the rapid expansion of agricultural and urban development. Between 1950 and 1982, there was a 66-percent loss in undeveloped upland, a 35-percent loss in seagrass, a 7-percent loss in mangrove and marsh area and a 16-percent increase in open water, all corresponding with a 420-percent increase in agricultural land and a 341-percent increase in urban areas.[42]

The loss of habitat such as seagrass beds and mangroves was linked to declines in landings of both spotted seatrout and snook during the period, which prompted considerable conservation efforts through programs such as the U.S. EPA's National Estuary Program. Recent successes in habitat restoration, pollution reduction and other strategies have helped reverse that trend. However, if the rate of sea-level rise continues to accelerate, the associated



Projections of Marsh Fate for Tampa Bay,
2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	147,401	138.858	137,174	133,362	46%	6% loss	7% loss	10% loss
Hardwood Swamp	8,882	8,568	8,576	8,264	3%	4% loss	3% loss	7% loss
Cypress Swamp	897	914	949	969	0%	2% gain	6% gain	8% gain
Inland Fresh Marsh	2,196	2,149	2,132	2,073	1%	2% loss	3% loss	6% loss
Tidal Fresh Marsh	16	12	10	7	0%	25% loss	39% loss	59% loss
Brackish Marsh	59	210	103	81	0%	256% gain	73% gain	36% gain
Saltmarsh	1,200	864	576	167	0%	28% loss	52% loss	86% loss
Mangrove	7,533	15,562	16,771	20,055	2%	107% gain	123% gain	166% gain
Estuarine Beach	331	520	416	317	0%	57% gain	26% gain	4% loss
Tidal Flat	17,973	5,004	1,507	690	6%	72% loss	92% loss	96% loss
Ocean Beach	59	124	120	125	0%	110% gain	103% gain	112% gain
Inland Open Water	2,189	2,200	2,108	2,072	1%	1% gain	4% loss	5% loss
Riverine Tidal	23	18	5	3	0%	21% loss	80% loss	87% loss
Estuarine Open Water	85,010	98,238	102,043	102,722	26%	16% gain	20% gain	21% gain
Open Ocean	49,557	50,083	50,836	52,421	15%	1% gain	3% gain	6% gain

loss of critical coastal habitat could ultimately undo much of Tampa Bay's conservation efforts and could have a devastating impact on the region's fisheries.

The vast tidal flats around Tampa Bay are projected to nearly disappear by the year 2050, and the majority of saltmarsh is expected to be lost by 2100. The barrier islands around Tampa Bay are expected to be hit hard, with a resulting loss of 10-percent of the dry land at the site, reducing it by more than 14,000 ha. Some cypress swamp saturation is expected, and mangroves are projected to roughly double under the mean scenario. It is uncertain how these changes would affect coastal water quality, as mangroves play a similar role to saltmarshes in filtering pollutants. However, the significant changes in the composition of habitat types in the region would no-doubt alter the overall dynamics of the coastal system. Species at greatest risk in this area are those that rely on saltmarshes and tidal flats for food and nursery habitat, including snook, redfish, spotted seatrout, flounder, tarpon, sheepshead and permit.

"A change in habitat means a change in water quality, fish varieties, populations and behaviors. For those that depend on Tampa Bay to provide a living, sea level rise is a critical concern. For those of us who depend on it to provide recreational opportunities it means that those opportunities as we know them will be lost, both to us and our children."

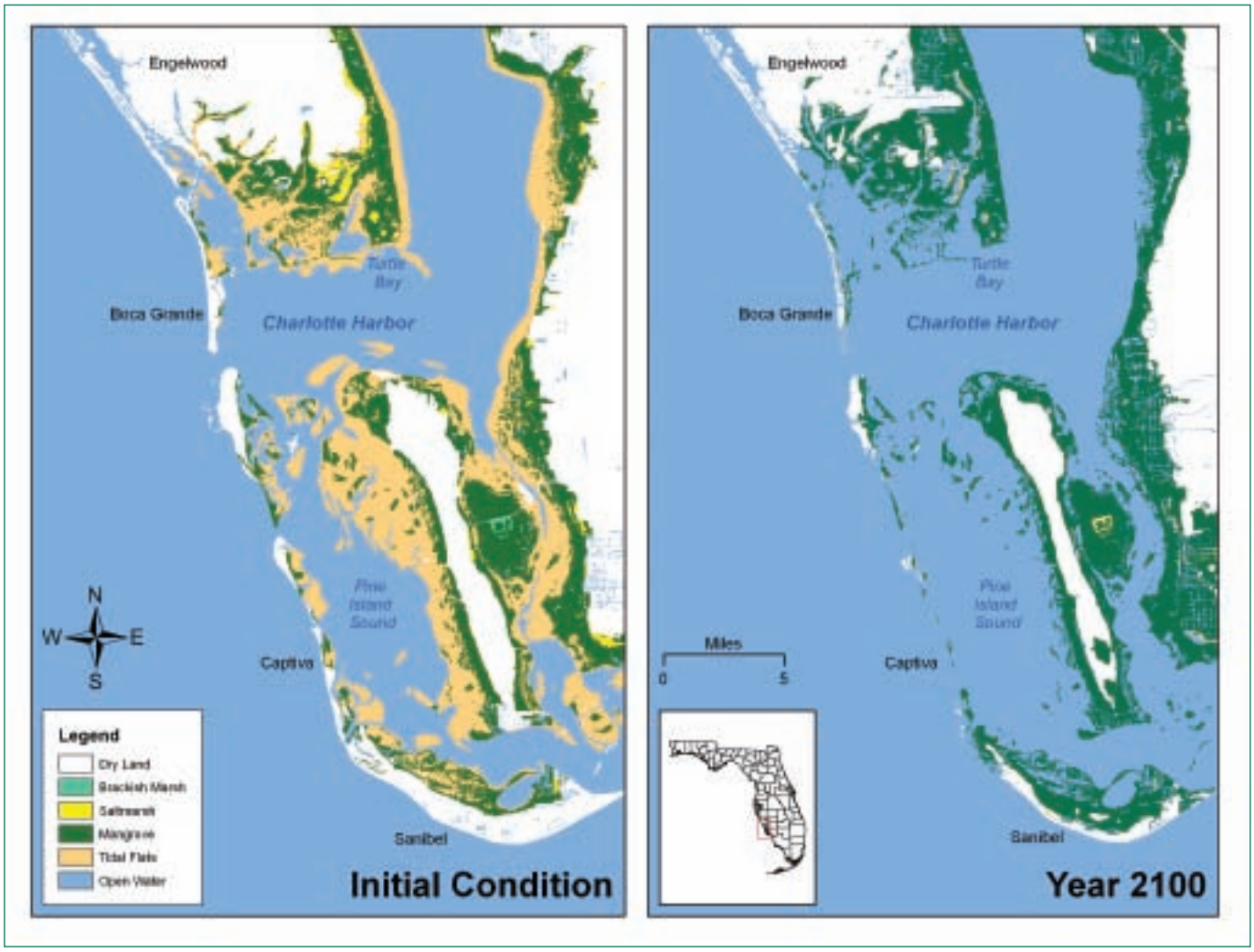
ANN VANEK-DASOVICH
VICE CHAIR, FLORIDA WILDLIFE FEDERATION
DAVIS ISLAND

CHARLOTTE HARBOR

Charlotte Harbor and its vicinity is one of the most popular sportfishing locales in Florida. For many recreational anglers, Charlotte Harbor's Turtle Bay is the holy grail of coastal Florida fishing. The estuary and nearby coastal waters are habitat for more than 270 species of resident, migrant and commercial fishes of the Gulf of Mexico.[43] Extensive seagrass beds, tidal flats and mangrove-fringed shoreline offer snook, redfish, spotted seatrout, permit, pompano, sheepshead and tarpon. Spanish mackerel and cobia often can often be found around the large artificial reef in the middle of the harbor.[44] In 2005, retail sales associated with saltwater recreational fishing in Charlotte and Lee counties totaled $301 million, supporting more than 5,300 jobs.[45]

As with Tampa Bay, the Charlotte Harbor area has seen considerable habitat loss due to development, altered water flows and pollution, and strategies to improve the management of the region's coastal resources through the National Estuary Program and other programs have been a high priority for Florida. And like Tampa Bay, sea-level rise is an added stressor that should be addressed.

The overall model results for Charlotte Harbor are similar to Tampa Bay, although lower elevations of dry land result in greater predicted impacts here. This area is projected to lose close to 95% of its tidal flats by 2050. Sea-level rise is also expected to cause significant over-



wash of the barrier islands around Charlotte, resulting in considerable dry land loss. Saltmarsh in the region would decline by close to 90 percent, converted in part by the considerable expansion of mangroves, which increase by 75 percent. Gamefish species that could be adversely affected by these changes include spotted seatrout, snook, tarpon, redfish, sheepshead, flounder, gray snapper and permit.

Projections of Marsh Fate for Charlotte Harbor, 2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	37,805	31,586	30,340	24,468	23%	16% loss	20% loss	35% loss
Hardwood Swamp	5,000	4,975	4,828	3,196	3%	1% loss	3% loss	36% loss
Cypress Swamp	31	31	32	32	0%	0%	5% gain	5% gain
Inland Fresh Marsh	1,261	1,314	1,302	1,036	1%	4% gain	3% gain	18% loss
Brackish Marsh	73	198	74	15	0%	171% gain	1% gain	80% loss
Saltmarsh	1,384	1,074	763	151	1%	22% loss	45% loss	89% loss
Mangrove	18,577	24,005	25,168	32,535	11%	29% gain	35% gain	75% gain
Estuarine Beach	492	318	239	143	0%	35% loss	51% loss	71% loss
Tidal Flat	22,835	3,998	884	612	14%	82% loss	96% loss	97% loss
Ocean Beach	97	196	121	70	0%	102% gain	25% gain	27% loss
Rocky Intertidal	3	3	3	3	0%	0%	0%	0%
Inland Open Water	517	473	301	212	0%	9% loss	42% loss	59% loss
Estuarine Open Water	50,921	70,434	73,927	74,501	31%	38% gain	45% gain	46% gain
Open Ocean	22,691	23,080	23,705	24,711	14%	2% gain	4% gain	9% gain

How I Spent my 2005 Summer:

This spring started out great as I jumped a tarpon over 100 pounds in my Cape Coral canal. I was so excited when it jumped half out of the water like a real big game fish. Boy did I think I was in for a great summer in Southwest Florida. Then the releases from Lake Okeechobee killed the fishing so I hung up my pole and I stopped visiting my fishing tackle and bait shop. I drove up the coast where I experienced a horrific red tide in Manatee County that lasted the entire summer – dead fish, an ocean and a bay that smelled like dead fish. Meanwhile, back in Cape Coral, the water turned fresh and the color turned black then pea green and then the duckweed started to bloom. Then the red tide rolled in to Lee County. What I understand now after reading the National Wildlife Federation's report is that the Summer of 2005 was a snapshot of fishing in a warming world. Warmer ocean temperatures lead to more intense hurricanes which lead to polluted discharges to our estuaries; nutrient loading from these discharges combine with warmer waters in the Gulf, leading to longer and more intense red tides; and sea-level rise means massive losses of coastal wetlands that provide nurseries for fish and clean the water. The Unfavorable Tide is now.

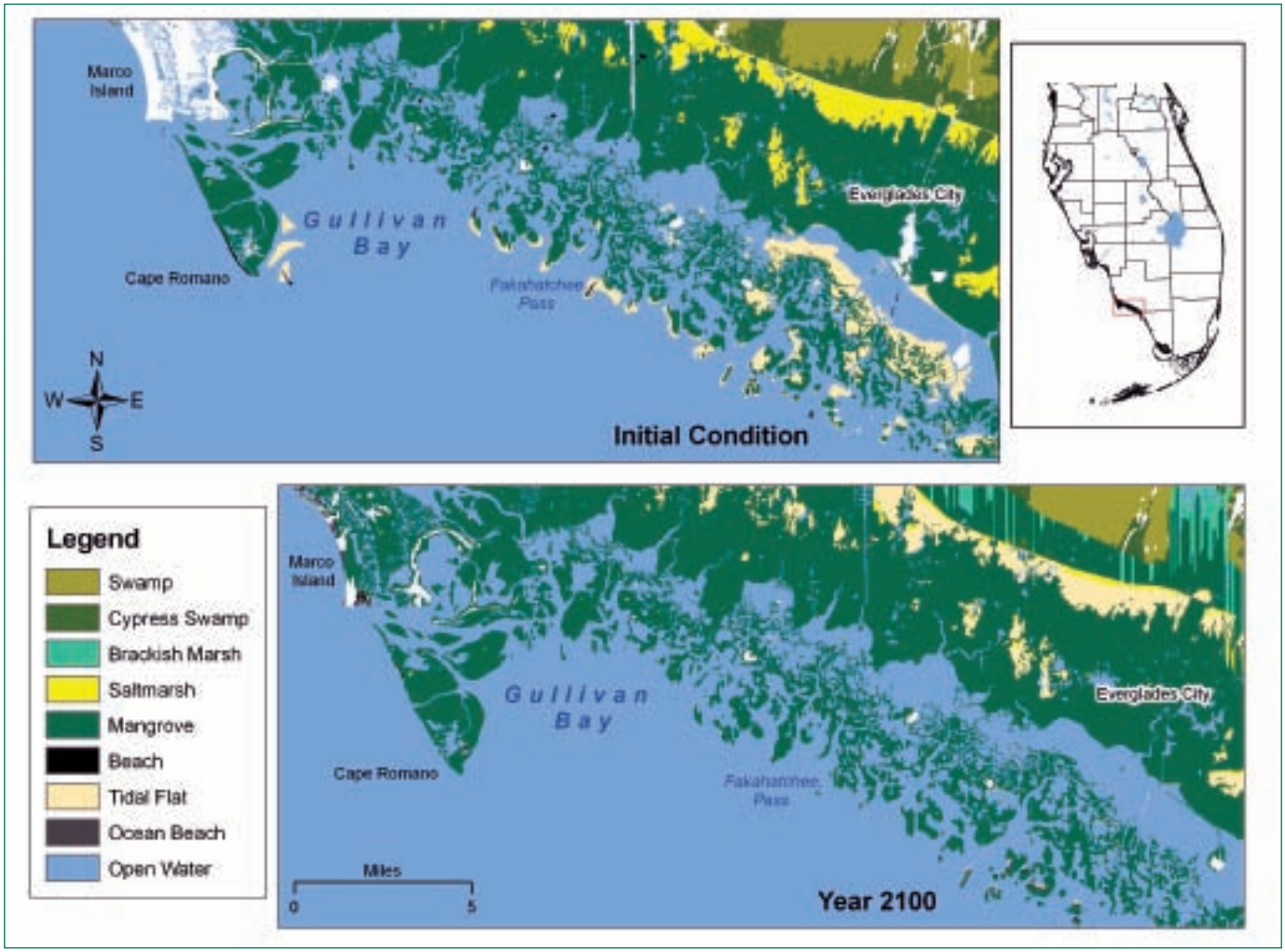
RALPH BROOKES
RECREATIONAL ANGLER, CAPE CORAL

TEN THOUSAND ISLANDS

The Ten Thousand Islands area is considered to be one of the most beautiful parts of Florida's coast. The region is famous for snook and redfish. Tarpon also is popular, particularly in the Everglades National Park area in spring, and there may often be grouper in the area's extensive mangrove forests.[46] In 2005, retail sales associated with saltwater recreational fishing in Collier and Monroe counties totaled $412.8 million, supporting more than 7,300 jobs.[47]

Although rapid population growth and associated development in surrounding areas have contributed to problems such as altered water flows and polluted runoff into the region's coastal waters, much of Ten Thousand Islands has been protected, and it remains one of the most ecologically-rich areas in the state.

Under the mean sea-level rise scenario, the area of mangroves – the dominant habitat type in this region – is projected to increase by about 16 percent by 2100. However, this mangrove migration takes its toll on inland fresh marsh and dry land, which decrease by 44 percent and 80 percent, respectively. In addition, 76 percent of the area's saltmarsh is lost, and some fresh marsh is predicted to be converted to brackish marsh, which was not initially present at this site. The most significant effects on fisheries in this area are likely to be on freshwater species that inhabit coastal fresh marshes and swamps. However, the region's saltmarsh-dependent fish such as snook, redfish, tarpon, gray snapper and spotted seatrout, as well as small prey species, also are at risk.



Projections of Marsh Fate for Ten Thousand Islands, 2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	3,274	2,114	1,678	654	3%	35% loss	49% loss	80% loss
Hardwood Swamp	5,744	5,863	5,861	3,963	5%	2% gain	2% gain	31% loss
Cypress Swamp	1,198	1,202	1,202	988	1%	0%	0%	18% loss
Inland Fresh Marsh	7,485	7,663	7,657	4,225	7%	2% gain	2% gain	44% loss
Brackish Marsh	0	240	271	1,946	0%	NA	NA	NA
Saltmarsh	3,667	3,208	2,462	898	3%	13% loss	33% loss	76% loss
Mangrove	32,500	33,018	33,401	37,857	31%	2% gain	3% gain	16% gain
Estuarine Beach	84	106	83	58	0%	26% gain	1% loss	30% loss
Tidal Flat	2,337	1,986	1,964	3,117	2%	15% loss	16% loss	33% gain
Ocean Beach	10	46	47	53	0%	360% gain	364% gain	424% gain
Inland Open Water	91	94	89	48	0%	3% gain	3% loss	48% loss
Estuarine Open Water	16,865	16,984	17,168	17,388	16%	1% gain	2% gain	3% gain
Open Ocean	33,073	33,805	34,444	35,133	31%	2% gain	4% gain	6% gain

"This report is timely and will hopefully result in more fishermen giving some serious thought to the very alarming long term effects of global warming and sea level rise. Based on the projected sea level rise in the Ten Thousand Islands region it is cause for genuine concern for anyone who knows and fishes the area. After reading the report, I can visualize seeing my favorite oyster bars and flats gradually disappearing in the not too distant future. Perhaps more important is my concern as someone who loves and fishes the Ten Thousand Islands area that my grandchildren may never have some of the wonderful experiences that I have been blessed with. I want to do whatever I can to spread the message about global warming and how all of us who guide, fish and just enjoy the beauty of the Ten Thousand Islands have an obligation to spread the word. Warmer is not better!"

CAPTAIN FRANKLIN ADAMS

FLORIDA WILDLIFE FEDERATION BOARD MEMBER AND

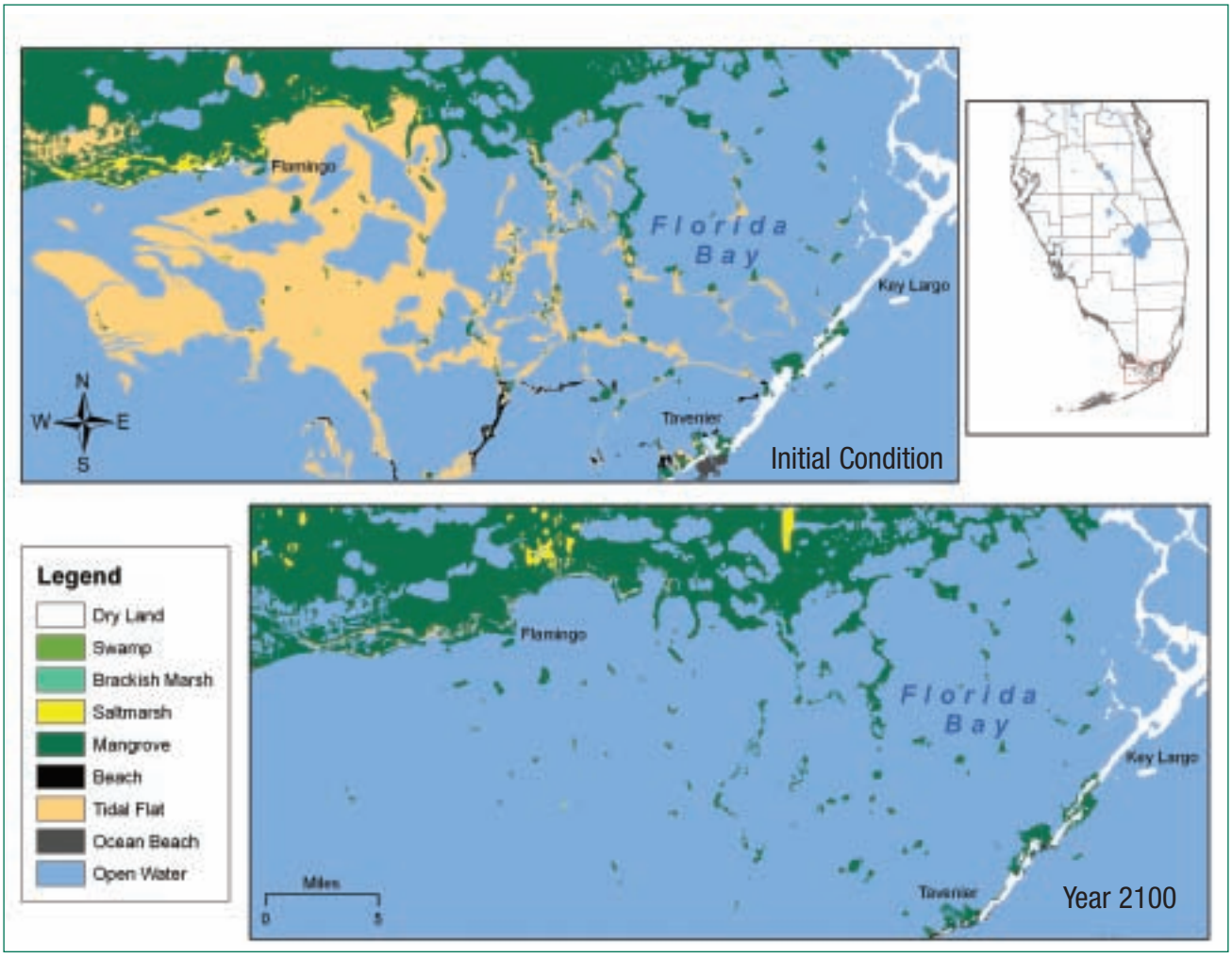
RENOWNED CHARTER GUIDE IN EVERGLADES CITY

FLORIDA BAY

Florida Bay has long been a prime destination for sportfishing enthusiasts. The upper part of Florida Bay falls within the boundaries of the Everglades National Park and is a popular fishing destination for snook, redfish, spotted seatrout and tarpon, and its seagrass beds are essential habitat for young snappers, shrimp and spiny lobster.[48] The Bay's extensive tidal flats also are enormously-popular spots for permit and bonefish. In 2005, retail sales associated with saltwater recreational fishing in Monroe and Dade counties totaled $408.7 million, supporting more than 7,200 jobs.[49]

Unfortunately, fishing pressure as well as reductions in suitable habitat have contributed to a decline in juvenile abundance and distribution of a number of gamefish species in the region in recent years.[50] In many ways, Florida Bay has been the poster child of conservation problems in Florida. The watershed throughout southern Florida has been extensively altered by the development of dikes, canals and levees in order to convert wetlands to farm land and urban developments, divert water for urban and agricultural use, and control flooding. As a result, the timing and extent of freshwater flows into Florida Bay no longer follow natural patterns, a factor that has caused considerable problems for ecological systems throughout the region.

In response to the serious problems that have plagued the region, both public and private stakeholders have begun investing in a multi-year, multi-billion dollar strategy – the Comprehensive Everglades Restoration Plan – to restore the Everglades system to more-



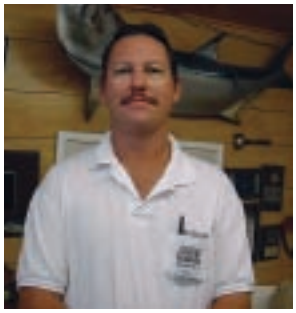
Projections of Marsh Fate for Florida Bay, 2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	1,269	1,062	808	616	1%	16% loss	36% loss	51% loss
Hardwood Swamp	8	6	6	5	0%	25% loss	28% loss	34% loss
Brackish Marsh	13	827	391	9	0%	6,262% gain	2,961% gain	30% loss
Saltmarsh	1,232	941	1,044	839	1%	24% loss	15% loss	32% loss
Mangrove	33,402	32,069	32,242	32,294	17%	4% loss	3% loss	3% loss
Estuarine Beach	485	210	68	52	0%	57% loss	86% loss	89% loss
Tidal Flat	32,561	2,951	669	484	17%	91% loss	98% loss	99% loss
Ocean Beach	226	166	119	54	0%	27% loss	47% loss	76% loss
Estuarine Open Water	118,336	149,042	151,753	152,477	62%	26% gain	28% gain	29% gain
Open Ocean	3,959	4,216	4,390	4,660	2%	6% gain	11% gain	18% gain

natural conditions. To be successful, however, that effort must factor in the likelihood that sea-level rise and other problems due to global warming would magnify many of the problems that already have been contributing to the demise of the region's ecological systems.

During this century, sea-level rise is predicted to inundate 99 percent of tidal flats in Florida Bay, which are currently a dominant feature. Saltmarsh is projected to decline by 32 percent by 2100, making the Bay more vulnerable to water quality problems and seagrass loss due to polluted runoff. In addition at least half of the small amount of dry land is predicted to be lost by 2100. Species at risk include spotted seatrout, redfish, snook, tarpon, permit, bonefish and yellowtail snapper.

"I am a captain of a charter boat in the Fl. Keys as well as a lifelong (47 year) resident of Marathon, Florida. In fact, I am a 5th generation native of the Florida Keys with an average of 40 years per generation. My family has lived in the Keys permanently since 1798 and had gone back and forth from the Bahamas prior to that. I as well as my family have seen quite a few changes in the region over that period of time. From my own personal observation in the past 30 years, I have seen quite a bit of change to the fish habitat in the region, particularly in Florida Bay. We have noticed an increase in water levels along the shoreline. This has translated to higher salt water levels up in the Everglades National Park as well which is the major estuary for the region. On a slow pace, nature may be able to compensate for these changing levels but with the dominance of what is regionally called, "Big Sugar," which has demanded so much of the natural fresh water that used to pass through the 'Glades naturally, it has become a major event. The lack of fresh water and the increase of the level of salt water have resulted in the intrusion of pure salt water into normally brackish water areas. This has caused major die offs of thousands of juvenile fish, not to mention its effect on the other marine life. The direct and rapid result to the region has been a combination of muddy, dead water as well as a major decrease of the fish and coral that used to flourish in the region. This in turn has affected the entire food chain of the region. The changes have become most pronounced in the past 15 years. I fear that global warming will only add fuel to an already raging fire. Unless we act now the next ten, 20, 50 and 100 years at might very well witness the end of the Florida Keys."

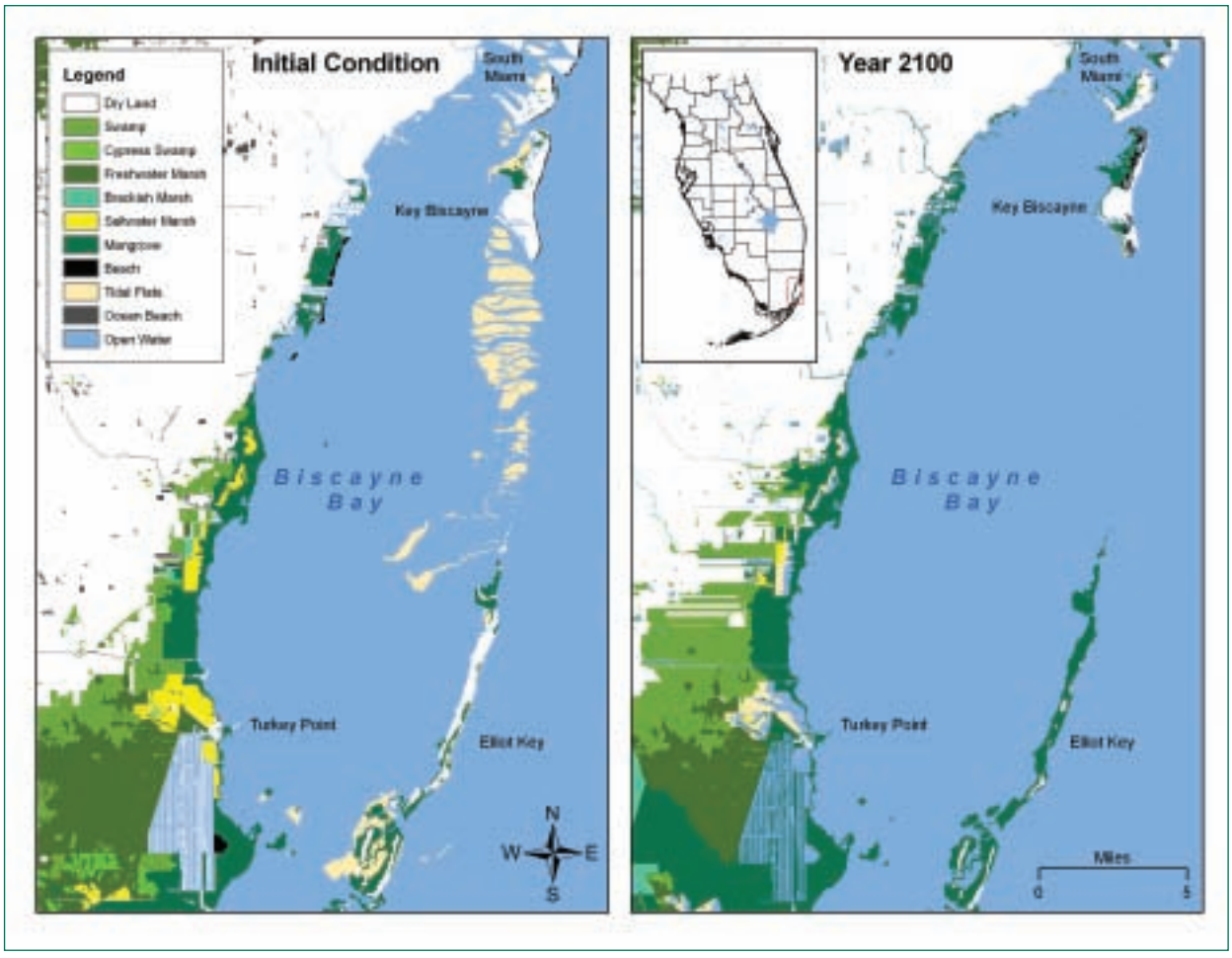


DAVID M. NAVARRO
WORLD CLASS ANGLER
MARATHON

BISCAYNE BAY

Biscayne Bay is home to a wide diversity of habitats and marine species. Its vast tidal flats are world-renowned for bonefishing. The area is also rich in seagrass and mangroves, and its proximity to Florida's coral reefs provides access to a number of reef-dependent species, including groupers and snappers, which use the bay as nursery habitat. Other species that may be caught in the Bay include snook, Spanish mackerel, bluefish, barracuda and small sharks. In 2005, retail sales associated with saltwater recreational fishing in Dade and Broward counties totaled $236.1 million, supporting more than 4,200 jobs.[51]

Biscayne Bay is surrounded by one of the most highly-urbanized areas in Florida, and polluted runoff has been one of the most significant problems affecting the Bay. Dredging and shoreline developments also have harmed some of the area's coastal habitats. Under the mean scenario, sea-level rise is not projected to cause significant additional habitat loss in the highly-developed northwestern portion of the study area, as those developments are build on relatively high land elevation. Farther south, however, lesser-developed low-lying dry land and freshwater wetlands are expected to undergo inundation and subsequent mangrove and brackish marsh expansion. By 2050, beach erosion also is projected to claim 60% of existing estuarine beaches at those sites; and tidal flats decline by 74% throughout the Bay, jeopardizing some of the area's most popular fishing spots. Gamefish species at risk include snook, redfish, tarpon, yellowtail snapper, bonefish and permit.



Projections of Marsh Fate for Biscayne Bay,
2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	57,841	53,133	51,985	50,278	34%	8% loss	10% loss	13% loss
Hardwood Swamp	3,993	6,143	6,433	5,656	2%	54% gain	61% gain	42% gain
Cypress Swamp	589	460	458	86	0%	22% loss	22% loss	85% loss
Inland Fresh Marsh	7,846	7,691	7,836	5,224	5%	2% loss	0%	33% loss
Brackish Marsh	119	576	394	1,642	0%	383% gain	231% gain	1,278% gain
Saltmarsh	1,387	1,046	896	639	1%	25% loss	35% loss	54% loss
Mangrove	8,556	10.781	11,274	14,654	5%	26% gain	32% gain	71% gain
Estuarine Beach	225	171	89	47	0%	24% loss	60% loss	79% loss
Tidal Flat	3,340	761	863	702	2%	77% loss	74% loss	79% loss
Ocean Beach	0	34	49	94	0%	NA	NA	NA
Inland Open Water	1,815	1,879	1,465	1,326	1%	3% gain	19% loss	27% loss
Estuarine Open Water	80,428	82,754	82,920	82,758	47%	3% gain	3% gain	3% gain
Open Ocean	5,794	28,041	7,271	8,828	3%	12% gain	25% gain	52% gain

"It is impossible to know what the loss of coral reefs to bleaching, grass flats to higher water levels and less sunlight, and fresh water coastal marshes to saltwater intrusion will mean for fish populations. We have never seen these effects occur over such a brief period of time. Surely many species will be devastated. On the other hand, there is a good possibility that by increasing tidal marshes and mangrove forests, other species will flourish. What is known for sure is that through environmental changes global warming will unleash, humankind faces changes that are of a greater threat to society than terrorism, bird flu pandemics, AIDS and all the other crises combined."

CAPTAIN DAN KIPNIS

PRESIDENT, MIAMI BEACH ROD AND REEL CLUB

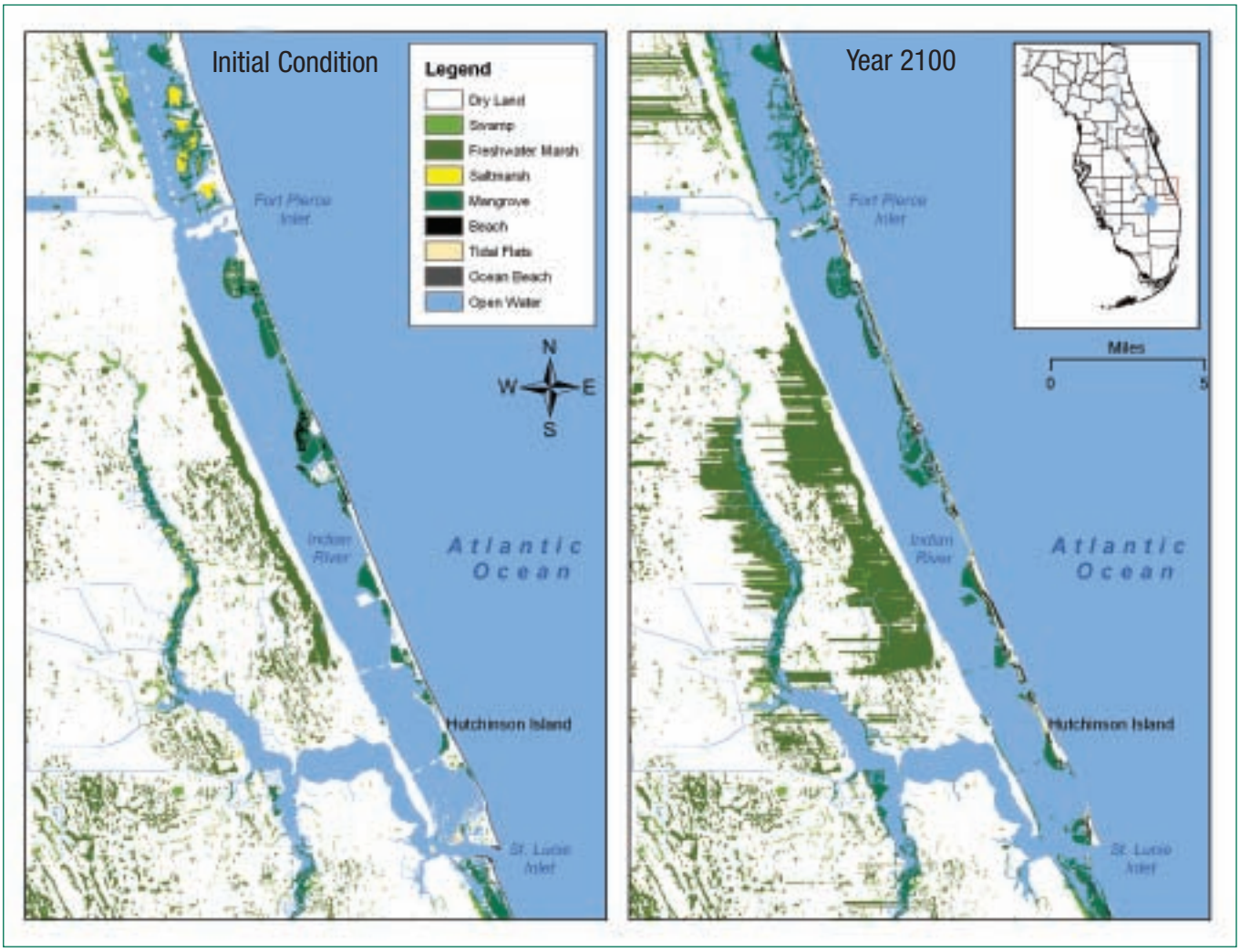
HOLDER OF SIX INTERNATIONAL FISHING WORLD RECORDS

ST. LUCIE

The St. Lucie estuary in the southern part of the Indian River region is a popular fishing destination for redfish, snook, flounder, tarpon, permit, snappers and groupers. The areas beaches provide opportunities for surf fishing for bluefish and pompano, and fishing offshore is enormously popular given the accessibility of the Gulf Stream.[52] In 2005, retail sales associated with saltwater recreational fishing in St. Lucie and Martin counties totaled $89 million, supporting more than 1,500 jobs.[53]

Water quality problems associated with altered freshwater flows have plagued the St. Lucie region in recent decades. During the summer of 2005, due to the frequency, duration and intensity of the hurricane season, the Army Corps of Engineers allowed massive discharges of polluted runoff into the St. Lucie River, resulting in catastrophic fish kills from excessive nutrients. An algal bloom ensued, making the river unfishable. Changes in salinity gradients due to alterations in the timing, distribution and volume of freshwater entering the estuary, nearby lagoon and ocean waters have had a significant effect on the region's fisheries. Species richness in many of the fish communities of the estuary has declined considerably since 1970.

With sea-level rise, the two dominant processes predicted to affect St. Lucie are overwash of barrier islands and saturation of dry land. Inland elevations of dry land are low, especially in



Projections of Marsh Fate for St. Lucie,
2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	74,677	69,550	68,130	67,169	54%	7% loss	9% loss	10% loss
Hardwood Swamp	2,275	2,334	2,341	2,312	2%	3% gain	3% gain	2% gain
Inland Fresh Marsh	8,425	12,193	13,255	13,465	6%	4% gain	57% gain	60% gain
Saltmarsh	405	217	28	3	0%	46% loss	93% loss	99% loss
Mangrove	3,231	4,197	3,936	3,871	2%	30% gain	22% gain	20% gain
Estuarine Beach	97	198	143	232	0%	104% gain	47% gain	139% gain
Tidal Flat	216	264	505	252	0%	22% gain	134% gain	16% gain
Ocean Beach	301	234	159	62	0%	22% loss	47% loss	80% loss
Inland Open Water	1,025	1,041	1,048	1,048	1%	2% gain	2% gain	2% gain
Riverine Tidal	73	73	73	73	0%	0%	0%	0%
Estuarine Open Water	15,864	16,047	16,502	17,134	12%	1% gain	4% gain	8% gain
Open Ocean	30,738	30,980	31,206	31,706	22%	1% gain	2% gain	3% gain

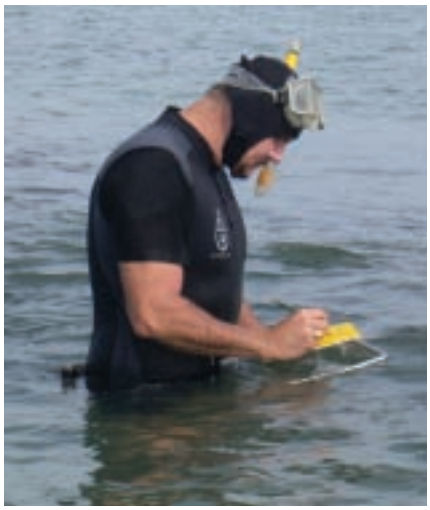
relation to the inland fresh marsh that occurs close to the bay. This results in significant predictions of saturation and a loss of 10 to 12 percent of dry land (which comprises more than 50 percent of this site) by 2100. Because this part of St. Lucie is heavily developed, this projection should be considered the "potential" for saturation as this process is likely to be offset by landowners bringing in fill when required, which may protect development but would not help fish. In addition, inundation of sea water into the estuary may exacerbate salinity fluctuations, affecting spotted seatrout, redfish and snook. Beach erosion and overwash is predicted to result in the loss of roughly half of the ocean beach at this site by 2050 and 80 percent by 2100, significantly reducing feeding habitat for pompano and other surf fish.

"We need to stop thinking only in terms of individual stressors upon coastal systems. Many human-induced stressors are interacting in damaging manners and these are now exacerbated by significant stressors associated with climate change, including sea level rise, declining coral health, and more intense storm events. The St. Lucie watershed system is a prime example of how interactions from all of these factors are threatening the economic and ecological future of a unique Florida resource. Managers and politicians need to listen closely to the voices of the actual coastal water users – the fishers, divers and surfers. They often see and understand more than the textbook experts."

DR. KEN LINDEMAN

SENIOR SCIENTIST, ENVIRONMENTAL DEFENSE

SATELLITE BEACH



INDIAN RIVER LAGOON

The Indian River Lagoon is considered to be one of the most biologically diverse estuaries in North America.[54] The upper Indian River area is a popular place to fish for redfish and spotted seatrout. Limited shrimping is also popular from September through April. Snook, flounder, bluefish and gray snapper are common catches in the beach areas.[55] In 2005, retail sales associated with saltwater recreational fishing in Volusia, Brevard and Indian River counties totaled $262.9 million, supporting more than 4,600 jobs.[56]

As is the case with St. Lucie, the primary threat to the fisheries throughout the Indian River Lagoon has been reduced water quality associated with urban development and freshwater management activities. In particular, altered and unstable salinity levels have limited oyster, mussel and clam abundance and contributed to an overall decline in the richness of the region's fish communities since the 1970s.[57]

The projected effects of sea-level rise here are generally similar to those for St. Lucie. Saturation and inundation are important processes at this East Coast site resulting in a loss of 15 percent of dry land and 11 percent of hardwood swamp, which is partly converted to marsh and tidal flats. Again, as this is a heavily-developed site with a considerable number of dikes in place, this may be more of a prediction of costs to be imposed on landowners rather

Projections of Marsh Fate for Indian River Lagoon, 2025, 2050 and 2100 (Mean Scenario)

	AREA OF HABITAT TYPE (IN HECTARES)				PERCENTAGE CHANGE			
	Initial Cond.	Year 2025	Year 2050	Year 2100	Percent of Init. Cond.	Percent Change (Loss/Gain) 2025	Percent Change (Loss/Gain) 2050	Percent Change (Loss/Gain) 2100
Dry Land	74,380	69,695	66,116	63,019	39%	6% loss	11% loss	15% loss
Hardwood Swamp	6,121	5,342	5,725	5,422	3%	13% loss	6% loss	11% loss
Cypress Swamp	48	48	53	53	0%	0%	9% gain	9% gain
Inland Fresh Marsh	16,784	16,526	18,286	17,764	9%	2% loss	9% gain	6% gain
Tidal Fresh Marsh	1,720	1,714	1,700	1,681	1%	0%	1% loss	2% loss
Brackish Marsh	0.7	5,550	2,365	4,098	0%	554,900% gain	328,000% gain	569,000% gain
Saltmarsh	104	98	4,524	3,755	0%	6% loss	4,252% gain	3,512% gain
Mangrove	549	549	548	548	0%	0%	0%	0%
Estuarine Beach	18	36	34	41	0%	100% gain	88% gain	128% gain
Tidal Flat	195	148	185	2,927	0%	24% loss	5% loss	1,398% gain
Ocean Beach	554	493	443	284	0%	11% loss	20% loss	49% loss
Inland Open Water	5,468	5,497	5,335	5,205	3%	1% gain	2% loss	5% loss
Estuarine Open Water	39,039	39,127	39,410	39,640	20%	0%	1% gain	2% gain
Open Ocean	46,685	46,843	46,943	47,229	24%	0%	1% gain	1% gain

than an actual loss of dry land. Overwash is not expected to be as important at this site, but beach erosion does claim roughly 50 percent of ocean beach, reducing access to nearshore fisheries. Species at risk include spotted seatrout, redfish, snook, flounder, snappers and pompano.

"While barrier islands have always been dynamic, impacting beachfront development even with the unsustainable measures of 'beach renourishment,' the impact of sea level rise will permanently diminish the amount of available beach access to recreate with Florida's waves and beaches."

ERICKA D'AVANZO

FLORIDA REGIONAL MANAGER

SURFRIDER FOUNDATION

JENSEN BEACH

Additional Effects of Global Warming

Sea-level rise is not the only problem that Florida faces due to global warming. The additional changes associated with higher average temperatures and altered precipitation patterns also would affect the state's coastal habitats and fish and wildlife species in many ways, as evidenced by recent trends.

Average temperatures in parts of the state have increased by about 2 degrees F since the 1960s, and precipitation over the past century has decreased in the south and increased in Central Florida and the Panhandle.[58] Global warming is having a significant impact on ocean temperatures as well. On average, the temperature of the upper 300 meters of the world's oceans has risen about 0.5 degrees F since the 1950s, a trend that scientists have determined is a direct result of human activities.[59] In the Tropical Atlantic, average sea surface temperatures have warmed 1 degree F over the past three decades. These higher sea surface temperatures are damaging coral reefs, enhancing marine diseases and making the region's hurricanes more intense and destructive.

Furthermore, all of these changes are amplifying the numerous other serious environmental problems that plague the state. Sea-level rise is putting an additional squeeze on saltmarshes, seagrass beds, mangroves and other coastal habitats that have already been reduced due to development. Changes in precipitation patterns, including more-extreme rainfall events and droughts, mean even more changes to freshwater availability and flows into coastal waters, altering salinity, water clarity and oxygen levels. And higher water temperatures are exacerbating the impact of excess nutrient runoff into coastal waters, enhancing harmful algal blooms and hypoxia events. Essentially, all of these changes combine to create a "perfect storm" for Florida fishing.

Temperature Comfort Zones for Selected Florida Gamefish

BLUEFISH 64-75° F
COBIA 68-86° F
DOLPHIN 78-85° F
KING MACKEREL 70-75° F
REDFISH 56-84° F
RED SNAPPER 57-60° F
SAILFISH 75-85° F
SNOOK 70-86° F
SPANISH MACKEREL 67°+ F
SPOTTED SEATROUT 65-75° F
TARPON 74-88° F

SOURCE: www.floridasportsman.com

Higher Average Air and Water Temperatures

Evidence indicates that average air temperatures in Florida will continue to increase in the coming decades, with average low temperatures in winter increasing 3-10 degrees F and average high temperatures in summer increasing 3-7 degrees F by 2100.[60] The range at which freeze events typically occur is expected to shift to the north, enabling some coastal and terrestrial species such as mangroves, whose northern habitat ranges are currently limited by where temperatures get too cold in winter, to become established in the upper parts of the state (assuming other habitat needs such as the right soils and salinity levels are also available in those areas).[61]

NOAA

Fish also can be affected by periodic freeze events, as changes in water temperatures are often directly correlated with changes in proximate air temperatures. With coastal waters, this typically occurs in those estuaries that are not highly influenced by tidal flows.[62] Highly temperature-sensitive coastal species such as snook are especially vulnerable to cold snaps. Historically, Tampa Bay has been the upper end of their habitat range, but milder temperatures in recent years, coupled with improved fishery management and habitat conditions, have enabled the fish to thrive in the region.[63]

For marine species in general, average ocean temperature on a broader scale is a major factor in determining viable habitat, and the preferred temperature ranges can vary considerably among different species. In fact, optimal temperatures are so important for 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. While highly-mobile species may be able to move to find more favorable conditions, more-sedentary species such as corals and mollusks would be forced to endure the changes where they occur.

In the northern Gulf of Mexico region, much of the popular fishing occurs in the summer months from May to October, when many of the species that prefer warmer waters migrate north. Warmer average water temperatures due to global warming may expand opportunities for fishing for some species such as snook and tarpon, assuming other essentialhabitat factors such as salinity levels and food sources are also favorable for the fish. On the other hand, there is considerable concern that warmer temperatures would facilitate the expansion of many opportunistic non-native species, whose current range may be limited primarily by temperatures.[64] Introduced tropical species such as the Australian pine tree thrive in warmer temperatures and already have been outcompeting native species in many coastal areas.[65] In addition, non-native tropical fish, including the Indo-Pacific lionfish (a marine species) and spotted and blue tilapia (freshwater species), have been thriving in the state's waters.

A study of the potential effects of warmer 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 this century is out because water temperatures would exceed their thermal tolerance for an extended period of time.

For other species that are already on 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 fish to retreat farther north in search of cooler waters is physically limited by the coastline.

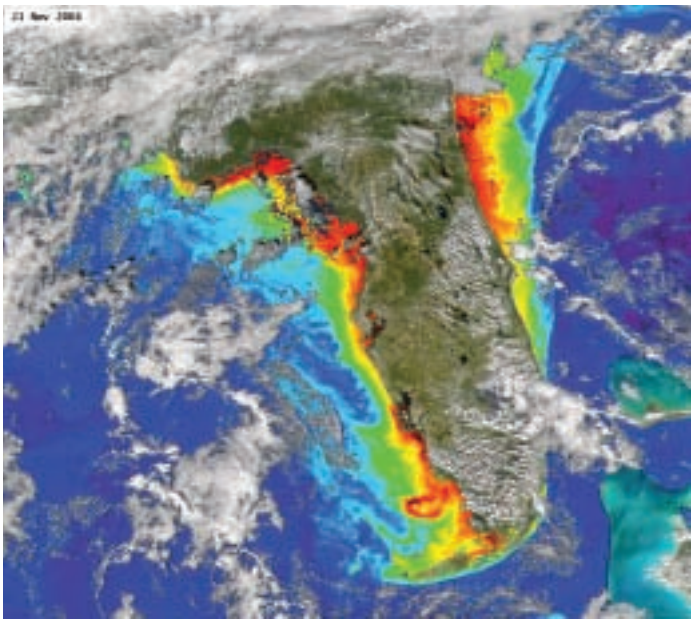
A study of the potential effects of warmer water temperatures in Apalachicola Bay due to global warming suggests that several important fishery species, including crabs, shrimp, oysters and flounder, might not be able to survive in the estuary before this century is out because water temperatures would exceed their thermal tolerance for an extended period of time.[66] 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 habitat range for striped bass, which cannot tolerate high ocean temperatures.[67] Higher average temperatures in the region due to global warming may eliminate striped bass from Florida altogether. Gulf of Mexico sturgeon and American shad are likely to face a similar fate.

In addition to affecting species' ranges, too-high water temperatures would cause a number of other problems throughout Florida's coastal regions, including extensive coral bleaching, harmful algal blooms, marine diseases, hypoxia events and more-intense hurricanes – all of which would affect sportfishing in the state.

CORAL BLEACHING

A striking sign that global warming is already affecting some ecosystems is the growing incidence of coral bleaching, which is caused largely by prolonged exposure of corals to warmer-than-normal ocean temperatures.[68] While corals normally rely on warm water for their survival, water that is too warm can cause them to lose a type of algae called zooxanthellae, which they host. Without the colorful algae, the corals appear white, or "bleached." Since zooxanthellae provides corals with energy and nutrients, a lack of the algae causes the corals to starve. Coral can recover from periodic bleaching, but if the stress if prolonged or extreme, the corals will die.

The number of massive bleaching episodes around the world has increased considerably since the late 1970s, corresponding with the trend of increasingly warmer ocean temperatures. Throughout the Florida Keys and the Caribbean, coral bleaching has contributed to a significant decline in stony coral diversity and cover.[69] In 2005, the thermal stress to the region's corals due to high sea surface temperatures reached a level greater than it had been in the previous 20 years combined. As a result, coral reefs have experienced unprecedented bleaching and die off. With so much of the region's reef habitat already damaged by factors such as pollution, boat anchors, dredging and unsustainable fishing practices, scientists are concerned that more frequent and extensive bleaching could ultimately be the last straw for these critical ecosystems.[70]



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Areas in red show high chlorophyll concentrations associated with red tide off Florida in November 2004.

Continued loss of the Florida's coral reef habitat would be devastating for reef-dependent fisheries, as well as the regional economy. In southeast Florida alone, coral reef-related activities (including fishing) contributed $4.3 billion in sales and $2 billion in annual income in 2001.[71]

HARMFUL ALGAL BLOOMS

Harmful algal blooms such as "red tides" also have become much more extensive in recent years, a trend that scientists attribute in part to global warming.[72] A number of different algae species can produce toxins that are harmful to fish, wildlife and people. Toxic "blooms" occur when environmental conditions such as warmer water temperatures and eutrophication (excess levels of nutrients such as phosphorus) cause these algae to multiply rapidly.

These trends have been identified as a primary cause of recent outbreaks of *Pfiesteria piscicida* in the mid-Atlantic region that have killed millions of rockfish and other important fishery species.[73] *Pfiesteria piscicida* can cause health problems for people as well, and public avoidance of affected waters and fish have contributed to significant economic losses to the

region. While *Pfiesteria piscicida* outbreaks have so far been limited to mid-Atlantic states, some new Pfiesteria-like organisms have started emerging throughout the Atlantic and Gulf Coast regions, including the discovery in 1998 of a similar type of algae in the estuarine waters of the St. Lucie River that caused fish lesions and kills.[74]

Another organism called *Karenia brevis* has been the most common cause of red tide events in Florida, and 2005 offered a profound example of just how devastating such events can be when the conditions are right. In the summer and fall, water temperatures in the Gulf of Mexico were the highest ever recorded, and heavy rainfall events associated with a highly active storm season led to extensive runoff and freshwater discharge into coastal rivers and estuaries. Consequently, it was the worst year on record for red tides. Almost the entire coastline of Florida was affected and thousands of fish were killed, as were numerous marine invertebrates, manatees, dolphins, and sea turtles.

OTHER MARINE DISEASES

Studies have shown that, in addition to contributing to harmful algal blooms, warmer average ocean temperatures are a significant factor in the growing incidence, range and severity of a number of other marine diseases.[75] When water temperatures are above an optimal threshold, some marine species may become stressed and more susceptible to disease. Shifts in water temperatures may also contribute to the expansion of some disease pathogens, vectors and hosts into areas previously unsuitable for them.

Studies have shown that, in addition to contributing to harmful algal blooms, warmer average ocean temperatures are a significant factor in the growing incidence, range and severity of a number of other marine diseases.

Coral diseases, in particular, are becoming an increasingly serious threat to the health of coral reefs in the Florida Keys and Caribbean, corresponding with a trend of higher sea surface temperatures.[76] Outbreaks of black band and white band disease, coral plague and Aspergillosis, for example, have led to massive, unprecedented die-offs among corals in many areas.[77] Between 1996 and 1999, the number of reef monitoring stations in the Florida Keys that have exhibited signs of coral diseases rose by a factor of four.[78]

Similarly, warmer conditions in the Gulf of Mexico, such as those that have historically occurred during La Niña events, have been shown to contribute to an increased prevalence and intensity of Dermo, a parasitic disease of the Eastern oyster. A 25-year trend of increasingly warmer waters along the East Coast, as well, may have contributed to a steady expansion of Dermo and MSX, another serious oyster disease, into northern waters.[79]

COASTAL HYPOXIA

Another problem associated in part with warmer water temperatures is hypoxia, a condition in which the oxygen content of the water falls below a certain level. While hypoxia is not a new phenomenon, its prevalence also has become much more widespread in recent decades due to a combination of excess salinity, eutrophication and the trend toward higher average temperatures.[80]

Warmer temperatures contribute to hypoxia in several different ways. High temperatures can cause water to become stratified, where colder water remains below the warmer surface water. Extended periods of stratification can cut off oxygen supply from the atmosphere to

FEMA

the bottom waters. Water at high temperatures also generally holds less oxygen at saturation relative to cooler water. In addition, high water temperatures can accelerate the bacterial decay of organic matter, exacerbating hypoxia events associated with eutrophication.[81] While some fish will avoid hypoxic waters altogether, extensive hypoxia can lead to significant fish kills among coastal species, particularly the smaller, schooling fish like menhaden. According to the National Oceanic and Atmospheric Administration, high water temperatures and related loss of oxygen were identified as the leading cause of major fish kills among 22 coastal states between 1980 and 1989.[82]

MORE-INTENSE HURRICANES

Scientists have discovered that the intensity and duration of hurricanes around the world have increased significantly in recent decades, fueled by warmer ocean temperatures associated with global warming.[83] Recent storm data indicates, for example, that the number of category 4 and 5 hurricanes in the Atlantic, Pacific and Indian oceans has almost doubled over the past 30 years, a trend that cannot be supported by natural variability or cycles alone.[84] Furthermore, sea level rise associated with global warming has made many coastal areas more vulnerable to storm surges and erosion. These factors, combined with the fact that more and more people are now living in coastal areas, are making hurricanes much more costly and destructive. Climate scientists, while not generally predicting more hurricanes, do believe that those which do occur will continue the trend of greater intensity. Although one must look at long-term trends in climate and cannot specifically attribute any particular hurricane to global warming, certainly few people will soon forget the past two hurricane seasons. The National Oceanic and Atmospheric Administration declared the 2005 Atlantic hurricane season as the busiest and most destructive on record. It was the first season to see three storms reach Category 5 on the Saffir-Simpson scale of hurricane intensity – Katrina, Rita and Wilma (the strongest storm ever recorded).[85]

2004 was an enormously destructive and costly hurricane season for Florida as well, revealing the potential toll of more-intense storms expected with global warming. Florida experienced four major storms in just a six-week period. Beyond the unfathomable human and ecological toll, the economic costs from these storms have been considerable. Insured losses in Florida resulting from hurricanes Charley, Frances, Ivan and Jeanne in 2004 totaled more than $20 billion; and some estimates have put the losses to the Gulf States region due to Hurricane Katrina alone at $100 to150 billion. Insurance costs are rising as a result, and many home insurance companies are pulling out of Florida and other coastal states altogether.

The region's fishing industry was affected by these storms in a number of ways. Several weeks after hurricanes Katrina and Rita struck the Gulf Coast, the National Oceanic and Atmospheric Administration announced an all-out fishery failure in the Gulf of Mexico.[86] Not

only did the storms destroy the majority of the boats, marinas, seafood processing facilities and other resources and infrastructure that support the industry, but they also have affected fish and shellfish directly by damaging coastal habitat and sending extensive amounts of pollution into the Gulf.[87]

Many of the larger fish that are popular with anglers were able to withstand the 2004 and 2005 barrage of hurricanes, spawning regular accounts of excellent fishing even in the days and weeks immediately following the storms. What worries fisheries managers, however, is how seriously the hurricanes may have affected important nursery habitat and young fish along the coasts. Seagrass beds in some areas have been wiped out altogether, and saltmarshes have been converted to open water. The long-term consequences of these storms remain to be seen, but it is likely that at least some of these changes will linger well into the future.

Shifts in Precipitation Patterns

On a local and regional level, identifying how global warming would affect precipitation patterns can be difficult and uncertain. For Florida, some models project a decrease in average precipitation in winter and an increase in summer, with an overall increase; others suggest an increase in average winter precipitation and a decrease in summer, with an overall decrease.[88] Despite the uncertainties, however, all of the commonly-used models agree that the hydrologic cycle in Florida would change, most likely including an increase in the extent of extreme rainfall events.[89]

These changes would create ripple effects throughout the state's ecosystems. Florida's hydrological systems have already been so significantly altered by flood control and other water resource management projects that any additional changes could be all the more problematic. The potential for wetter average conditions and more-extreme downpours during the "wet" (summer) season, for example, would make it more difficult for resource managers to reduce excessive flows of freshwater from channels into bays and estuaries. This could result in reduced salinity as well as greater discharge of nutrients, sediments and chemicals into the coastal waters.

Similarly, drier average conditions during the "dry" (winter) season would exacerbate many of the problems currently associated with too little freshwater entering coastal waters, including higher salinity levels and destruction of seagrass and other habitat. For example, a study of global warming-induced reductions in freshwater inflow coupled with sea-level rise in Apalachicola Bay suggests that associated increases in salinity could have devastating consequences for the region's oysters, blue crabs, white shrimp and finfish.[90]

With Florida's population of people expected to grow considerably in the coming decades, overall demand for water for alternative uses will no doubt grow, placing an added strain on the state's resources.[91] Ultimately, it is the combination of many stressors – increased development, pollution, unsustainable fishing practices and global warming – that poses the greatest threat to Florida's coastal resources and the numerous benefits they provide for people and wildlife alike.

VISIT FLORIDA, NOAA

Changing The Forecast for Sportfishing in Florida
A Plan of Action

Fortunately there are solutions to the many problems, including global warming, that threaten Florida's coastal resources. By taking a longer-term, more comprehensive approach to managing and protecting those resources, Florida has an opportunity to prevent the worst-case scenarios from occurring and ensure that its treasured natural heritage – and its sportfishing legacy – will endure for generations to come. This report recommends two overarching strategies that, taken together, will be an important part of an effective plan of action:


NATURAL RESOURCES CONSERVATION SERVICE

1. MINIMIZE THE THREAT OF GLOBAL WARMING BY REDUCING GLOBAL WARMING POLLUTION.

Most importantly, Florida and the rest of the nation should do much more to minimize the impact of global warming altogether by reducing the pollution causing it. Less carbon dioxide and other heat-trapping gases in the atmosphere will mean less global warming and, turn, less-severe impacts. However, effective action to reduce global warming pollution must to be taken sooner rather than later, including significant steps to slow the continuing growth in emissions within the next decade. Delaying action will only allow more and more carbon pollution to accumulate in the atmosphere, making the more-extreme projections for sea-level rise and other impacts more likely to occur. Furthermore, delaying action will mean that even greater pollution reductions would have to occur down the road, making them more difficult and costly to achieve.

With so much at stake, Florida must be part of the solution to global warming by taking meaningful actions at the local and state levels as well as by supporting strong national policy. Florida ranks fifth in the nation in terms of its carbon dioxide emissions from burning fossil fuels, most of which comes from electric power plants and motor vehicles. In addition, Florida's energy use is rising at a rate that is nearly twice as fast as the nation as a whole.[92] By taking greater advantage of already-existing energy efficiency and renewable energy technologies, Florida has a real opportunity to meet its growing energy needs in a way that not only reduces the state's contribution to global warming, but protects regional air and water quality, reduces pressure to drill for oil, saves consumers money and positions Florida to capitalize on emerging markets for cleaner energy solutions. As the "Sunshine State," Florida should be the national leader in solar energy.

To date, 17 Florida cities are among at least 224 cities across the country that have stepped up to the plate by endorsing the U.S. Mayors Climate Protection Agreement, an initiative begun in 2005 to engage cities in solutions to global warming. Cities participating in

the program have agreed to implement programs to reduce global warming pollution in their own jurisdictions through community-based activities such as promoting carpooling and public transit, increasing recycling and improving the energy efficiency of buildings.

They are also sending a strong message to the state and federal governments to enact meaningful policies and programs to curb global warming pollution on a broader scale, including:

- Strengthening state and federal policies and programs to reduce dependence on fossil fuels by promoting energy efficiency, renewable energy and cleaner transportation options;
- Encouraging protection and restoration of natural habitats (wetlands, grasslands, forests) that have a net use of carbon dioxide (often called carbon sequestration);
- Setting specific limits on the nation's global warming pollution; and
- Reengaging in international cooperation on global warming.

10

Simple Steps You Can Take to Combat Global Warming

Five Things You Can Do at Home

1. When you replace the light bulbs in your home, buy compact fluorescent bulbs, which reduce energy use up to 75%.
2. Clean or replace your air conditioner filters every month, and set your thermostat between 76 and 78 degrees.
3. Reduce gasoline consumption by keeping your tires properly inflated and your engine tuned up. If you have a power boat, keep that engine tuned up as well.
4. Recycle aluminum cans, glass bottles, plastic, cardboard and newspapers, which will reduce the energy needed to make new products.
5. Plant shade trees near your home to help keep it cool. Planting new trees can also help combat global warming by absorbing and storing carbon dioxide.

Five Things You Can Do in Your Community

1. Persuade your workplace to improve the energy efficiency of its buildings and office machinery and support transportation alternatives such as carpooling and teleworking.
2. Urge your local electric utilities to offer "green" electricity programs, which enable customers to purchase electricity produced from clean, renewable energy sources like the sun and wind.
3. Promote curbside recycling programs in your workplace and neighborhood.
4. Encourage your mayor to sign onto the U.S. Mayors Climate Protection Agreement (www.ci.seattle.wa.us/mayor/climate).
5. Contact your representatives in Congress and urge them to enact meaningful policies to reduce global warming pollution.

2. DEVELOP AND IMPLEMENT MORE-RIGOROUS FISHERY AND COASTAL RESOURCE MANAGEMENT STRATEGIES THAT FULLY INCORPORATE THE LIKELY IMPACTS OF GLOBAL WARMING ON HABITATS.

On top of the growing demands for Florida's coastal resources as its human population grows, the added pressures associated with sea-level rise, more-intense storms and other global warming impacts would make managing those resources to meet the needs of fish, wildlife and people all-the-more challenging in the coming decades.

The emphasis on habitat protection and ecosystem-based approaches to managing fisheries and other coastal resources over the past decade has set an important foundation on which to deal with the multitude of stressors that are affecting them. However, it is becoming increasingly clear that state and federal agencies must pay greater attention to these longer-term problems as they develop and prioritize projects in their respective management plans.[93]

A number of actions will provide on-the-ground benefits in the near term while at the same time help protect habitats against additional threats down the road. For example, whenever possible, resource managers and land-use planners should steer away from structural approaches such as seawalls and levees for coastal protection. Coastal armoring hinders the ability of habitats and species to migrate inland in response to rising sea levels, and it reduces the ability for coastal wetlands to replenish themselves by preventing the build-up of sediments from riverflows. Nor are coastal protection structures fail-proof in protecting coastal communities from storm surges, as evidenced by the devastating destruction in New Orleans that resulted from broken levees during Hurricane Katrina in 2005.

A more effective strategy to protect coastal habitats and communities alike should include expanding projects to restore coastal systems to more natural conditions by removing structural barriers, restoring natural water flows, replanting native vegetation and requiring only the most ecologically sound practices for beach nourishment projects. It should also include policies and programs to ensure that currently undeveloped coastal areas remain protected. One priority should be expanding funding for the Florida Forever Land Acquisition Campaign, an innovative program that facilitates the state purchase of lands that are considered particularly important for conservation. Moreover, coastal managers and developers should take full consideration of the "true" costs of proposed projects, including the likely impacts on ecosystems and the critical services they provide.

The National Wildlife Federation and the Florida Wildlife Federation strongly support increased federal funding to state fish and wildlife agencies to help them incorporate these activities to address global warming into their long-term conservation efforts.

Florida Cities for Global Warming Action

(as of April 2006)

Gainesville
Hallandale Beach
Holly Hill
Hollywood
Key Biscayne
Key West
Lauderhill
Miami
Miramar
North Miami
Pembroke Pines
Pompano Beach
Port St. Lucie
Sunrise
Tallahassee
Tamarac
West Palm Beach

Conclusion

Florida's vast coastal resources and its sportfishing tradition are truly an American treasure. Whether it is the thrill of reeling in that record-breaking gag grouper off the Florida Panhandle or the pure enjoyment of spending a beautiful winter afternoon teaching one's children how to cast for seatrout in Florida Bay, the value that Florida's coastal resources bring to the state and the nation is a legacy that is worth protecting.

As this report has shown, however, global warming poses a significant threat to Florida's coasts and the fisheries they support. Left unchecked, global warming would lead to rapidly rising sea levels and coastal inundation. It would mean more marine diseases, red tides and coral bleaching. It would place Florida's people and wildlife alike at greater risk from catastrophic storms and other extreme events. Making the situation worse is the fact that these impacts would fall on top of the many other problems that continue to plague the state.

But it is not too late to act. It will take some foresight, the right investments and determination to reduce the risk rather than wait for its consequences. By taking action now, people can change the forecast for Florida's coasts and ensure that the economic opportunities, ecological benefits and outdoor traditions they provide will endure for generations to come.

NOAA

Endnotes

1 Florida Fish and Wildlife Conservation Commission, www.myfwc.com (September 13, 2005).

2 *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

3 "U.S. Census Bureau News: Florida, California, and Texas to Dominate Future Population Growth," *Census Bureau Reports,* April 21, 2005.

4 www.visitflorida.org (September 13, 2005).

5 Florida Fish and Wildlife Conservation Commission, "More Than Just 'Fish,'" www.myfwc.com/marine/fishinglines/fish_mngt.pdf (January 3, 2006).

6 K.C. Lindeman, et al., "Developmental Patterns Within a Multispecies Reef Fishery: Management Applications for Essential Fish Habitats and Protected Areas," *Bulletin of Marine Science,* Vol. 66(3), 2000: 929-956.

7 Florida Fish and Wildlife Conservation Commission, "Florida's Varied Marine Habitat," www.myfwc.com/marine/fishinglines/habitat2.pdf (September 19, 2005).

8 NOAA "Habitat Connections: Wetlands, Fisheries and Economics," http://www.nmfs.noaa.gov/habitat/habitatconservation/publications/habitatconections/habitatconnections.htm (September 13, 2005).

9 J. Humphreys, S. Franz and Bill Seaman, *Florida's Estuaries: A Citizen's Guide to Coastal Living and Conservation*, Florida Sea Grant, March 1993.

10 Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Synthesis Report* (Cambridge: Cambridge University Press, 2001).

11 E.J. Brook, "Atmospheric Science: Tiny Bubbles Tell All," *Science,* Vol. 310, 25 November 2005: 1285-1287.

12 P.N. Pearson and M.R. Palmer, "Atmospheric Carbon Dioxide Concentrations Over the Past 60 Million Years," *Nature,* Vol. 406, 17 August 2000: 695-699.

13 IPCC, *Climate Change 2001: Synthesis Report* (Cambridge: Cambridge University Press, 2001).

14 Goddard Institute for Space Studies, "Global Temperature Trends: 2005 Summary," http://data.giss.nasa.gov/gistemp/2005/ (March 20, 2006).

15 D.R. Easterling, et al., "Climate Extremes: Observations, Modeling, and Impacts," *Science,* Vol. 289, 22 September 2000: 2068-2074.

16 IPCC, *Climate Change 2001: Synthesis Report* (Cambridge: Cambridge University Press, 2001).

17 National Aeronautics and Space Administration (NASA), "NASA Mission Detects Significant Antarctic Ice Mass Loss," http://www.nasa.gov/home/hqnews/2006/mar/HQ_06085_arctic_ice.html (March 8, 2006).

18 E. Rignot and P. Kanagaratnam, "Changes in the Velocity Structure of the Greenland Ice Sheet," *Science,* Vol. 311, no. 5763, 17 February 2006: 986-990.

19 U.S. Global Change Research Program (USGCRP), *Preparing for a Changing Climate: Potential Consequences of Climate Variability and Change – Southeast,* 2001.

[20] Treasure Coast Regional Planning Council, *Sea Level Rise in the Treasure Coast Region* (Submitted to the Southwest Florida Regional Planning Council, December 5, 2005).

[21] C.L. Walker, T.J. Smith, III, K.R.T. Whelan, "Short Term Dynamics of Vegetation Change Across a Mangrove – Marsh Ecotone in the South-west Coastal Everglades: Storms, Sea-level, Fire and Freeze." Poster Presentation, Greater Everglades Ecosystem Restoration Conference, April 23, 2003.

[22] K. Williams, et al., "Sea-Level Rise and Coastal Forest Retreat on the West Coast of Florida, USA," *Ecology,* Vol. 80, No. 6 (Sep., 1999): 2045-2063.

[23] T.W. Doyle, G.F. Girod, and M.A. Brooks, "Chapter 12: Modeling Mangrove Forest Migration Along the Southwest Coast of Florida Under Climate Change," *Integrated Assessment of the Climate Change Impacts on the Gulf Coast Region* (Gulf Coast Climate Change Assessment Council and Louisiana State University, June 2003): 211-221.

[24] V.S. Kennedy, et al., *Coastal and Marine Ecosystems & Global Climate Change* (Arlington, VA: Pew Center on Global Climate Change, August 2002).

[25] F.T. Short and S. Wyllie-Echeverria, "Global Seagrass Declines and Effect of Climate Change," in: C.R.C. Sheppard, ed., *Seas at the Millennium: An Environmental Evaluation, Vol. III* (Amsterdam: Pergamon, Elsevier, 2000): 10-11.

[26] U.S. Environmental Protection Agency (EPA), "Global Warming Impacts: Coastal," http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsFisheriesCoastal.html (July 20, 2005).

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

[28] R.E. Turner, "Chapter 6: Coastal Ecosystems of the Gulf of Mexico and Climate Change," in Z.H. Ning, et al., *Integrated Assessment of the Climate Change Impacts on the Gulf Coast Region* (Gulf Coast Climate Change Assessment Council and Louisiana State University Graphic Services, June 2003): 85-103.

[29] Restore America's Estuaries (RAE), *A National Strategy to Restore Coastal and Estuarine Habitat* (Arlington, VA: RAE, April 2002).

[30] I. Valiela and M.L. Cole, "Comparative Evidence that Salt Marshes and Mangroves May Protect Seagrass Meadows from Land-derived Nitrogen Loads," *Ecosystems,* Vol. 5, No. 1, January 2002: 92-102.

[31] M.W. Beck, et al., "The Role of Nearshore Ecosystems as Fish and Shellfish Nurseries," *Issues in Ecology,* Number 11, Spring 2003.

[32] R.E. Turner, "Chapter 6: Coastal Ecosystems of the Gulf of Mexico and Climate Change," in Z.H. Ning, et al., *Integrated Assessment of the Climate Change Impacts on the Gulf Coast Region* (Gulf Coast Climate Change Assessment Council and Louisiana State University Graphic Services, June 2003): 85-103.

[33] R.A. Park, "Modeling the Impacts of Sea-Level Rise," http://www.oceanservice.noaa.gov/programs/nccos/nos_science/SeaLevelRisePark.pdf (September 19, 2005).

[34] http://www.gulfbase.org/bay/view.php?bid=pensacola (January 24, 2006).

[35] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), pp. 45-51.

[36] *The Economics of Saltwater Fishing in Florida*, David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[37] L. Schwenning, *Seagrass Management Plan for Big Lagoon and Santa Rosa Sound* (Pensacola, FL: Florida Department of Environmental Protection, December 2001).

[38] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), p. 80.

[39] *The Economics of Saltwater Fishing in Florida*, David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[40] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), pp. 218-235.

[41] *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[42] P.J. Rubec and R.H. McMichael, Jr., "Ecosystem Management Relating Habitat to Marine Fisheries in Florida," *GIS Applications for Fisheries and Coastal Resources Management, Gulf States Marine Fisheries Commission,* 1996: 113-145.

[43] Charlotte Harbor National Estuary Program, "The Green Light for Action," http://www.chnep.org/info/ProgramReports/NEP_overview.htm (January 24, 2006).

[44] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), pp. 260-262.

[45] *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[46] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), pp. 288-289.

[47] *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[48] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), p. 330.

[49] *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[50] J.C. Ogden, et al., "The Use of Conceptual Ecological Models to Guide Ecosystem Restoration in South Florida," *Wetlands,* Vol. 25, No. 4, December 2005: 795-8-9.

[51] *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[52] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), p. 306-312.

[53] *The Economics of Saltwater Fishing in Florida*, David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[54] P. Sime, "St. Lucie Estuary and Indian River Lagoon Conceptual Ecological Model," *Wetlands*, Vol. 25, No. 4, December 2005: 898-907.

[55] K. Thoemke, *Fishing Florida* (Guilford, CT: The Globe Pequot Press, 1995), p. 188-192.

[56] *The Economics of Saltwater Fishing in Florida,* David B. Harding, Ph.D., Chief Economist, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, 2005.

[57] P. Sime, "St. Lucie Estuary and Indian River Lagoon Conceptual Ecological Model," *Wetlands,* Vol. 25, No. 4, December 2005: 898-907.

[58] U.S. EPA, *Climate Change and Florida* (EPA-230-F-97-008i).

[59] T.P. Barnett, D.W. Pierce, and R. Schnur, "Detection of Anthropogenic Climate Change in the World's Oceans," *Science* Vol. 292, 13 April 2001: 270-274. Also "Scripps Researchers Find Clear Evidence of Human-Produced Warming in World's Oceans," For Release: February 17, 2005. AAAS Annual Meeting.

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

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

[62] D.F. Boesch, *Summary of Climate Change Assessments: Implications for Estuarine Biocomplexity* (Port Republic, MD: Estuarine Research Federation, March 28, 2002).

[63] P.J. Rubec and R.H. McMichael, Jr., "Ecosystem Management Relating Habitat to Marine Fisheries in Florida," *GIS Applications for Fisheries and Coastal Resources Management, Gulf States Marine Fisheries Commission*, 1996: 113-145.

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

[65] A. Markham, *Trouble in Paradise: The Impacts of Climate Change on Biodiversity and Ecosystems in Florida* (Washington, DC: World Wildlife Fund, July 2001).

[66] R.J. Livingston, "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, December 1989).

[67] Stripers 247, "Florida Striped Bass Fishing," http://www.stripers247.com/floridaplaces.htm (February 1, 2006).

[68] R.W. Buddemeier, J.A. Kleypas, and R.B. Aronson, *Coral reefs & global climate change* (Arlington, VA: Pew Center on Global Climate Change, February 2004).

[69] B.D. Causey, et al., "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, 2005): 101-118.

[70] C. Wilkinson, ed., *Status of Coral Reefs of the World: 2002* (Global Coral Reef Monitoring Network and Australian Institute of Marine Science, 2002, 363 pp).

[71] G.M. Johns, et al., *Socioeconomic Study of Reefs in Southeast Florida. Final Report submitted to Broward County, Palm Beach County, Miami-Dade County, Monroe County, Florida Fish and Wildlife Conservation Commission, and National Oceanic and Atmospheric Administration,* 2001 (revised April 2003).

[72] C.D. Harvell, et al., "Emerging Marine Diseases – Climate Links and Anthropogenic Factors," *Ecology,* Vol. 285, No. 5433, 3 Sept 1999: 1505-1510.

[73] P. Epstein, *Marine ecosystems: emerging diseases as indicators of change* (Boston, MA: Harvard Health Ecological and Economic Dimensions of Global Change Program, 1998).

[74] L.E. Fleming, et al., "Emerging Harmful Algal Blooms and Human Health: Pfiesteria and Related Organisms," Toxicol Pathol. 27(5), Sept-Oct 1999: 573-81.

[75] C.D. Harvell, et al., "Emerging Marine Diseases – Climate Links and Anthropogenic Factors," *Ecology*, Vol. 285, No. 5433, 3 Sept 1999: 1505-1510.

[76] B.D. Causey, et al., "*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, 2005): 101-118.

[77] L. Richardson, "Coral diseases: what is really known?" *Trends in Ecology and Evolution,* Vol. 13, no. 11, 1998: 438-443.

[78] R.T. Barber, "The Coral Response to Climate Change," *Abstract for the U.S. Global Change Research Program Seminar Series, June 22*, 1999.

[79] C.D. Harvell, et al., "Emerging Marine Diseases – Climate Links and Anthropogenic Factors," *Ecology*, Vol. 285, No. 5433, 3 Sept 1999: 1505-1510.

[80] D. Justic, R.E. Turner, N.N. Rabalais, "Impacts of Climate Variability on Coastal Fisheries in Low Oxygen Environments," *National Institute for Global Environmental Change Annual Report* (Davis, CA: University of California, 2001).

[81] Varekamp, J.C., et al. "The Paleo-environmental History of Long Island Sound as Traced by Organic Carbon, Biogenic Silica and Stable Isotope/Trace Element Studies in Sediment Cores," *Proceedings of 6th Biennual Long Island Sound Meeting, Groton, CT, October 2002.* Published 2004, p. 109-113.

[82] A.J. Lowe, et al., "Fish kills in coastal waters: 1980-1989," *NOAA Strategic Environmental Assessments Division Report* (Silver Spring, MD: NOAA, 1991): 69 pp.

[83] K. Emanuel, "Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years," *Nature,* Vol. 436, 4 August 2005: 686-688.

[84] P.J. Webster, et al, "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science,* Vol. 309, 16 September 2005: 1844-1846.

[85] NOAA, "NOAA Reviews Record-Setting 2005 Atlantic Hurricane Season" *NOAA Magazine,* November 29, 2005. http://www.noaanews.noaa.gov/stories2005/s2540.htm (November 29, 2005).

[86] NOAA, "Hurricane Katrina Triggers Fishery Failure and Fishery Resource Disaster in the Gulf of Mexico," *NOAA Magazine,* September 9, 2005. http://www.noaanews.noaa.gov/stories2005/s2501.htm (October 10, 2005).

[87] Louisiana Seagrant, "Louisiana Hurricane Recovery Resources: Fisheries & Seafood." http://www.lasea-grant.org/hurricane/fisheries.htm (December 16, 2005).

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

[89] Ibid.

[90] R.J. Livingston, "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, December 1989).

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

[92] The Florida Solar Energy Center and CPI Consulting, *Florida's Energy Future: Opportunities for Our Economy, Environment and Security,* January 16, 2004.

[93] D. Fluharty, "Evolving Ecosystem Approaches to Management of Fisheries in the USA," *Marine Ecology Prog. Series,* Vol. 300, 2005: 241-296.

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