Florida Biodiversity under a Changing Climate

A White Paper on climate change impacts and needs for Florida

January 2012




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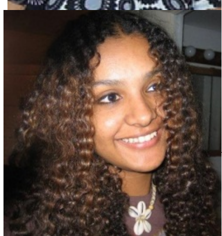

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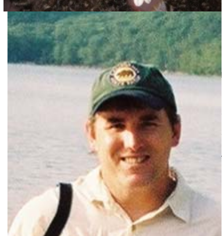

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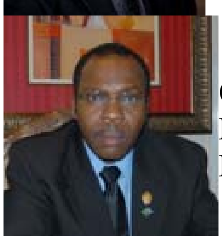

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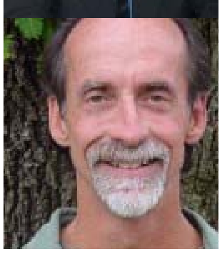

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ABSTRACT

Florida has abundant and unique biological resources that are expected to be negatively affected by global climate change. Florida is at particularly high risk for climate change impacts because of its low topography, extensive coastline, and frequency of large storm events. Climate change is already making large sweeping changes to Florida's landscape, especially along the coasts. The drivers of this change are both physical and biological in nature. Changes in air and water temperature, freshwater availability, salt water intrusion, ocean acidification, natural disturbance regime shifts (e.g., fire, storms, flood), and loss of land area have already been observed in Florida. Florida's average air temperature has increased at a rate of 0.2 - 0.4^0C per century over the past 160 years and is expected to increase around another 5^0C by 2100. Rainfall in Florida has generally increased by 10% over the last 120 years, and more frequent heavy precipitation events are expected in the future. Both globally and in Florida, ocean pH has been lowered 0.1 unit since the pre-industrial period and another 0.3–0.5 pH unit drop is predicted by 2100. Many of Florida's disturbances regimes such as algae blooms, wildfires, hypoxia, storms, droughts and floods, diseases, pest outbreaks are already showing signs of change. Finally, Florida's sea level is currently rising at 1.8-2.4 mm per year and may rise by another meter by 2100.

Florida's biodiversity is already responding to climate change through changes in physiology, distribution, phenology, and extinction risk. Physiological stress is being observed among marine species in reduced rates of calcification, photosynthesis, nitrogen fixation, and reproduction brought on by increased acidity. Northward movement is becoming more common as a result of temperature shifts. Unfortunately, for Florida, species movement brings increased risk for invasions by non-native species, like the Cuban treefrog. Sea turtle nesting and tree flowering dates are starting to shift earlier in time to keep pace with increasing temperatures in Florida. Climate change also brings elevated extinction risks for Florida's numerous endemic species and species of conservation concern.

Maintaining species and ecosystem resiliency is critical to conserving Florida's biodiversity, and we recommend an active adaptive management framework to achieve this goal. The application of adaptive management demands that science take a leading role in management. As we outline here, the major scientific research needs are to improve predictive ecological models and their application; increase focus on general climate change impacts patterns and trends; improve the understanding of disturbance regimes and the interactions of climate drivers; and enhance monitoring programs that link to clear management actions. Resource management can take a leading role, especially in embracing an experimental and flexible approach. Support is also needed for managers to improve data management and infrastructure; embrace and work openly with uncertainity, engage in more climate change related public outreach; and reach out to other management agencies across political and bureaucratic boundaries. Management and science together need to promote the conservation of natural resources; reduce other anthropogenic threats to biodiversity; consider the use of assisted migration and other adaptation strategies; create migration corridors; and promote strategy development that is both creative and experimental.

Fortunately, there are numerous agencies, institutions, and scientists in Florida who can facilitate both improved scientific research and management of climate change impacts on biodiversity. Federal programs such as the White House's Interagency Climate Change Adaptation Task Force and the Department of Interior's Landscape Conservation Cooperatives are being implemented to enable holistic adaptive management across state borders. Within

Florida, The Fish and Wildlife Commission, Water Management Districts, and Florida Oceans and Coastal Council should continue to work across county and habitat borders with Florida research scientists and non-profit organizations to promote active adaptive management approaches to protecting biodiversity.

Numerous direct economic benefits are associated with conserving Florida's natural resources, such as tourism, recreation, and fisheries. In addition, Florida's biodiversity and natural systems provide significant ecosystem services that benefit all the citizens of Florida. To develop effective active adaptive management in Florida, several administrative challenges need to be addressed such as current interpretation of legislation, lack of funds, stakeholder conflict, self-serving behavior, and the pace of change. "The challenge to researchers is to shift their focus from discovery to the science of implementation, while managers and policy-makers must depart from their socio-political norms and institutional frameworks to embrace new thinking and effectively utilize the wealth of powerful new scientific tools for learning by doing" (Keith and others 2011). Structured and transparent decision making can unveil options for science and management to effectively address Florida's biodiversity conservation in the face of climate change. The preservation of Florida's rich biodiversity is critical to maintaining the unique and unparalleled natural beauty of the state and the ecosystem services provided by these natural systems to the citizens of Florida.

EXECUTIVE SUMMARY

This summary sets out the key findings in the white paper titled *Florida Biodiversity under a Changing Climate* and was written by the Florida State University System Taskforce on Climate Change. This report describes the current scientific understanding of the impacts of climate changes on the natural systems of Florida. The statements in this summary are based on the chapters in the white paper and principal sources are given at the end of each paragraph here.

The challenge of preserving Florida's unique and rich biodiversity in the face of climate change is immense. Climate change is already making large sweeping changes to Florida's landscape, especially along the coast. Traditional place-based conservation measures that set aside land to preserve a suite of species in a static state is not sufficient to preserve biodiversity in the face of climate change. Effective management to preserve the aesthetics and functions of Florida's natural systems can be enhanced through adaptive management strategies designed to keep pace with the changing climate and needs of Florida's biodiversity. [Chapter 1]

Biodiversity is described by the United Nation's Convention on Biological Diversity as the variety of life on Earth and the natural patterns it forms. Biodiversity is exhibited over a range of levels of organization from cells to landscapes. The maintenance of all levels of biodiversity is critical to protecting current and future biodiversity in Florida. Florida's biodiversity results from the unique geographical position, climate, and geology of the region. The Florida Natural Areas Inventory identifies eighty-one natural communities, defined by distinct and recurring assemblage of populations of plants, animals, fungi and microorganisms naturally associated with each other and their physical environment. Florida hosts an impressive array of species making it a biodiversity hot spot in the U.S. There are an estimated 700 terrestrial vertebrate species and over 30,000 invertebrates in Florida. In addition, there are a large number of plant and animal species that are found nowhere else: 295 endemic plants, 147 endemic vertebrates, and 410 endemic invertebrates. Unfortunately, Florida also stands out in the high number of ecological communities and species at risk of decline and extinction, with 131 species designated as listed as threatened or endangered by the Florida Fish and Wildlife Commission. Biodiversity loss has been attributed to habitat degradation, fragmentation, destruction, overexploitation, and invasive species introduction. In addition to habitat loss and transformation, anthropogenic climate change is also a major threat to biodiversity, perhaps even more threatening to biodiversity than other factors. Global estimates of future extinctions as a result of climate change range from 10 to 37 percent of all species.[Chapter 1]

Climate change is caused by the over abundance of human-generated greenhouse gases in the atmosphere, primarily carbon dioxide. Carbon dioxide emissions grew by 80 percent between 1970 and 2004, and as of July 2011 the global atmospheric concentration of carbon dioxide was 392.39 ppm. Atmospheric carbon dioxide is expected to continue to increase as a rate of one percent per year for at least the next few decades. Increased greenhouse gases in the atmosphere cause a cascade of abiotic (physical) changes that influence biodiversity on earth. Changes in air and water temperature, freshwater availability, salt water intrusion, ocean acidification, natural disturbance regime shifts (including fire, storms, flood), and loss of land area, have been observed in Florida and elsewhere. The Florida Fish and Wildlife Commission has identified changes in precipitation, ocean acidification, increased air and water temperatures, and sea level rise as major drivers of change and risk to Florida ecosystems and species. While many of these drivers of environmental change are not new, the rates and trajectories of change are considered unprecedented at least over the last 10,000 years. The physical changes in natural systems will lead to changes in the biotic or ecological drivers of biodiversity. Biogenic disturbances originate from biological systems and include the impacts of herbivorous insects, mammals, and pathogens, many of which are responsive to climate changes. In Florida, diseases of coral reef communities have been increasing in recent years in association with higher water temperature. Higher water temperature also increases marine diseases and algal blooms that are also negatively affecting marine fish. Southern pine beetle outbreaks are a concern in Florida's forests and climate change may increase damage by up to 4 to 7 times current mortality rates.[Chapter 1.1.1]

Human land and natural resource use are responsible for the vast majority of threats to biodiversity in Florida and globally, therefore, the reaction of humans to climate change will have much influence on natural ecosystems. The resiliency of many natural ecosystems to climate changes has already been compromised by human land/natural resource use. Land use, pollution, habitat fragmentation, and overexploitation of resources are all expected to change with a warming climate. For example, increased variability in precipitation along with hotter weather is expected to increase human demand on freshwater reserves leading to less water availability for natural systems. In Florida, this problem will be magnified by salt water intrusion from rising sea levels and increased diversion for agriculture. Any changes in agricultural practices in Florida as a result of climate change will have large impacts on freshwater availability to natural systems. Water shortages are widely predicted for agricultural areas across Florida, putting natural systems in these regions at risk for water shortage. [Chapter 1.1.1]

The response of biodiversity to the various physical drivers of climate change is the subject of a prodigious amount of scientific research. Well over 15,000 scientific papers have been published on the topic of climate change and biodiversity. The literature shows that species responses can be broadly categorized into changes in physiology, distribution, phenology, adaptation, and extinction. [Chapter 1.1.2]

All flora and fauna live within their own unique set of physical constraints dictated by the abiotic environment. Temperature is an important component of the physical environment. Increased temperatures challenge the performance of organisms by negatively affecting growth, reproduction, foraging, susceptibility to disease, behaviors and competitiveness. Physical stress is not limited to temperature. Shifts in carbon dioxide concentration, disease, hypoxia, eutrophication, salinity levels, ocean acidification and precipitation also directly affect metabolism and development in animals and plants. Under warming temperatures, over 1,000 species have been documented to be moving towards the poles at an average rate of 6.1 km per decade. Other changes in the environment, such as changes in rainfall and seasonality will also induce movement. These shifts will lead to changes in species home ranges, distributions, migration routes, and species invasions. The frequency and magnitude of these changes depend on how important the species-specific climate niche is to the persistence of species and that individuals within a species can identify changes and move appropriately. [Chapter 1.1.2]

Because species distributions are rapidly shifting under climate change, non-native species invasions will likely increase. Successful invaders often outcompete native species and reduce biodiversity. This negative influence will be magnified by the weakened state of many native species as they are stressed by climatic changes. In Florida, hundreds of invasive species from plants, reptiles, amphibians, birds, insects, fish and other aquatic species have become established in Florida. These species cause widespread damage to Florida's native biodiversity through direct habitat modification, competition, spreading of disease, hybridization, predation, and other mechanisms. As many species distributions shift with climate change, the difference between "native" and "invasive" will be blurred. Range shifts in native species could become problematic species invasions, necessitating management action for the preservation of biodiversity and ecosystem function. It will become more difficult to determine which species require management intervention and which are welcome changes. [Chapter 1.1.2]

Changing patterns in climate are altering environmental cues that many species use to determine the timing of life cycle events. Across thousands of species, there has been a documented advance of the start date of springtime wildlife activities by 2.3 days per decade. Examples are plentiful: the timing of vegetation development, spawning date in frogs and toads, return date of migrant butterflies, and egg hatching date in insects. Unfortunately, phenological (timing) changes often cause a mismatch in important ecological interactions, such as predator-prey relationships, pollination, and competition. [Chapter 1.1.2]

Species may also evolve *in situ* in response to environmental changes. Evolution is observed when a change in an individual, such as shifts in timing or temperature tolerance increases their survival and reproduction and can be inherited by the next generation. It is uncertain as to how many of today's species will have the ability to respond to climate change via evolution and some scientists speculate that it will be a minority. Species with short generation times, large populations, and rapid population growth rates relative to climate change rates may have better chances for evolutionary adaptation. Climate change induced micro-evolution has been observed through changes in color patterns in owls, body sizes in lizards, and phenological changes in mosquitoes, squirrels and birds. [Chapter 1.1.2]

Roughly a million species are thought to be at risk of extinction due to climate change. Because they are already in decline, species of current conservation concern are among the most imperiled by climate change. There are a number of characteristics that elevate extinction risk from climate change: ecothermic or "cold-blooded" species, species with small ranges, tropical species, species with small populations, island species, species that live in extreme environments, marine species that use calcium carbonate, endemic species, coastal lowland species, and species with slow life history traits. Because of the high number of endemic species and species of conservation concern, in combination with climate change threats, Florida is considered to have a very high number of species at risk of extinction from climate change. These species include elkhorn coral, marine sea turtles, Key tree cactus, Key deer, Lower Keys marsh rabbit, Florida panther, Florida manatee, gopher tortoise, and a wide array of coastal species. In addition, many Florida species concentrate in coastal habitats that are at high risk from rising sea levels. [Chapter 1.1.2]

The drivers of biodiversity loss do not act in isolation and multiple factors often interact to magnify impacts. These interactions are likely to have large negative impacts on biodiversity. For example, sea level rise may result in human migration away from Florida's heavily populated coastlines which would result in significant inland habitat loss and fragmentation further reducing the ability of native species to adapt to climate changes. [Chapter 1.1.3]

Although advances have been made, much uncertainty surrounds scientific models of complex ecological systems, especially under a rapidly changing climate and under various human policy interventions. Our best way forward into this unknown future may be in the modification of ecosystem management. Ecosystem management, formally in use since the 1980's, is a useful technique for managing dynamic systems while incorporating the socioeconomic, political and cultural needs of humans. Applying ecosystem management to climate change will require stricter practice and modernization to preservation of ecosystem processes and resiliency. Ecosystem management is not prescriptive in terms of the specific management actions, but is rather a framework for how to approach the integration of science, societal values, and natural resource management in a dynamic and flexible manner. Scientific research and resource management are intimately connected in ecosystem management through an iterative process of optimal decision making, called adaptive management. [Chapter 2]

Adaptive management is an approach to natural resource management that emphasizes learning through management based on the philosophy that knowledge is incomplete. Ecological systems are incredibly complex, filled with interactions, feedbacks and synergistic properties that are difficult to discern, resulting in much scientific uncertainty. Adaptive management is a method for navigating what is known, as well as what is unknown in a learning framework to best inform and update management actions. It is not a panacea and tends to work best when real action-based management can be applied. In the case of climate change, the identification of what problems are controllable via management are not always clear and this framework provides a method for making that determination. The ultimate goal of adaptive management is to meet environmental, social and economic goals, increase scientific knowledge, and reduce tension among stakeholders. These goals are very much aligned with managing Florida's biodiversity resources under climate change. [Chapter 2]

Active adaptive management begins with the conceptualization of a problem, in this case the threats to biodiversity stemming from climate change. The second step is devising an action plan, ideally outlining several management options with clearly defined goals and measurements of success. Several actions can be carried out at once to more quickly identify the best method for achieving goals. Clearly defining a monitoring plan aimed at evaluating the influence of actions is a critical component of step two. The implementation and monitoring of action is step three. Management can only be deemed a success or failure by carefully monitoring the changes brought about due to management interventions. Step four is a careful analysis of the monitoring data, followed by evaluation of results to redesign management actions for improved or further success. The final step is to document learning and share information so that progress can be achieved. This step should feed back into the first and thus, continue the iterative process of managing biodiversity.[Chapter 2]

The application of active adaptive management to biodiversity conservation under climate change demands that science take a leading and direct role in management. Scientific research is a source for generating management strategies and measurements of success. Research needs to focus on several issues to improve application to biodiversity conservation under climate change.The first need for science in addressing climate change is accurate climate models, built at a variety of spatial and temporal scales appropriate for assessment impacts on biodiversity in Florida. In addition, land cover maps, high precision elevation data (LiDAR) and hydrology models need to be updated. [Chapter 2.1]

The measurement and predictions of biodiversity impacts from climate change are very active fields of science. The methods of evaluation are rapidly evolving and constantly improving. Major areas for continued improvement include the further development of ecological models, especially species distribution and species interaction models; increased focus of general patterns and trends in climate change impacts on biodiversity; increased understanding of the changes in disturbance regimes under climate change; increased understanding regarding the interaction of climate change drivers; and improved efficiency and accessibility of monitoring data. [Chapter 2.1]

Active adaptive management is widely recommended for addressing the management of biodiversity in the face of global climate change in Florida. One of the greatest challenges to the application of active adaptive management is that it calls for managers to become more experimental and flexible. The pace of management can be improved with access to data and importantly, scientific interpretations of data for management needs. Management can also be improved through taking action in spite of uncertainty and managing for dynamic systems within the adaptive management framework. Other management improvements include improving public outreach and stakeholder engagement. [Chapter 2.2]

Within Florida there are several strategies for promoting biodiversity in the face of global climate change that should be considered. Many of the strategies focus on managing for expected changes in species distributions. Strategy development should reach beyond these spatial considerations and include species interaction and temporal needs. The strategies outlined here are not meant to serve as an exhaustive list, but as a baseline for early intervention. [Chapter 2.2]

- Protection of high quality habitat
- Increasing species migration corridors
- Assisted migration
- Reduce other anthropogenic threats

The box below details several specific state policies for Florida that we recommend to preserve biodiversity and provide resilience in the face of climate change.

State policy proposals for promoting biodiversity

1) Permanently establish the Florida Forever Program through constitutional amendment with a dedicated revenue source;
2) Extend and expand support for the Century Commission's Critical Lands/Waters Identification Project, the Florida Natural Area Inventory, and the Cooperative Conservation Blueprint;
3) Develop a comprehensive research and practitioner training program in climate change adaptive management;
4) Develop a climate protection and adaptation strategy for the Florida Keys;
5) Expand and permanently fund the Florida Coastal Ocean Observing System, and the Florida Oceans and Coastal Resources Council;
6) Establish a cap-and-trade policy;
7) Reassess Florida's beach management strategies, including devising a plan for relocating some beach developments, where retreat is the optimal choice.

Adapted from: Center for Urban and Environmental Solutions 2008

Numerous direct economic benefits are associated with conserving Florida's natural resources, such as tourism, recreation, and fisheries. Florida's tourism industry contributes approximately $65 billion annually to the economy and natural resources are one of the major attractions for visitors. Recreational activities such as hiking and nature viewing provide approximately $1 billion annually through the Florida State Park System. In a given year, Florida's fishing industry supports more than 500,000 jobs, $12.7 billion in wages, and $3.1billion towards Florida income.[Chapter 3]

Florida's coast provides approximately $11 billion annually in coastal protection from storms, with coastal wetlands serving as "horizontal levees" against hurricanes. Mangrove forests block wave action via their trunk and root systems during storm surges. In South Florida, the Everglades function as a major carbon sink, offsetting CO_2 atmospheric emissions, and are a major freshwater source for the state. Climate change is anticipated to reduce or eliminate some of these ecosystem services resulting in a net negative effect. Implementing strategies to mitigate impacts on Florida's ecosystems is recommended to reduce biodiversity loss, as well as maintain vital ecosystem services and economic benefits for Florida's citizens. As previously mentioned, adaptive management can be a cost effective way to reduce the negative impacts of climate change on Florida's natural systems.[Chapter 3]

Maintaining ecosystem resiliency is critical to ensure that Florida's biodiversity is able to cope with the inevitable changes associated with global climate change. Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Managing for resiliency in a changing climate does not necessarily imply that the current state or even the historic natural range of variability should be the end goal. Challenges to biodiversity preservation in the face of climate change include current interpretation of legislation, lack of funds, stakeholder conflict, self-serving behavior, and the pace of change. A holistic and integrated approach can unlock these options for science and management to effectively address Florida's biodiversity conservation in the face of climate change to maintain ecological processes and function that are critical to preserving biodiversity and the human systems that depend upon it. [Chapters 4,5]

Florida species at risk of extinction due to climate change. (clockwise from upper left: leatherback sea turtle, mangrove cuckoo, elkhorn coral, Florida panther, and in the center: manatee.)

CHAPTER 1
1. Introduction

Biodiversity is described by the United Nation's Convention on Biological Diversity as "the variety of life on Earth and the natural patterns it forms." Biodiversity is often defined in terms of the number and richness of species in a given place (Franklin 1993); however, this is a narrow view of the diversity of life and the mechanisms by which it is created and maintained. More holistically, biodiversity is categorized into a hierarchy stemming from three elements that interact to create all of the variety of life on earth (Figure 1.0-1).

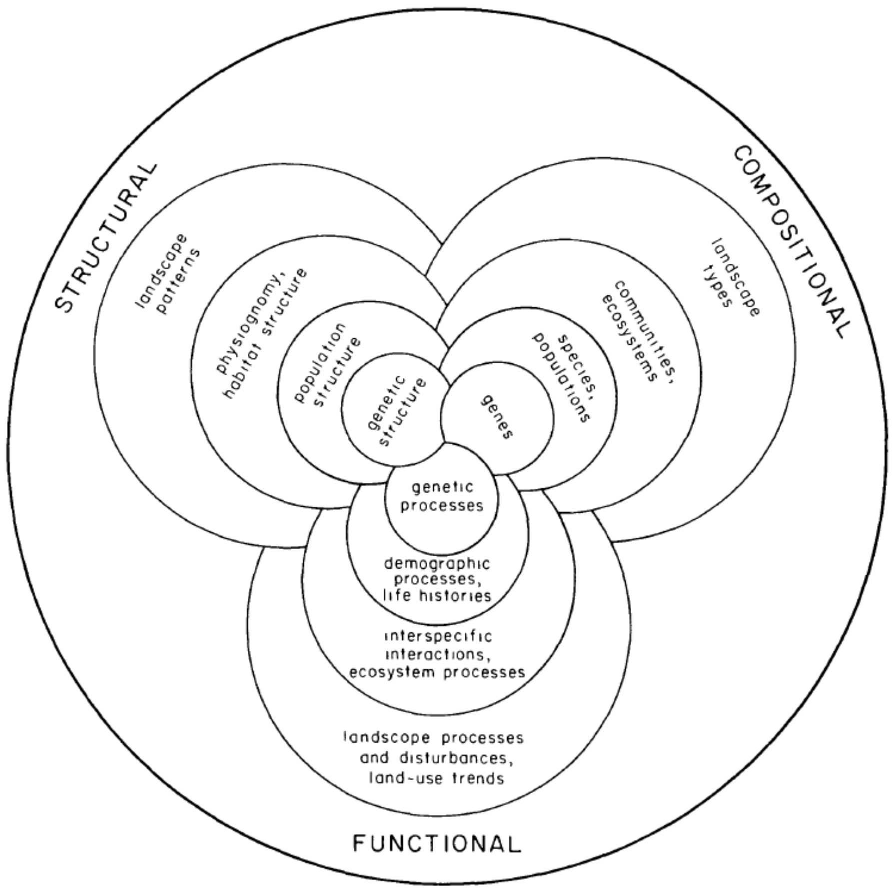


Figure 1.0-1. The hierarchy of biodiversity. From Noss (1990)

These three elements are composition, structure, and function. Within this hierarchy biodiversity is exhibited over a range of levels of organization from cells to landscapes. The maintenance of all the levels of biodiversity is critical to protecting current and future biodiversity in Florida and elsewhere (Noss and Harris 1986, Noss 1990, Salwasser 1990).

Florida's biodiversity results from the unique geographical position, climate, and geology of the region (Figure 1.0-2).

Figure 1.0-2. The Florida peninsula as seen from space From NASA.

Florida's land area is roughly 50,000 square miles, with over 1,000 miles of Atlantic Ocean and Gulf of Mexico coastline (FHSMV 2000). The climate of this long peninsula stretches from temperate in the north to tropical in the south. Climatically driven disturbances that shape Florida's biodiversity include wildfires and hurricanes. Many wildfires are ignited by lightning strikes, not surprising given that there are more lightning strikes per square mile compared to any other state (Whitney and others 2004). Pine woodlands and savannas are particularly flammable, though fires burn across a variety of habitats including swamps and marshes. In a typical year (1981-2010) 3,100 fires and 76,000 acres burn from January through June (FFS 2011). Hurricanes and tropical storms also cause widespread disturbances through coastal flooding, heavy rain and high winds. More hurricanes hit Florida than any other state, most occurring from August to October (NWS 2011). Thunderstorms are also very common in Florida, especially in the hot and humid summer months. Because Florida is surrounded by water, including the humid Gulf of Mexico, a lot of precipitation (annual average: 53 inches) is received despite its latitudinal position which is usually associated with dry conditions (Whitney and others 2004). Rainfall is more consistent during the summer months in South Florida and is more even year-round in the northern part of the state. The northern portion of the state is also subject to freezes in the winter, which are rare in the south.

There are several notable hydrological features that contribute to Florida’s high biodiversity: Lake Okeechobee which is the second largest fresh water lake wholly within the United States; a vast fresh water spring system with over 200 springs; and over 10,000 miles of streams and rivers (FHSMV 2000). The Everglades, originating at Lake Okeechobee is a slow moving river that creates the largest sawgrass marsh in the world, covering 5,000 square miles and the majority of the southern tip of the state (FHSMV 2000).

Florida is a flat plateau, with much of the land barely above sea level and the highest point at 345 feet, located in the Florida Panhandle (FHSMV 2000). Three topographic zones radiate out from the center of the state to the coasts. Furthest inland are the highlands, ridges, and upland plains, which cover the highest ground in Florida and are dominated by clay and sand deposits. The lowlands are found at intermediate elevations located between the highlands and the coastal zone and are characterized by a variety of flatwoods and coastal wetlands. The coastal zone is composed of diverse estuaries from salt marshes in the north to lagoons and mangroves further south. The coastal zone also includes a large number of low-lying islands, the most significant being the Florida Keys. Florida is ranked second in the U.S. in the number of islands over 10 acres in size (FHSMV 2000).

The number of ecological communities delineated in Florida varies depending on the classification system employed. The Florida Natural Areas Inventory identifies eighty-one natural communities , defined by " distinct and recurring assemblage of populations of plants, animals, fungi and microorganisms naturally associated with each other and their physical environment " (FNAI 2010).

Four widely used land cover classification systems for the state of Florida. Classification systems vary in large part due to spatial scales examined, which is dictated by the intended use.

Florida Natural Areas Inventory (FNAI) : The 2010 FNAI classification recognizes 81 distinct natural community types, which are characterized by landform, substrate, soil moisture condition, climate, fire, and characteristic vegetation. Used widely, including the Florida Department of Environmental Protection and The Nature Conservancy

Florida Land Use, Cover, and Forms Classification System (FLUCCS): a general purpose mapping system, devised by the Florida Department of Transportation, that includes both natural and altered categories that are distinguishable on aerial photographs. This system is used by the Florida Water Management Districts.

Florida Cooperative Land Cover map: a hierarchical classification consisting of more than 200 classes that integrates the FNAI system with FLUCCS. Produced by the Florida Fish and Wildlife Conservation Commission and FNAI.

U. S. National Vegetation Classification (USNVC): developed by The Nature Conservancy (maintained by NatureServe) for conservation purposes and continuously updated, uses dominant plant species to define its finest units, called "associations", of which it has recognized over 350 in Florida. This system is used in the Southeast GAP analysis sponsored by the Biological Resources Division of the United States Geological Survey.

Florida hosts an impressive array of species making it a biodiversity hot spot in the U.S. (Ewel 1990, Noss and Peters 1995). There are an estimated 700 vertebrate species and over 30,000 invertebrates in Florida (FNAI 2010). Among plants, the state holds the largest diversity of plant families in the U.S. and has 2,840 native plant species. The Florida Panhandle has been singled out as "one of the richest hotspots of biodiversity in North America" (Stein and others 2000, Pearlstine and others 2002, Blaustein 2008). In addition, there are a large number of plants and wildlife species that are found nowhere else: 295 endemic plants, 147 endemic vertebrates, and 410 endemic invertebrates (FNAI 2010, FWC 2011). Two areas of higher elevation, Lake Wales Ridge in the central part of the state and Pine Rocklands in south Florida have particularly high levels of endemism.

Unfortunately, Florida also stands out in the high number of ecological communities and species at risk of decline and loss (Figure 1.0-3).

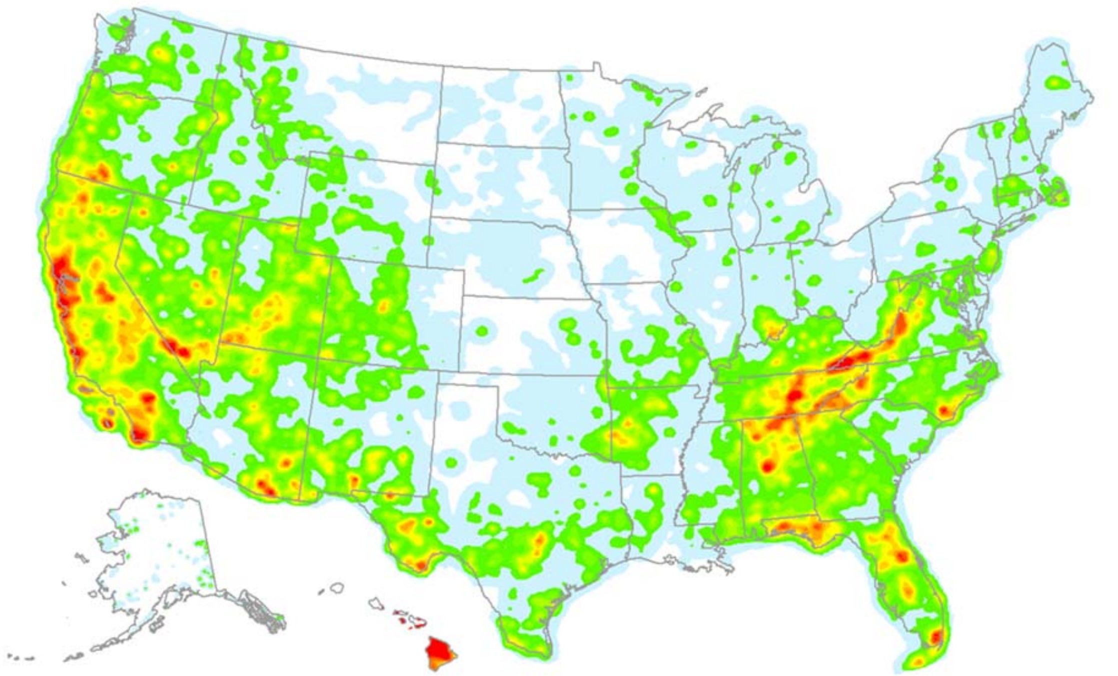


Figure 1.0-3. Hotspots of rarity-weighted richness for globally critically imperiled and imperiled species in the United States. From NatureServe (2008).

Florida is number one in the U.S. for risk of ecosystem loss (FWC 2011). South Florida contains most of the ecosystems at high risk, though others are found throughout the state (FWC 2011). The Florida Fish and Wildlife Commission have identified several habitats of the greatest conservation concern (FWC 2011). These threatened habitats include eight terrestrial, three freshwater, and nine marine habitat types (see Section 1.8 for list). Many Florida species are also at risk of decline or loss with 131 species designated as listed as threatened or endangered by the Florida Fish and Wildlife Commission (see Section 1.8 for list; FWC 2011). These species include 67 animals that are also listed under the federal Endangered Species Act.

Biodiversity loss has been attributed to habitat degradation, fragmentation, destruction, overexploitation, and invasive species (Wilcove and others 2000). Globally, current extinction rates are 1,000 times the expected natural rate of species extinction (Secretariat of the Convention on Biological Diversity 2010). In addition to habitat loss and transformation, anthropogenic climate change is also a major threat to biodiversity (Parmesan and Yohe 2003, Williams and others 2003, Feehan and others 2009, Ross and others 2009, Beever and others 2011), perhaps even more threatening to biodiversity than other factors (Pimm 2008). Global estimates of future extinctions as a result of climate change range from 10 to 37 percent of all species (Thomas and others 2004, Maclean and Wilson 2011). Unfortunately, the threat from climate change is expected to increase with time (Thomas and others 2004, Parry and others 2007, Heller and Zavaleta 2009, Beaumont and others 2011, Wiens and others 2011). In addition, climate changes are negatively affecting ecosystems already stressed by other anthropogenic impacts, which may lead to unprecedented negative changes (Beaumont and others 2011). Our ability to conserve biodiversity depends upon the ability of individual species and ecosystems to adapt to current and future threats, the extent to which future climate regimes differ from today, and the resilience of ecosystems to perturbations (Beaumont and others 2011).

> "The current rate and magnitude of climate change are faster and more severe than many species have experienced in their evolutionary history...putting them at risk of extinction"- Anthony Barnosky, quoted in The New York Times, April 4, 2011, Article by Carl Zimmer.

The challenge of managing biodiversity in the face of climate change is immense. Climate change is already making large sweeping changes to Florida's landscape, especially along the coast (Noss 2011). The reliance on traditional place-based conservation measures that sets aside land to preserve a suit of species in a static state is not sufficient to preserve biodiversity in the face of climate change (Harris and Cropper 1992, Grumbine 1994, Harris and others 1996, Hagerman and others 2010, Wiens and others 2011). Florida has the largest public land acquisition program of its kind in the United States, with approximately 9.9 million acres of conservation land in Florida (DEP 2011). However, stable static states do not exist under a rapidly changing climate. For example, at Withlacoochee Gulf Preserve in Yankeetown, Florida sea level rise is converting forest to marsh. This conversion completely changes the suite of biodiversity within the preserve. Even in the Everglades, the largest roadless area in the United States, where habitat types have lots of room to move around; sea level rise is also expected to change ecosystems in this park dramatically. A sea level rises of 23 inches, could submerge the park’s pinelands, one of the rarest ecosystems in South Florida (Kimball 2007). Rapid changes like these are being observed throughout Florida's protected lands and are expected to increase over time. Rapid impacts due to climate change require management strategies that will be able to keep pace with the changing state of Florida's biodiversity.

Case Study - Coastal forest retreat at Withlacoochee Gulf Preserve

Photo: Jennifer Seavey

This photograph shows coastal forest retreat under sea level rise at Withlacoochee Gulf Preserve in Yankeetown, FL. Hammock vegetation dies off as salt water intrudes into fresh water. The dying forest fragments are the last representatives of what was a diverse forested island, filled with numerous tree species and a rich understory of herbaceous plants. The conversion of forest to salt marsh under rising sea levels is exacerbated by storms and reductions in freshwater supply due to inland development and drought cycles.

Hydric hammock is estimated to be retreating from the Gulf coast at a rate of 7 m per year over the last 100 years. At this rate, it will migrate out of the Preserve's boundaries in about 20 years. Preserves and parks along all of Florida's coasts face the same problem: the very habitats they are trying to protect are moving right out from under their protection.

More information about this case study:
Williams K and others. 2000. Interactions of Storm, Drought, and Sea-Level Rise on Coastal Forest: A Case Study. Journal of Coastal Research 19(4): 1116-1121.

1.1. Supporting Science

Anthropogenic climate change is caused by the over abundance of human-generated greenhouse gases in the atmosphere, primarily carbon dioxide (Solomon and others 2007, Hansen and Sato 2011). Carbon dioxide emissions grew by 80 percent between 1970 and 2004 (Solomon and others 2007), and as of July 2011 the global atmospheric concentration of carbon dioxide was 392.39 ppm (Tans 2011). This level of carbon dioxide is at least over 30% higher than the natural range over the last 650,000 years (Siegenthaler and others 2005). Atmospheric carbon dioxide is expected to continue to increase at a rate of one percent per year for at least the next few decades (Solomon and others 2007), bringing with it a suite of changes in the global climate system.

1.1.1. Drivers of Change

Increased greenhouse gases in the atmosphere cause a cascade of abiotic (physical) changes that influence biodiversity on earth (Figure 1.1-1).

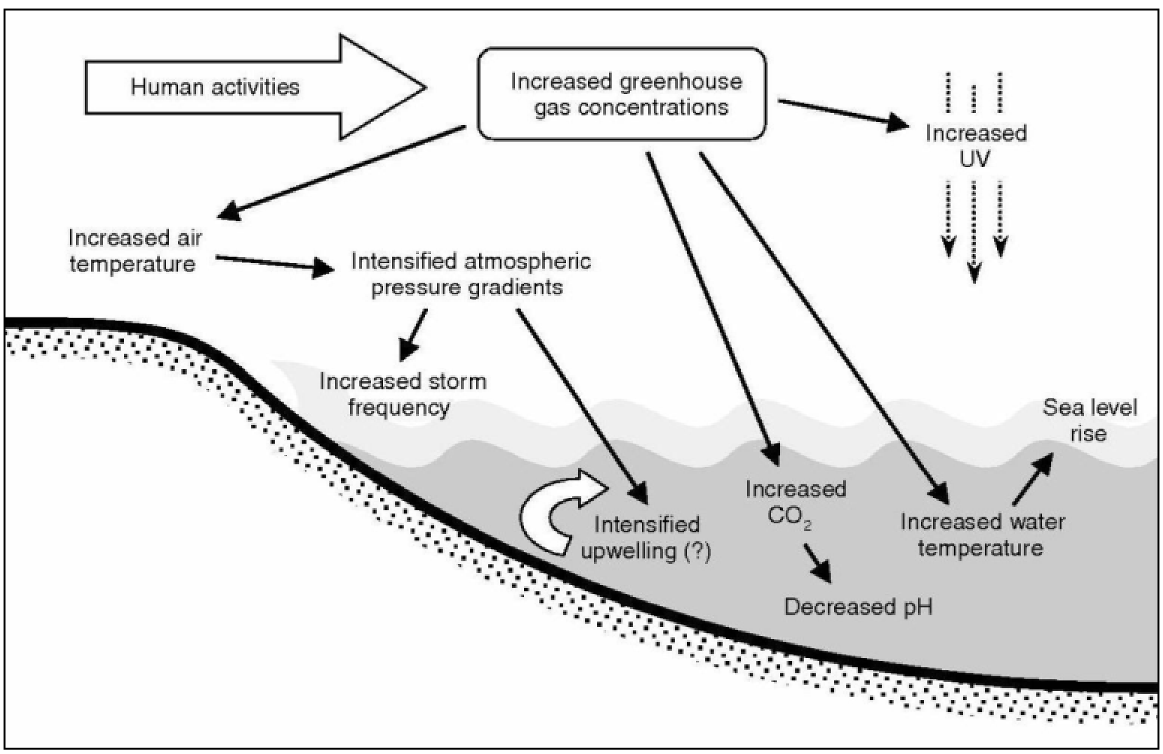


Figure 1.1-1. Abiotic changes associated with climate change in marine systems. From Harley and others (2006).

Changes in air and water temperature, freshwater availability, salt water intrusion, ocean acidification, natural disturbance regime shifts (fire, storms, flood, etc.), and loss of land area, have been observed in Florida and elsewhere. The Florida Fish and Wildlife Commission (FWC) has identified changes in precipitation, ocean acidification, increased air and water temperatures, and sea level rise as major drivers of change and risk to Florida ecosystems and species (FWC 2011). While many of these drivers of environmental change are not new, the rates and trajectories of change are considered unprecedented at least over the last 10,000 years (Smith and others 1999, Parry and others 2007, Solomon and others 2007, Murphy and others 2010, Barnosky and others 2011, Beever and others 2011).

Temperature

Air and water temperatures have increased globally (Figure 1.1-2).

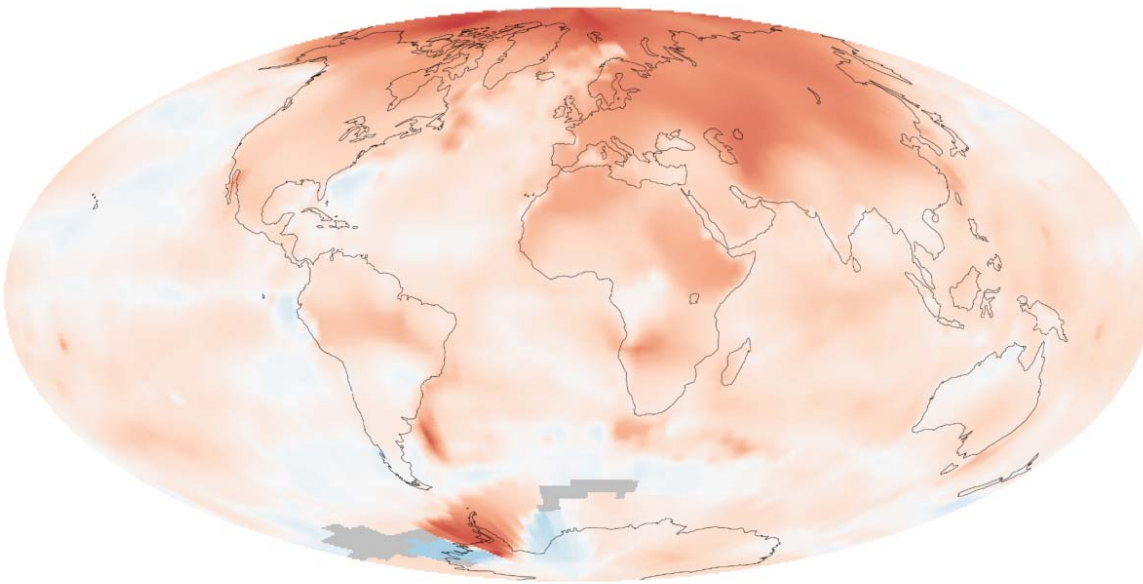


Figure 1.1-2. The map illustrates temperature anomalies in the decade (2000-2009) compared to average temperatures recorded between 1951 and 1980 (a common reference period for climate studies). The most extreme warming, shown in red, cooler than average temperatures in blue, gray areas are places where temperatures were not recorded. From Voiland (2010).

Over the last century, air temperature has increased by 0.74 °C (1.33 °F) (Solomon and others 2007) (Figure 1.1.-3) and is expected to rise another 3.8 to 6.1°C (7 to 11°F) by 2100 (Karl and others 2009).

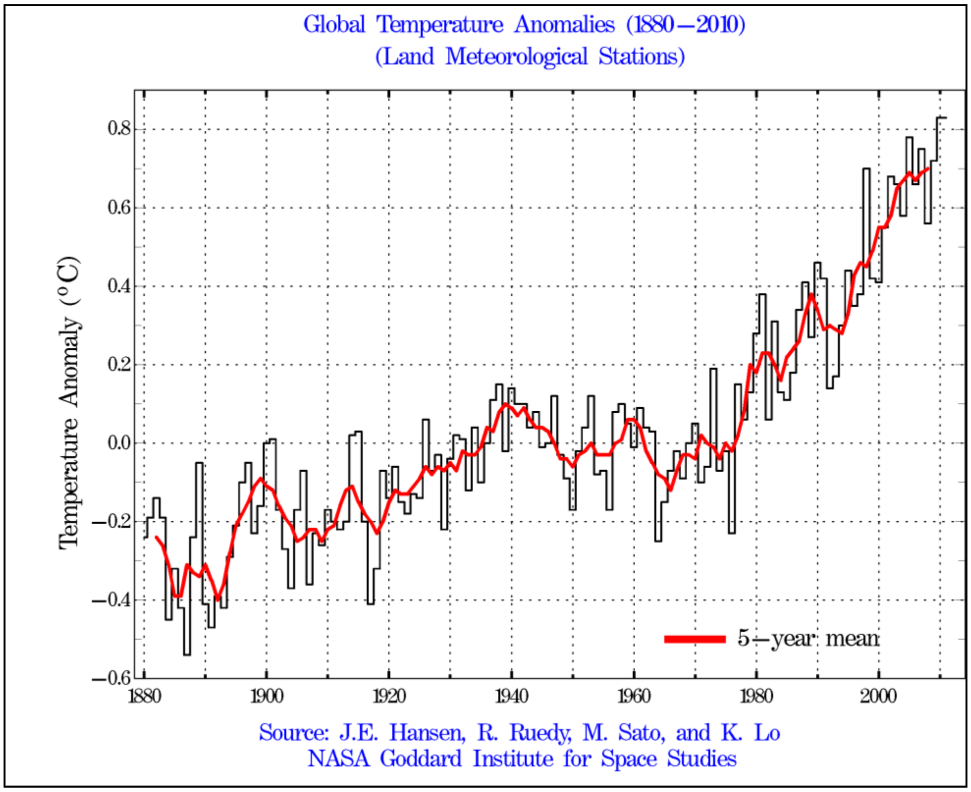


Figure 1.1-3. Global temperature anomalies since 1880 through 2010. From Hansen and others (2011).

This pace of global temperature change is twenty times faster than rates over the past two million years on earth (Riebeek 2010). Recent examination of ocean sediment data (Figure 1.1-4)

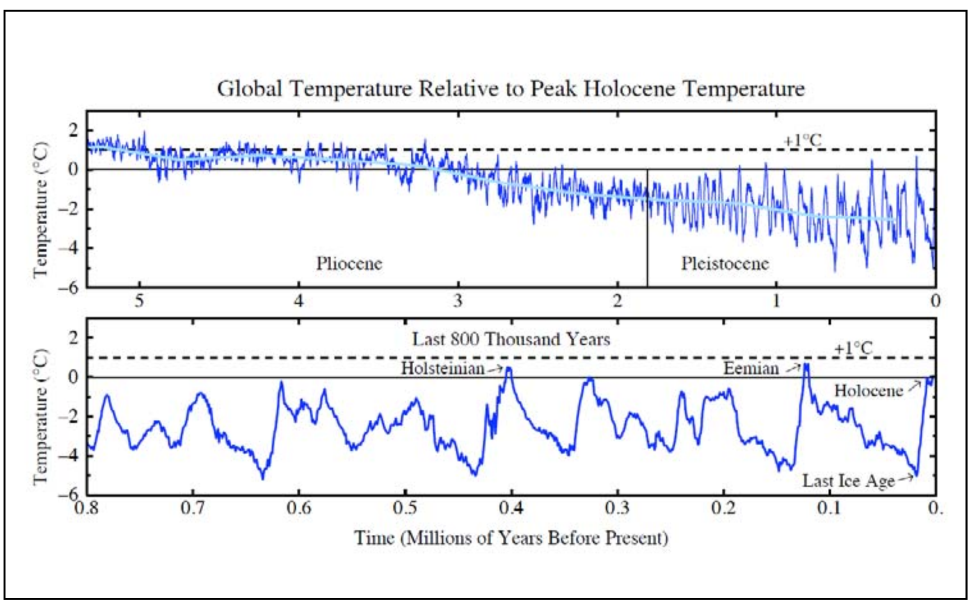


Figure 1.1-4. global surface temperature for the past 5.3 million years as inferred from cores of ocean sediments taken all around the global ocean (From: Hansen and Sato 2011).

reveals that a 1^0C increase in temperature will put global temperatures just above the temperature range of the Eemian period, which is the time when human civilization developed on earth (Hansen and Sato 2011).

In Florida, the average temperature has increased at a rate of 0.2 - 1.4^0C per century over the past 160 years of data collection; this increase is not uniform across the state and therefore the trends are not consistently statistically significant (Soule 2005, Maul and Sims 2007, Shearman and Lentz 2010). Future predictions include steady temperature increase across the state (Figure 1.1-5)

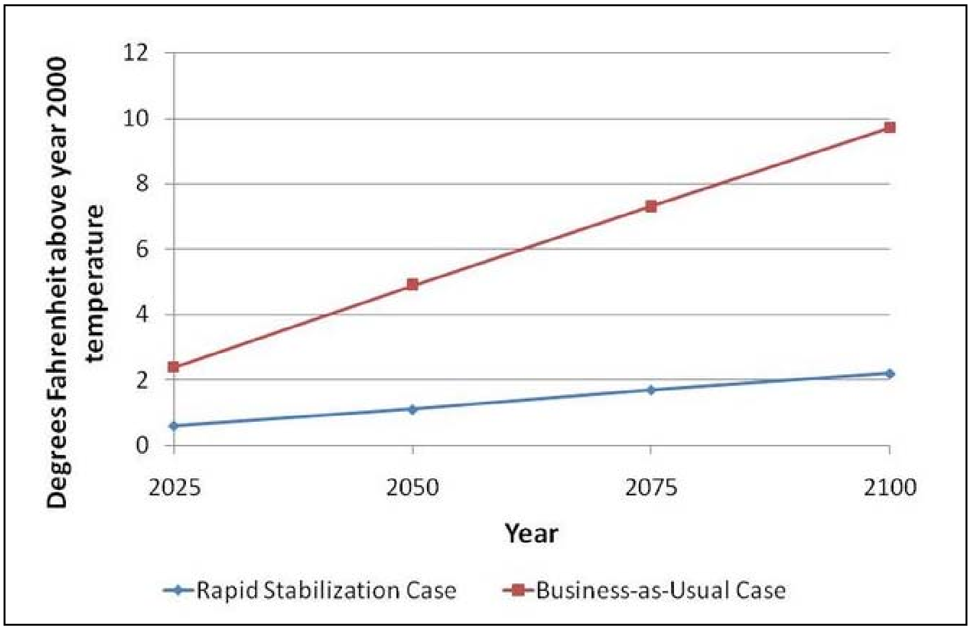


Figure 1.1-5 Predicted annual average temperature (Fahrenheit) for two future climate scenarios for Florida. From Stanton and Ackerman (2007).

<u>Precipitation</u>

Increased air and water temperatures influence global precipitation patterns. In the U.S., the average precipitation has increased about five percent over the past 50 years (Karl and others 2009). Scientists predict that more pronounced seasonality is likely in the future, with more precipitation in the fall and winter and less in summer months (Karl and others 2009)

In Florida, rainfall has generally increased by 10% (Figure 1.1-6).

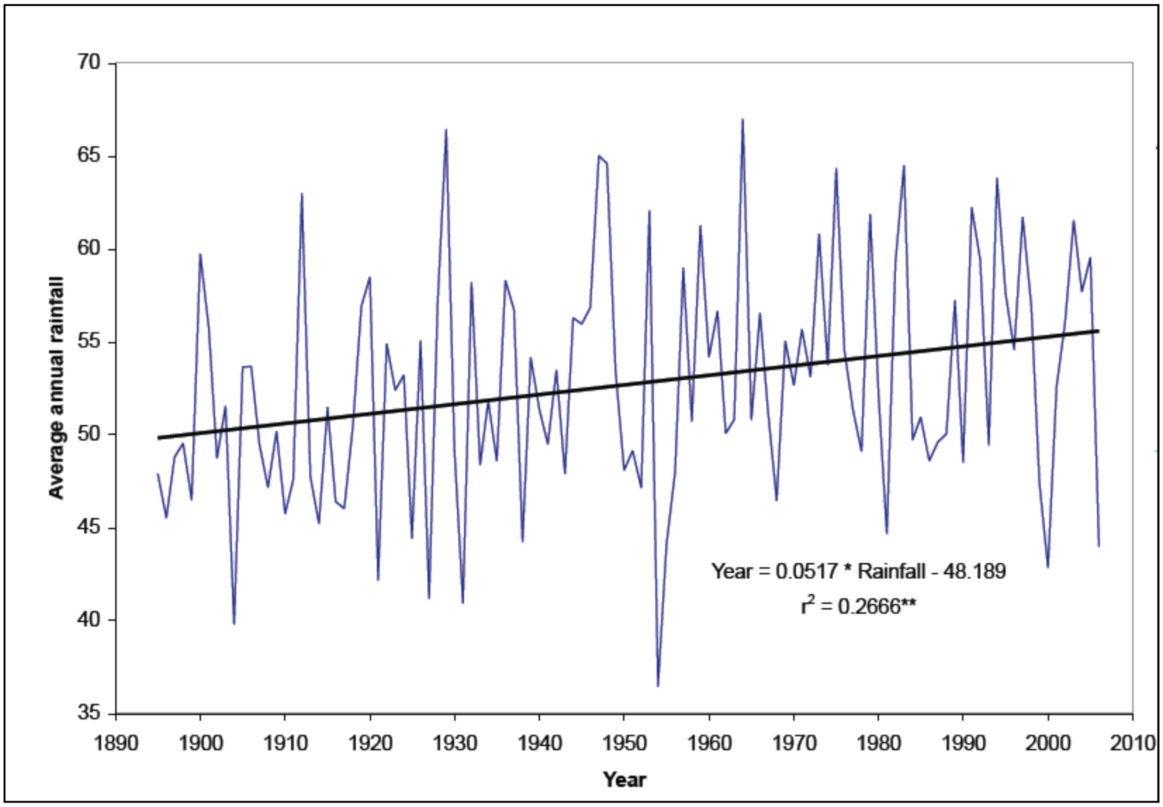


Figure 1.1-6. Annual total rainfall averaged for Alabama, Florida, and Georgia from 1895 through 2006. From Consortium (2008).

Most locations in the state are expected to become wetter overall, though increasing variation is also predicted (Figure 1.1-7). Furthermore, more seasonality is expected with rainier wet periods and drier dry seasons (Kunkel and others 2011).

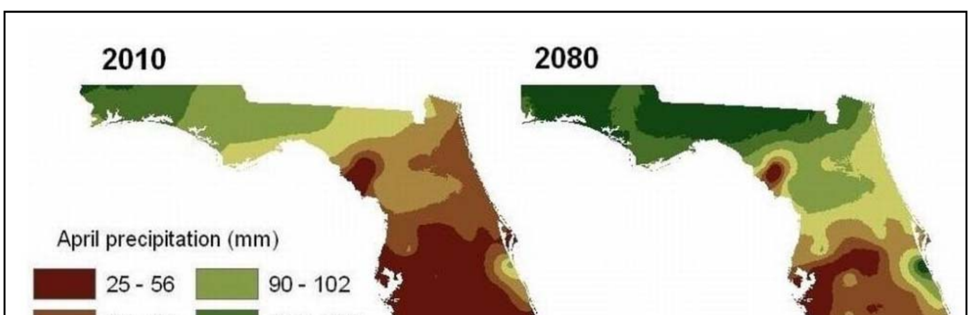


Figure 1.1-7. April 2010 precipitation data, compared to predicted values in 2080. From Brandt and others (2010).

More specifically, heavy (top 10% by rain amount) precipitation events and light (bottom 5%) rain events increased during 1979-2003 and moderate (25-75%) rain events decreased (Lau and

Wu 2007) and this trend is expected to continue. Tropical storms are expected to increase (Knutson and others 2010), adding to large rain events in Florida (Knight and Davis 2007). However, rainfall trends are complicated by other factors such as land cover. For example in Southeast Florida there is evidence that rainfall is reduced by urbanization and wetland destruction (Pielke and others 1999). This finding points to the importance of including land cover data in future rainfall prediction models.

Amplifying these precipitation-based changes in freshwater is human use which diverts freshwater water from natural systems. For example, in the Suwannee River, Florida's second largest river, a significant negative change in the relationship between discharge and rainfall has occurred over the last 50 years (Figure 1.1-8).

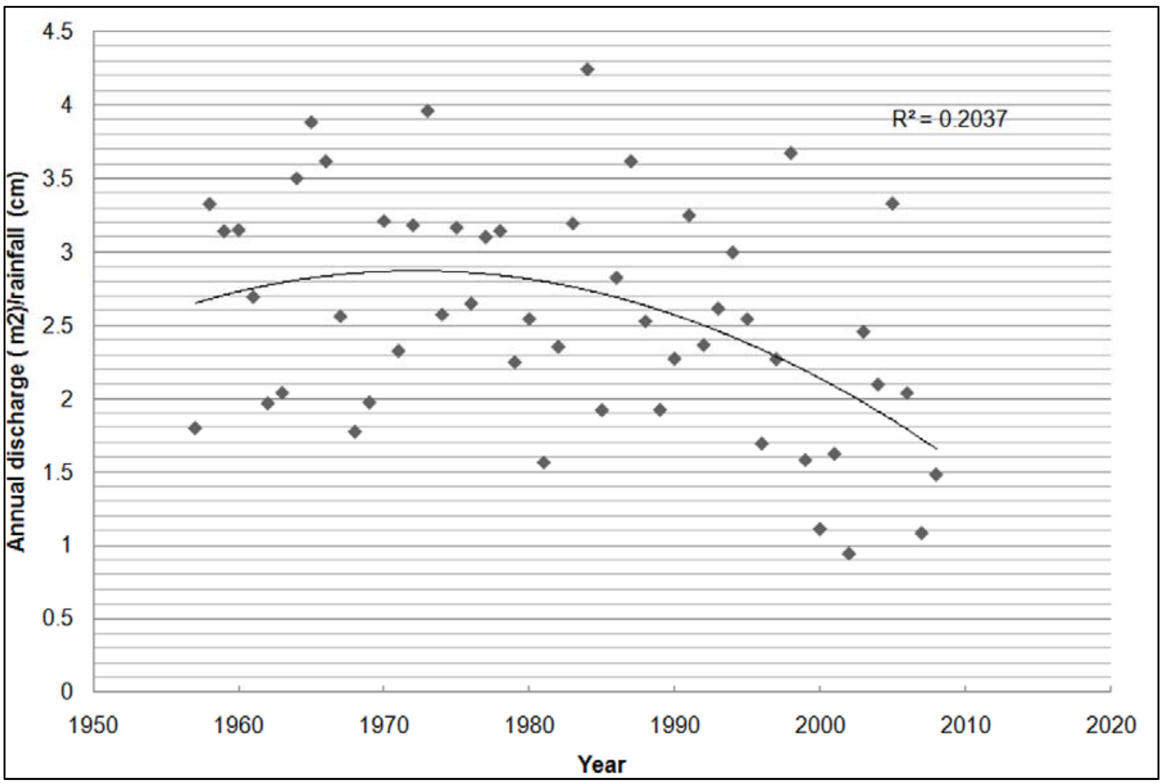


Figure1.1-8. Annual freshwater discharge/annual rainfall in the Suwannee River drainage basin, 1957 - 2008. From Seavey and others (2011).

Since annual rainfall has not changed significantly during this 50-year period in this particular region, the declining output rates suggest that usage or retention of freshwater for human uses is the main driver of the reduced discharge of the Suwannee (Seavey and others 2011). This results in less freshwater input into coastal estuaries in the Gulf of Mexico. Human water use and modification of hydrological cycles is reducing freshwater inputs into natural systems throughout the state, most famously in the Everglades (Davis and Ogden 1997). This trend is expected to increase with increasing development and temperatures in Florida (Gibson and others 2005).

<u>Ocean acidification</u>

Over the past 200 years, the oceans have taken up roughly 40% of the anthropogenic carbon dioxide in the atmosphere (Zeebe and others 2008). Carbon dioxide levels in the ocean are higher now than in the last 300 million years (Caldeira and Wickett 2003). As carbon dioxide is absorbed by ocean water, the pH is lowered and the water becomes more acidic (Figure 1.1-9).

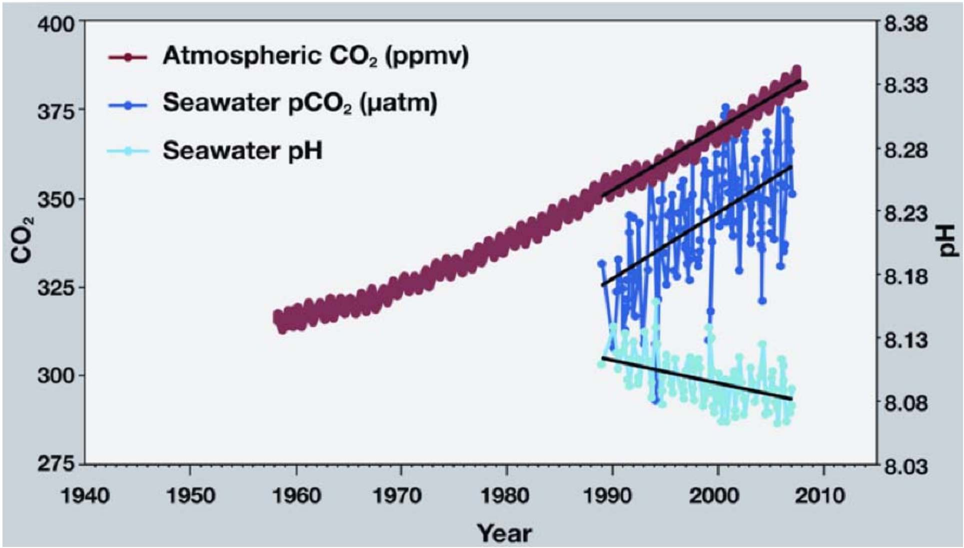


Figure 1.1-9. Correlation between increasing carbon dioxide, seawater carbon dioxide levels, and seawater pH levels. From Doney and others (2009).

Ocean pH has been lowered 0.1 unit compared to the pre-industrial period and is expected to be reduced another 0.3–0.5 pH units by the end of this century (Sabine and others 2004, Solomon and others 2007). Higher acidity reduces the capacity of marine organisms to produce calcium carbonate, which is an important component in the bodies and shells of a wide array of species (Sabine and others 2004), including calcite plankton, which provide the basis for many oceanic food webs (Orr and others 2005). Ocean acidification, in conjunction with warming water temperatures, has also been demonstrated to induce bleaching and loss of productivity in corals (Anthony and others 2008) and is predicted to have serious consequences for coral reefs and associated reef communities in the future (Hoegh-Guldberg and others 2007). At a pH of 7.8, the predicted value in 2100, coral reef communities dramatically homogenize due to loss of species that cannot survive at this acidity level(Fabricius and others 2011). Furthermore, new coral reef formation has been shown to cease below a pH of 7.7 (Fabricius and others 2011). Marine species in Florida and throughout the Caribbean are already at risk as increased ocean acidity in the region is well on its way to reaching the projected 7.8 pH by 2100 (Kleypas and others 2006).

Natural disturbance regime shifts

Climate change affects the frequency, intensity, and length of natural disturbances (Pachauri and Reisinger 2007). Hurricanes, floods, droughts, extreme temperatures, and wild fires are already changing and the change is expected to increase over time (Dale and others 2001, Solomon and others 2007). In general, disturbances are expected to become more variable and extreme over time (Stanton and Ackerman 2007).

Natural disturbance regimes are the result of a complex interaction between the biotic and abiotic characteristics of a landscape (Turner and others 2001). These characteristics are influenced by both climate change and human land use, thus any changes in human use may produce feedbacks to natural disturbance regimes (Figure 1.1-10).

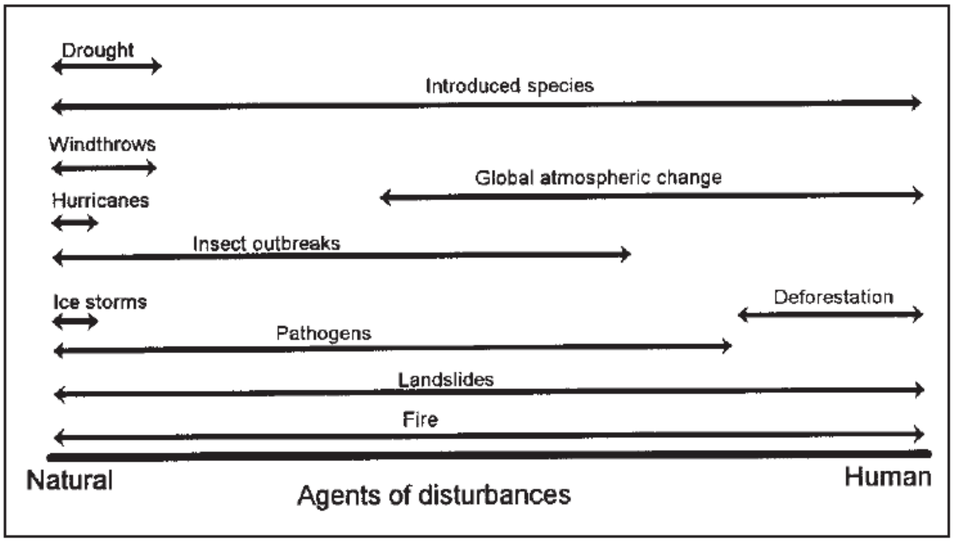


Figure 1.1-10. Natural and anthropogenic agents of ecosystem disturbances that result from climate change. The arrows relates to the extent of natural versus anthropogenic influence. From Dale and others (2001).

In Florida, many disturbances regimes are already changing and more changes are expected (FOCC 2009). Hypoxia events, which create oxygen-starved dead zones as a result of elevated water temperature, are increasing and expanding (Turner and others 2006, Rabalais and others 2010). Algae blooms are also increasing with increased water temperature (Paerl and Huisman 2008), though Florida data does not support a consistent pattern (Alcock 2007). Warming waters and changing weather patterns are working to promote coastal storms and hurricanes in the Gulf of Mexico (Twilley and others 2001) and in the wider Atlantic region (Figure 1.1-11).

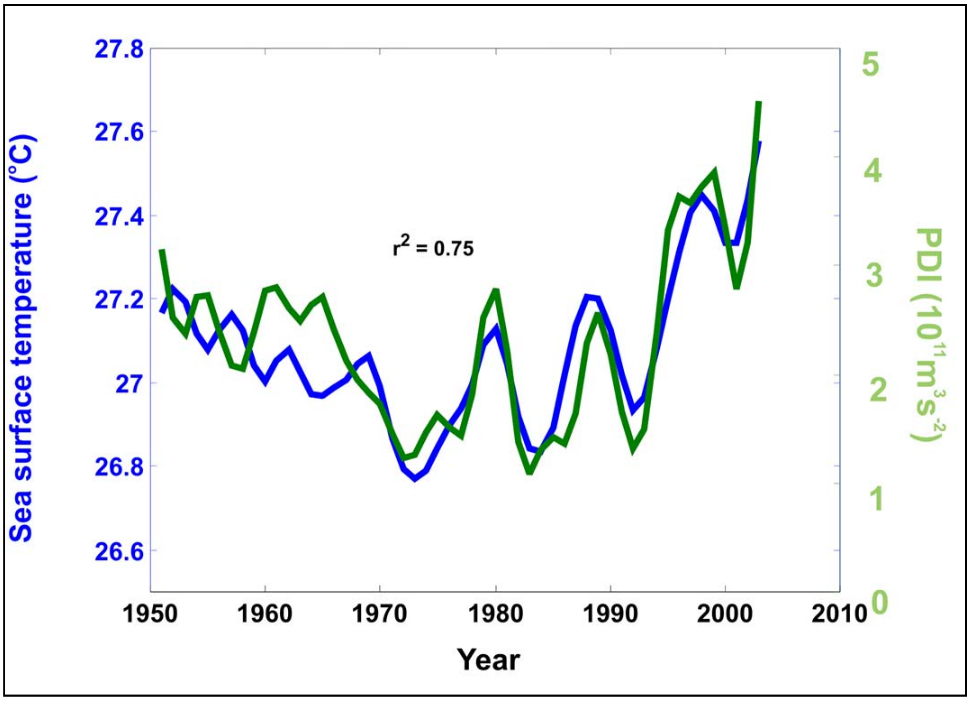


Figure 1.1-11. Time series of late summer tropical Atlantic sea surface temperature (blue) and the Power Dissipation Index (green), a measure of hurricane activity which depends on the frequency, duration, and intensity of hurricanes over a season. From Emanuel (2007).

The intensity of large hurricanes (Bender and others 2010) and frequency of thunderstorms (Trapp and others 2007) are expected to increase with increasing sea surface temperature. Note that changes to hurricane frequency are not well associated with climate change, though this is the focus of much research (Bender and others 2010). Elevated hurricane intensity will increase storm surges and wave height (Komar and Allan 2008, Lynn and others 2009) with probable negative effects on coastal biodiversity, such as reduced nesting success of sea turtles (Fish and others 2005) and conversion of coastal marshes to open water (Barras 2006). Recent storm models predict a 20% increase in rainfall rate within100 km (62 miles) of storm centers (Knutson and others 2010). These changes are expected to increase coastal flooding. Increasing wildfire frequency in Florida is associated with increased lightening and decreased rainfall (Duncan and others 2010, Slocum and others 2010), and thus is expected to increase with climate change (Liu and others 2010). However, long-term predictions are complicated by a complex, but positive (Fedorov and Philander 2000) relationship between Florida fire frequency and La Niña (Harrison and Meindl 2001). While fires are expected to increase due to a predicted higher frequency of El Niño/ La Niña events under climate change (Collins 2005), long-term fire predictions for Florida are not clear (Merryfield 2006). However, it is important to note that fire risk and intensity can increase rapidly even under short periods of drought. This means that even under a higher average amount of rainfall in Florida, fires could become more frequent (Beckage and Platt 2003). Finally, with increased variability in precipitation events, land cover changes, and increased rain seasonality, more drought and flood events have been observed (Marshall and others 2004) and are expected to increase in Florida (Conservancy 2009a).

> "Of all the ongoing and expected changes from global warming...the increase in the volume of the oceans and accompanying rise in the level of the sea will be the most immediate, the most certain, the most widespread, and the most economically viable in its effects." -Pilkey and Young 2009

Sea level rise

Increasing air and water temperatures are leading to global sea level rise (Solomon and others 2007). From the 1990s through 2010, average global sea level increased at a rate of 3.3 mm per year (Figure 1.1-12).

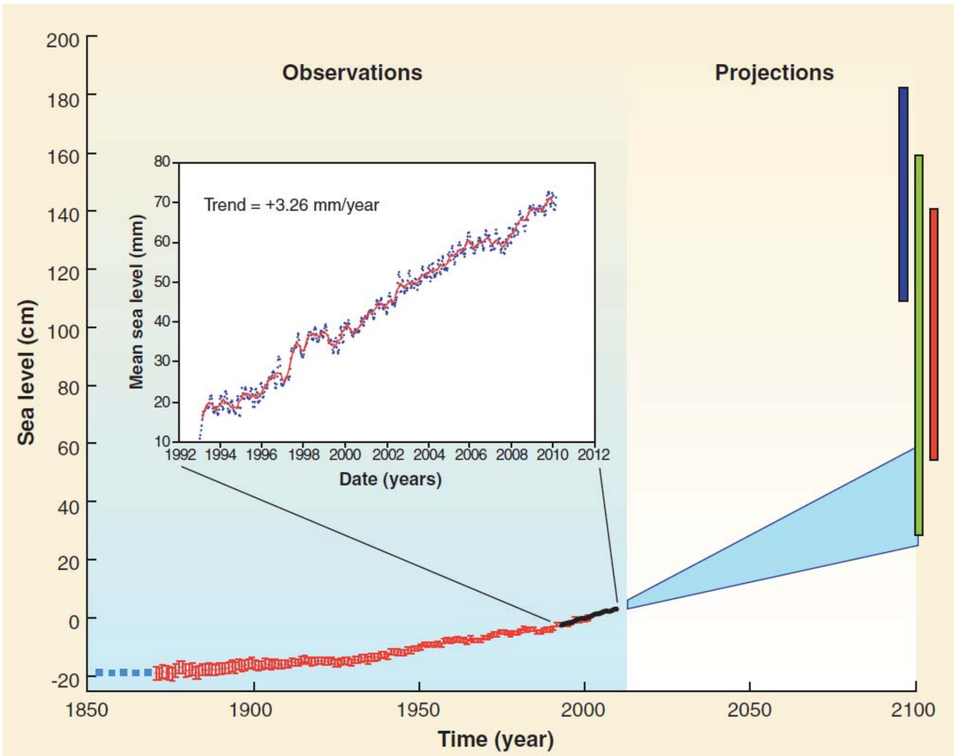


Figure 1.1-12. Global mean sea level evolution over the 20th and 21st centuries. The red curve is based on tide gauge measurements. The black curve is the altimetry record (zoomed over the 1993–2009 time span). Projections for the 21st century are also shown. The shaded light blue zone represents Intergovernmental Panel on Climate Change AR4 projections for the A1FI greenhouse gas emission scenario. Bars are semi-empirical projections. From Nicholls and Cazenave (2010).

Sea level rise is primarily the result of thermal expansion from warming sea water and land-based ice melt from increased air temperature (Nicholls and Cazenave 2010). Though predictions are constantly improved with increased model accuracy and data, sea level is expected to increase between 0.7 to 2 m by 2100 (Rahmstorf and others 2007, Allison and others 2009, Grinsted and others 2010). There is the potential for sea level rise above 2 m (Hansen 2007, Nicholls and others 2011). The increasing rate of sea level rise is significant and is expected to continue even if carbon dioxide levels in the atmosphere are capped today (FOCC 2010). Models of West Antarctica ice-sheet melting reveal that sea level along U.S. coastlines will be 25 to 30% higher than the global mean (Bamber and others 2009, Mitrovica and others 2009). In addition, abrupt ice melting may lead to abrupt and concentrated periods of dramatic sea level rise (Gregory and others 2004). Uneven sea level rise also results from local variation in water temperature, chemistry, changes in ocean currents, underlying topography and other factors (Solomon and others 2007). (Figure 1.1-13).

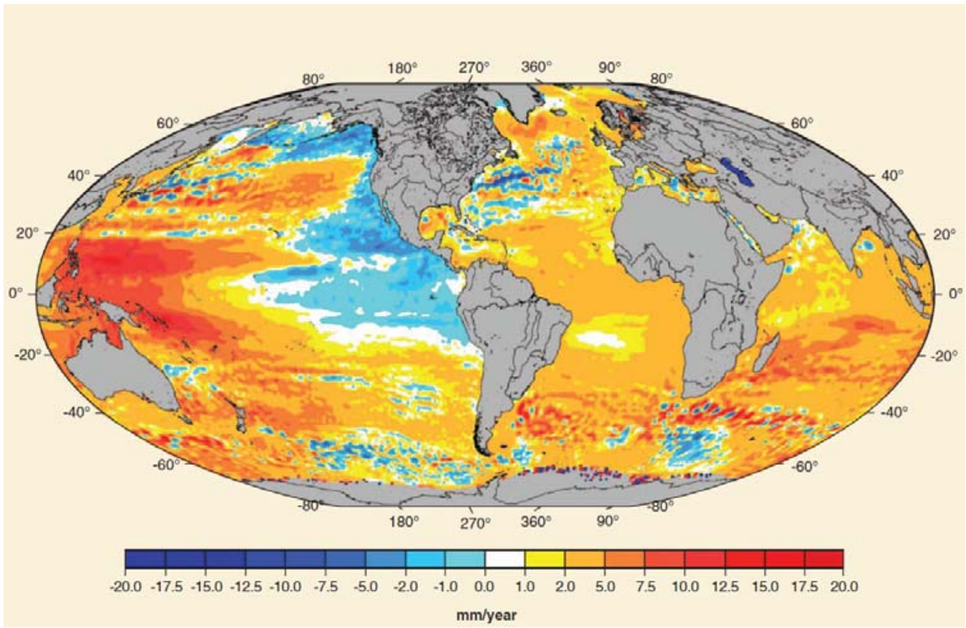


Figure 1.1-13. Regional sea-level trends from satellite altimetry for the period October 1992 to July 2009. From Nicholls and Cazenave (2010).

Because of low topography, the vast amount of shoreline, and even localized coastal land subsidence (sinking), Florida is particularly at risk from sea level rise. Sea level rise is considered Florida's gravest and most immediate threat from climate change (FOCC 2010, FWC 2011, Noss 2011). Because of lower elevations, sea level rise is having more immediate impacts in South Florida compared to the Panhandle (FOCC 2010). However, effects are being seen throughout the state (Williams and others 2003, Ross and others 2009, FOCC 2010). Across Florida, rates of sea level rise are variable (Figure 1.1-14), though all are increasing over time (Walton 2007).

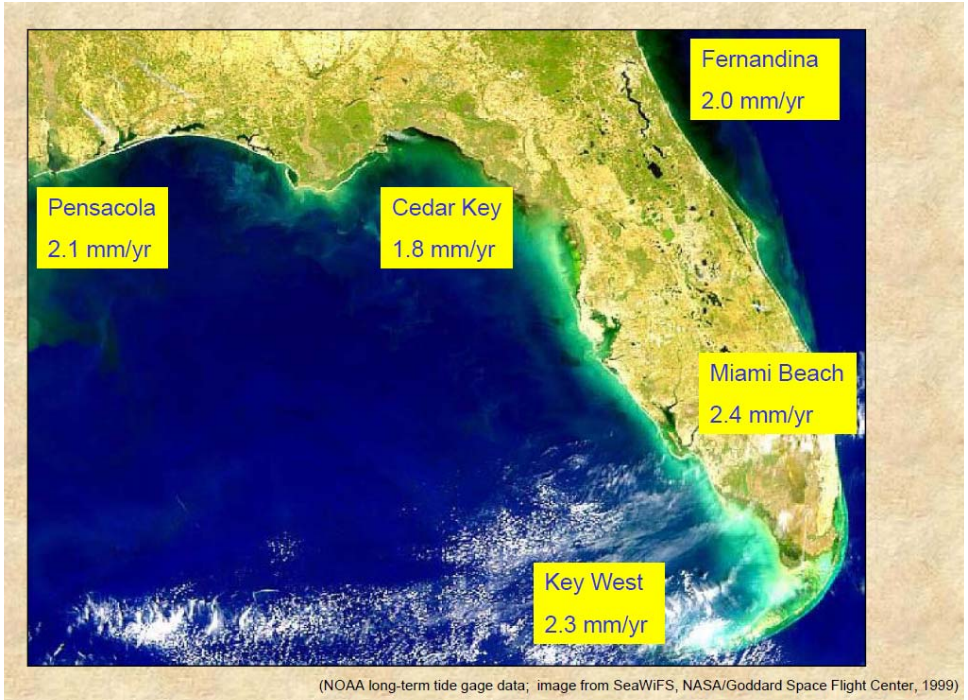


Figure 1.1-14. Rates of sea level rise in Florida from long-term tide gage records. From Donoghue (2009).

Predictions for salt water inundation in Florida are quite alarming (Figure 1.1-15),

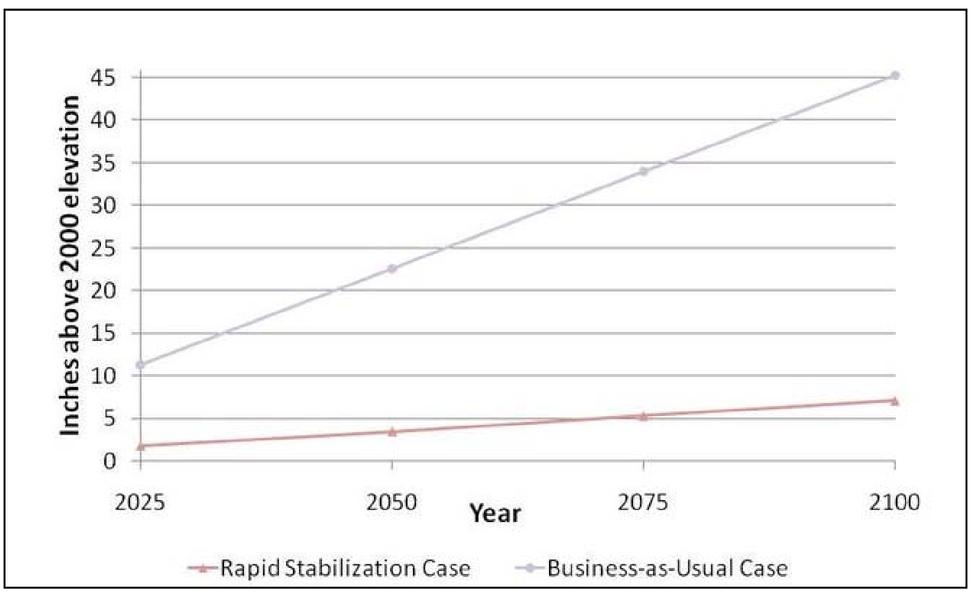


Figure 1.1-15. Two future climate scenarios for Florida sea level rise (inches). From Stanton and Ackerman (2007).

even under a conservative 1 meter (39 inches) rise, 10% of the state will be under water (Noss 2011). The percent of inundated land increases dramatically with higher sea level rise estimates (Figure 1.1-16).

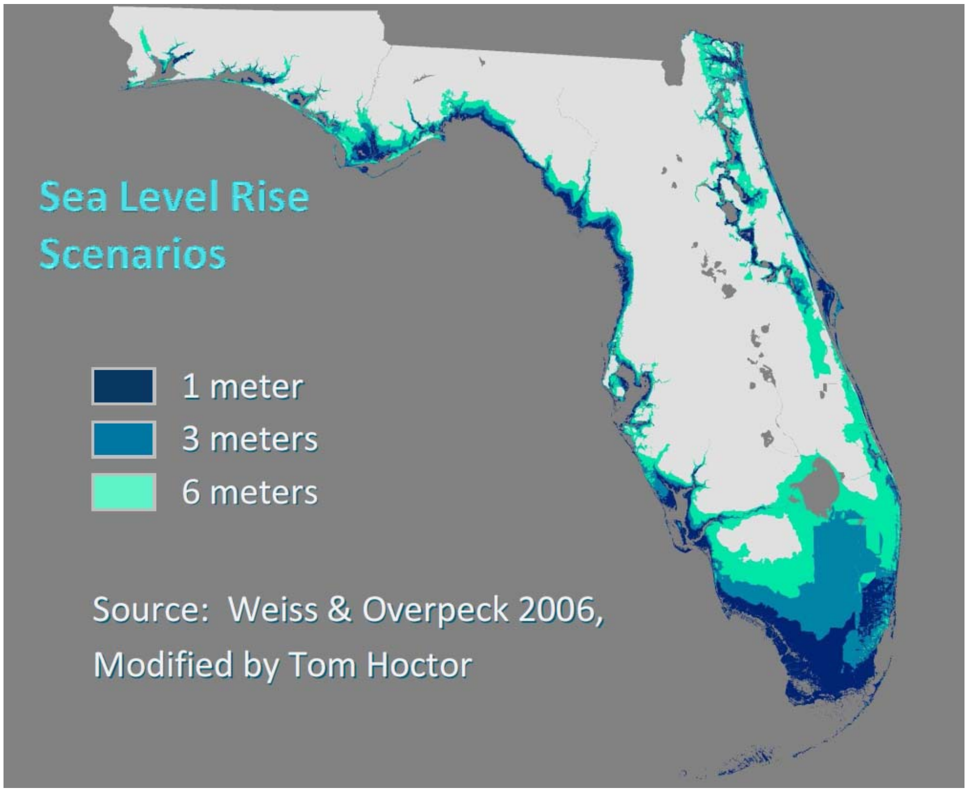


Figure 1.1-16. Sea level rise projections of 1 m, 3 m, and 6 m for Florida. From Oetting and others (2010).

Observed impacts from sea level rise include shoreline erosion, intrusion of salt water into surface and ground freshwater resources, and habitat flooding/loss (Williams and others 2003, Ross and others 2009, Seavey and others 2011). These impacts are compounded with the high frequency of coastal storms and hurricanes in Florida (Frazier and others 2010). Comparisons of Florida coastal flooding across a variety of storm categories reveals that flooding is much greater when sea levels rise (Figure 1.1-17).

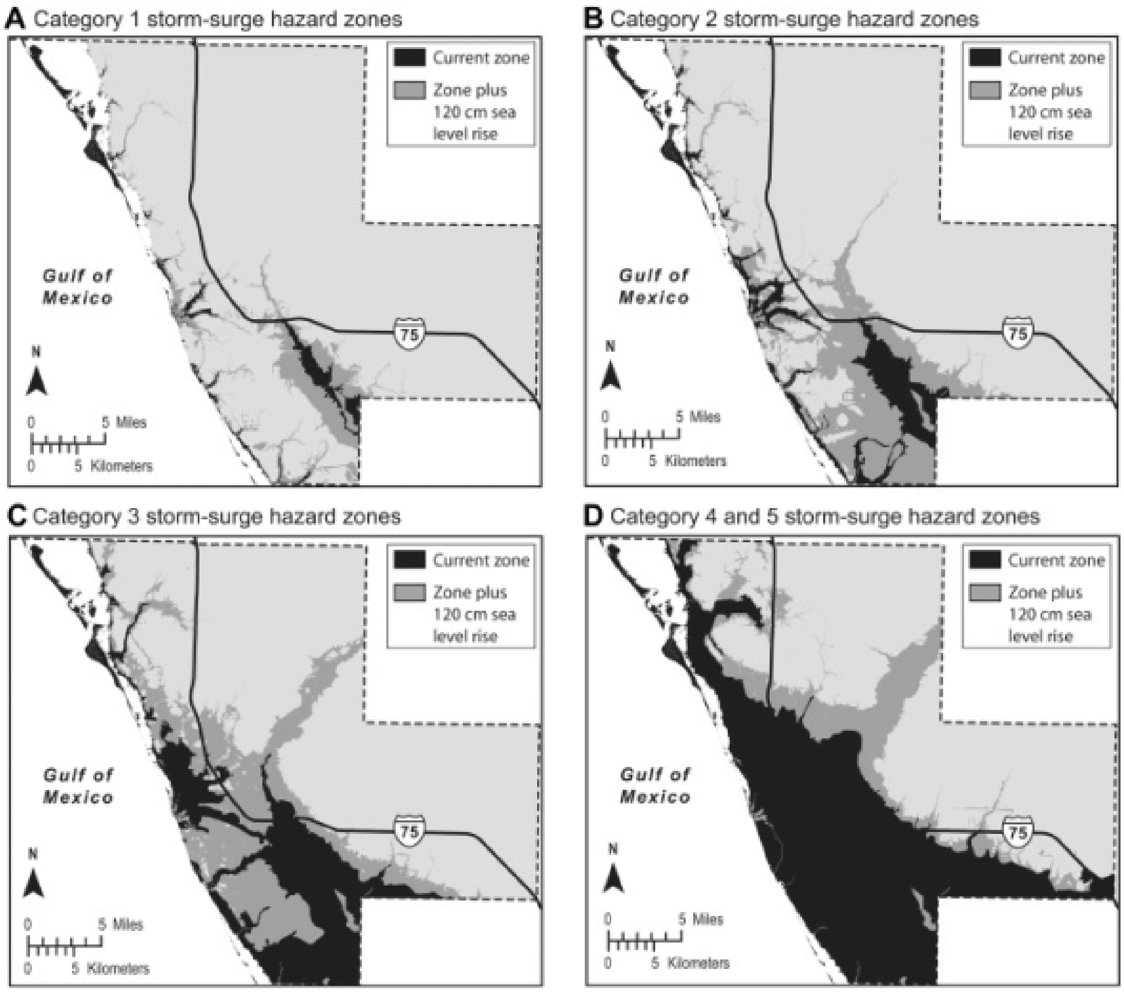
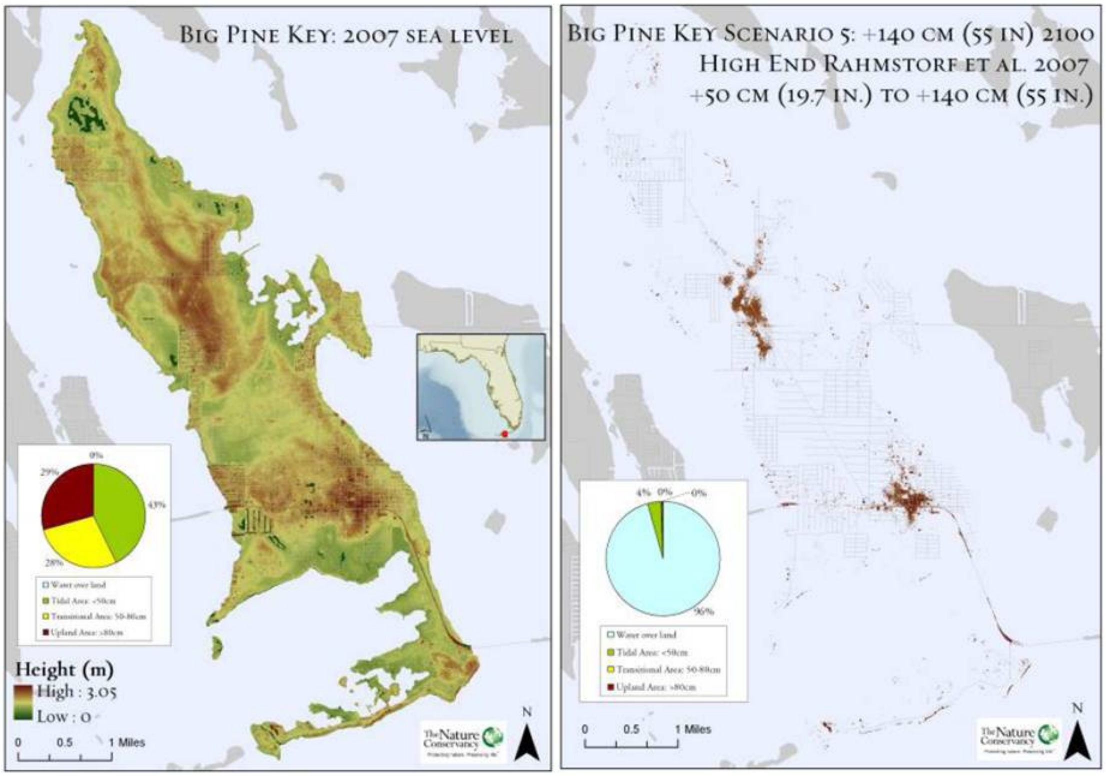


Figure 1.1-17. Storm-surge hazard zones enhanced by sea-level-rise projections in Sarasota County, Florida, for various hurricane categories. From Frazier and others (2010).

In addition, in many regions of Florida canals that were built several decades ago to control flooding have reduced capacity to drain storm waters due to higher sea level (Park and others 2011). Land loss is widely expected for low-lying areas, such as the Florida Keys, much of the mainland in South Florida and along the majority of the coast (Stanton and Ackerman 2007, Noss 2011). Salt water intrusion is exacerbated by human extraction of freshwater resources throughout Florida (Reviewed in Lin and others 2009).



Map source: Bergh (2011)

The archipelago of the Florida Keys extends 338 km southwest of mainland Florida. The sea level at the most southern island has risen at a rate of 2.4 cm per decade from 1913 to 1990 (Ross and others 1992) and more recently at a rate of 3.8 cm per decade (Walton 2007). The low elevation of the Florida Keys (mostly below 2 m) (Ross and others 1992), puts them at great risk for inundation. The outlook under most sea level rise predictions is for complete or significant loss of these islands within the next century (Bergh 2011).

More information about this case study:

Bergh C. 2011. Initial estimates of the ecologcial and economic consequences of sea level rise on the Florida Keys through the year 2100. The Nature Conservancy. Available at: http://www.frrp.org/SLR%20documents/FINAL%20-%20Aug%2021%20final.pdf. Access date: September 27, 2011.

Maschinski J and others. 2011. Sinking ships: conservation options for endemic taxa threatened by sea level rise. Climatic Change 107(1-2): 147-167.

Physical changes in natural systems will lead to changes in the biotic or ecological drivers of biodiversity. Biogenic disturbance regime shifts (pests, diseases, etc.) and ecosystem functions (primary productivity changes, decomposition, nutrient and water cycle shifts, connectivity changes, pollinators, etc.) have and are expected to continue to change under climate change (FWC 2011, Geyer and others 2011). Human land and natural resource use is also expected to change with a shifting climate, which will also drive biodiversity changes (Solomon and others 2007).

Biogenic disturbance regime shifts

Biogenic disturbances originate from biological systems and include the impacts of herbivorous insects, mammals, and pathogens, many of which are responsive to climate changes. Wildlife diseases are sensitive to temperature and moisture and are therefore shifting under climate change (Harvell and others 2002). The direction and amount of change among diseases is variable and dependent of the specific disease (Harvell and others 2002). However, some broad patterns have been observed, especially in, but not limited to aquatic systems. Diseases are on the rise in amphibians, turtles and corals (Lafferty and others 2004, Bruno and others 2007, Rohr and Raffel 2010, Johnson and others 2011b, Okamura and Feist 2011). Because of narrow baseline seasonal temperature ranges, small changes in the climate of semi-tropical and tropical regions may lead to large changes among tropical hosts and parasites compared to higher latitudes (Deutsch and others 2008, Fuller and others 2011).

Many insect outbreaks are also on the rise in forests (Breshears and others 2005, Cudmore and others 2010) and agriculture (Petzoldt and Seaman 2008). Because insects are dependent on air temperature, the intensity and frequency of outbreaks are increasing under the influence of global warming (Tobin and others 2008, Jonsson and others 2009). For example, it has been estimated that with a 2^0 C temperature increase, insects might experience one to five additional life cycles per season, allowing them to overwhelm host species and quickly expand (Yamamura and Kiritani 1998). Insects, like many species, are expanding their ranges poleward, leading to outbreaks in previously undisturbed landscapes (Cudmore and others 2010). Southern pine beetles are a concern in Florida's forests and climate change may increase damage by up to 4 to 7 times current mortality rates (Gan 2004).

Unfortunately, increased insect and disease outbreaks among agricultural crops will lead to increased pesticide/chemical use and other changes in crop management, which will have important environmental impacts (Petzoldt and Seaman 2008). For example, outbreaks of citrus canker, which can devastate citrus groves, has been linked to hurricane intensity and thus may increase under climate change (Irey and others 2006).

Diseases of coral reef communities have been increasing in recent years in association with higher water temperature (Porter and others 2001). Black band disease (Figure 1.1-18) is common in hard corals in the Florida Keys and is expected to continue to rise, along with extinction risk for these species (Rosenberg and Ben-Haim 2002). Marine diseases and algal blooms are also negatively affecting marine fish (National Wildlife Foundation 2006).

Figure 1.1-18. Black band disease on coral. Source: Wikipedia commons.

Ecosystem functions

Ecosystem function is the capacity of natural processes and components to provide goods and services that satisfy biodiversity needs, either directly or indirectly. As a result of climate change impacts on physical and biotic environment, ecosystem functions are expected to be affected (Geyer and others 2011). Examples of important services include primary productivity, which forms the basis of the food chain. These organisms, such photosynthetic algae and plants; and chemosynthetic bacteria, directly or indirectly feed the rest of life on earth. Negative impacts have been documented in ocean primary productivity (Fabry and others 2008, Ainsworth and others 2011, Wetz and others 2011), decomposition (Solomon and others 2007, Schindlbacher and others 2011), nutrient and water cycle shifts (Solomon and others 2007), habitat structure via the loss of ecosystem engineers (Seavey and others 2011), habitat connectivity (Sieck and others 2011), and pollinators (Solomon and others 2007, Aldridge and others 2011). These impacts are expected throughout Florida and will be addressed in more detail under biodiversity response below. The key point is that change in any component of an ecosystem can alter function, leading to cascading effects on biodiversity (Johnson and others 2011a, Wetz and others 2011).

Land use and natural resource use

Human-mediated land and natural resource use are responsible for the vast majority of threats to biodiversity in Florida and globally, therefore, the reaction of humans to climate change will have much influence on natural ecosystems (Solomon and others 2007). The resiliency of many natural ecosystems to climate changes has already been compromised by human activities (Pachauri and Reisinger 2007). Land use, pollution, habitat fragmentation, and overexploitation of resources are all expected to change with a warming climate (Pachauri and Reisinger 2007). For example, increased variability in precipitation along with hotter weather is expected to increase human demand on freshwater reserves leading to less water availability for natural systems (Pachauri and Reisinger 2007, Hall and others 2008). In Florida, this problem will be magnified by saltwater intrusion from rising sea levels (FOCC 2009) and increased diversion to human use by a growing population (Hall and others 2008). This freshwater demand is not limited to drinking water, in fact the majority freshwater use is for agricultural irrigation (81% of U.S. consumptive water use) (Hall and others 2008) and climate change is expected to increase demand for agricultural irrigation. Increased demand for agricultural irrigation may create conflicts over availability of freshwater needed for sustaining natural systems. Water shortages are widely predicted for agricultural areas across Florida (Figure 1.1-19), putting natural systems in these regions also at risk for water shortage.

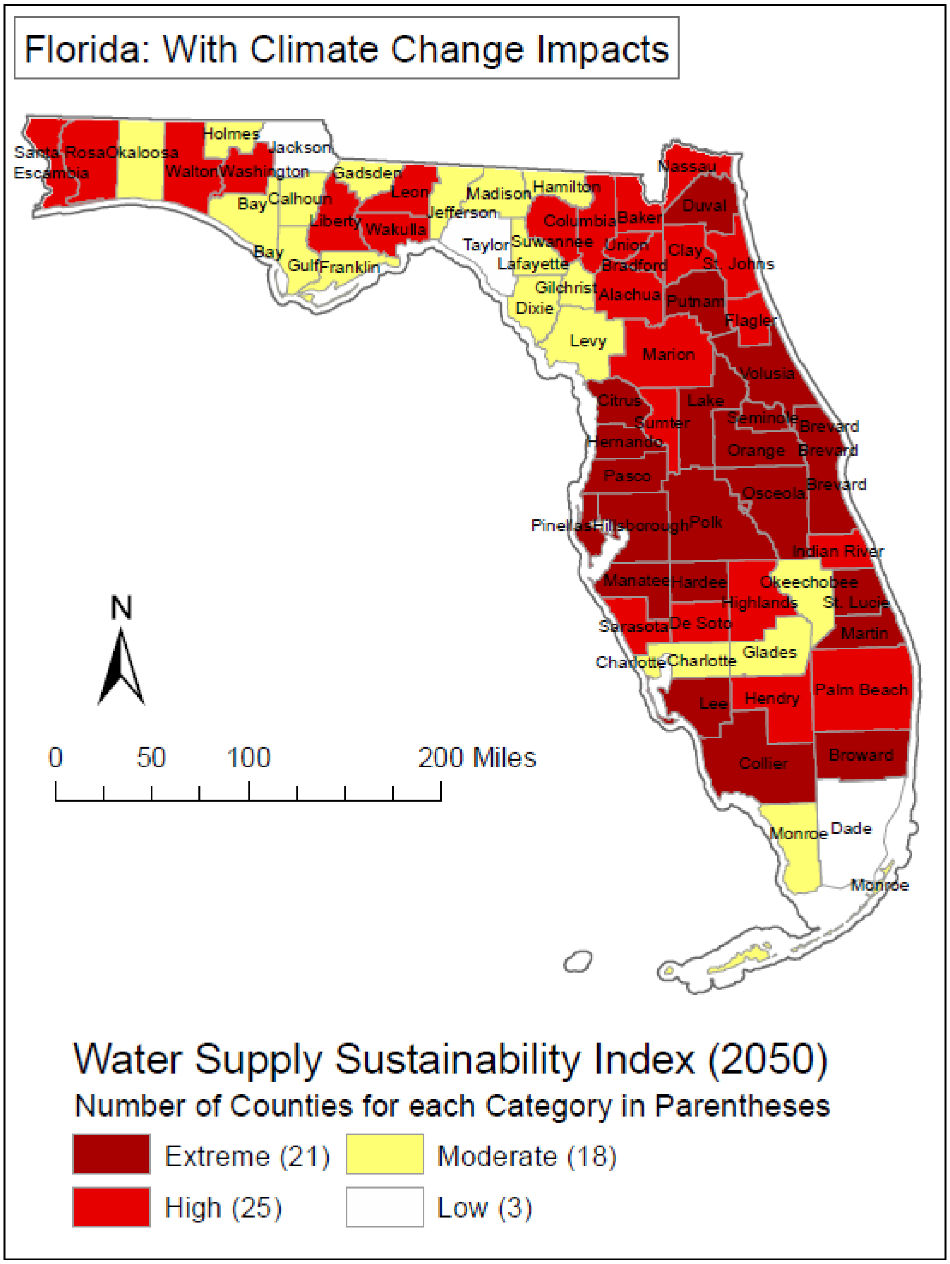


Figure 1.1-19. Estimated agricultural water shortage risk for Florida counties by 2050. Water demand projections were estimated from a business-as-usual trends in growth, particularly of population and energy demand, and renewable water supply projections are based on the average results of an ensemble of sixteen established climate models. From Tech (2010).

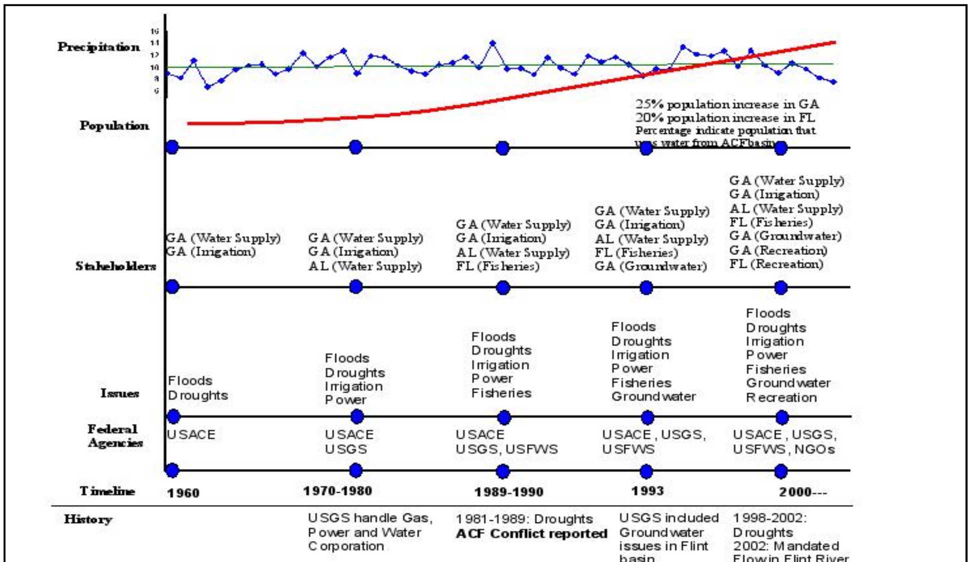


Figure 1: Evolution of the ACF Basin Water Conflict

Source: Lin (2009).

This graph illustrates the feedbacks between climate change, human use, and freshwater limitations for natural systems. The Apalachicola-Chattahoochee-Flint River system runs from Georgia to Florida and is at the center of a 30-year conflict over access to freshwater. Both human and natural systems are being stressed by decreasing freshwater supply. The conflict began when droughts and floods began to negatively impact the consistency of Georgia's water supply. Georgia's growing population and their associated demand for water led to a cascade of water claims among river system stakeholders, which includes agricultural and fishing interests. Increasing variation in precipitation, warming temperatures, and sea level rise is making the situation worse and the politics more contentious. In Florida's Apalachicola Bay, estuaries have lost many ecological functions as a result of reduced freshwater input, which threatens the local economy based on seafood and recreational fisheries that is estimated at several billion dollars annually (Ruhl 2005). Legal battle lines have put stakeholders and natural systems at odds with each other. Human use of freshwater resources in a warming world will become more intense, challenging our ability to balance the needs of a growing population and natural ecosystems.

More information about this case study:
Union of Concerned Scientists. 2009. Apalachicola Bay System, Running dry: The Panhandle regional ecosystem (Alabama-Florida). Available at: http://www.ucsusa.org/gulf/gcplacesapa.html. Access date: September 29, 2011.

1.1.2. Potential Responses of Biodiversity to Drivers

> "Climate change is predicted to become a major threat to biodiversity in the 21st century."- Dawson and others 2011

The response of biodiversity to the various physical drivers of climate change is the subject of a prodigious amount of scientific research. Well over 15,000 scientific papers have been published on the topic of climate change and biodiversity (Web of Science keyword search 24 August 2011). Species responses can be broadly categorized into changes in physiology, distribution, phenology, evolutionary adaptation, and extinction (Figure 1.1-20). There is little doubt that many species are already responding to changing conditions and that many more will do so in the future (Hughes 2000).

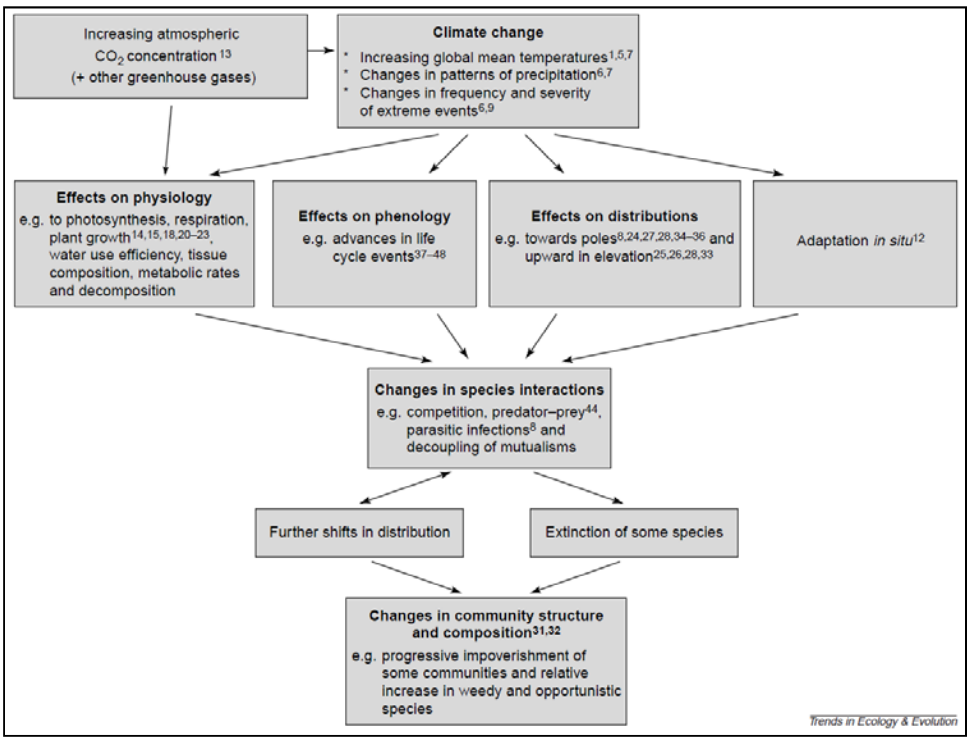
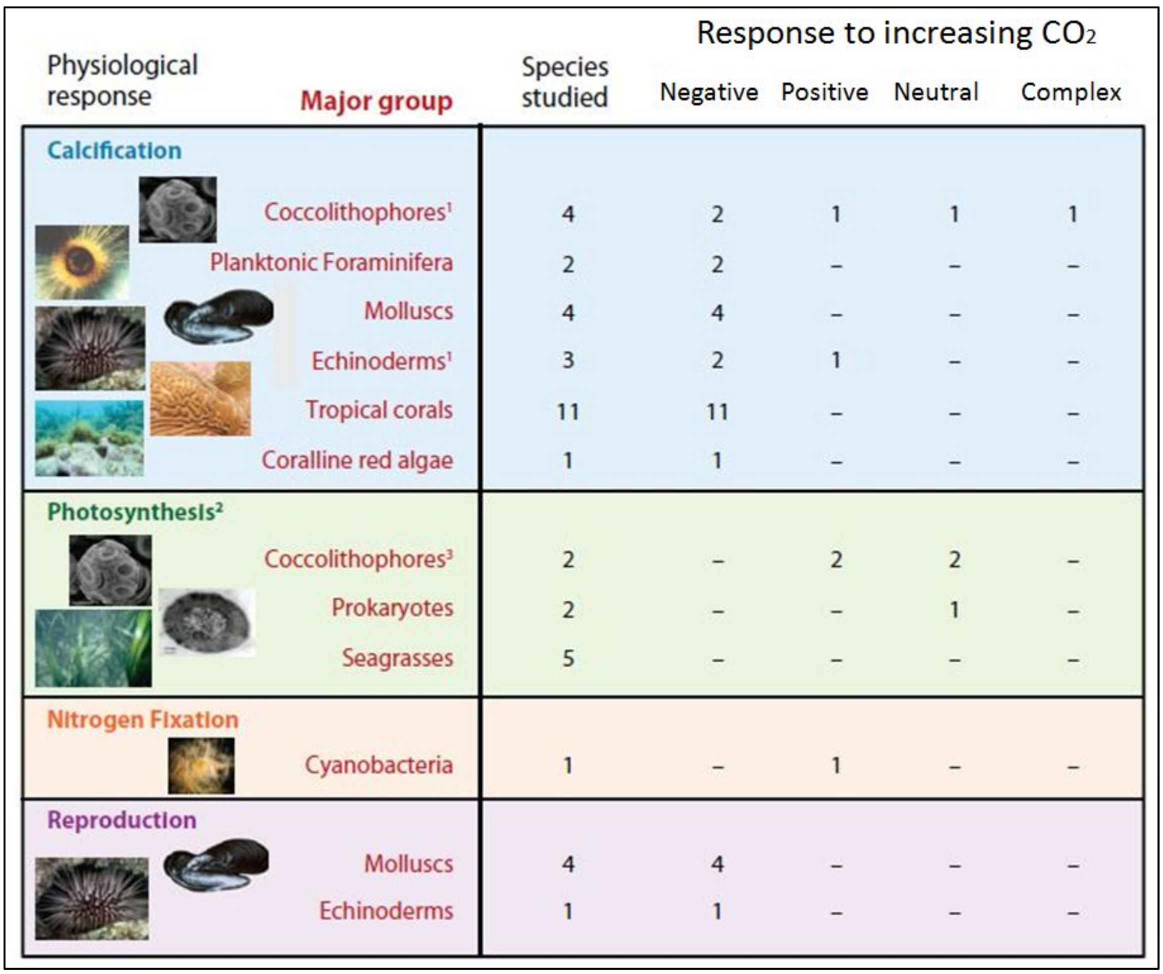


Figure 1.1-20. Potential pathways of biodiversity response to climate change. From Hughes (2000).

<u>Physiological response</u>

All flora and fauna live within their own unique set of physical constraints dictated by the abiotic environment. Temperature is an important component of the environment (Portner and Farrell 2008). Increased temperatures challenge the performance of organisms by affecting growth, development, reproduction, foraging, immune competence, behaviors and competitiveness (Portner and Farrell 2008). The thermal operation range for most species is likely to be as narrow as possible in order to minimize maintenance costs; therefore, small changes to global temperatures may have large effects on physiological function (Portner and Farrell 2008). Species in warm Florida climates have evolved under conditions of less temperature fluctuation and thus are likely to be even more susceptible to climate change (Deutsch and others 2008). Ectotherms (fish, amphibians, reptiles) are also highly susceptible to increased temperature, because of their limited ability to control body temperatures (Somero 2011). "Thermal tolerances of many organisms have been shown to be proportional to the magnitude of temperature variation they experience: lower thermal limits differ more among species than upper thermal limits, and upper thermal tolerance is often positively related to acclimatory ability" (Williams and others 2008).

Physical stress is not limited to temperature. Shifts in carbon dioxide concentration, disease, hypoxia, eutrophication, salinity levels, ocean acidification and precipitation also directly affect metabolism and development in animals and plants (Hughes 2000, Portner and Farrell 2008). For example, many marine species are experiencing difficulty with calcification, photosynthesis, nitrogen fixation, and reproduction brought on by increased ocean acidity (Figure 1.1-21).



Physiological response	Major group	Species studied	Response to increasing CO_2: Negative	Positive	Neutral	Complex
Calcification	Coccolithophores[1]	4	2	1	1	1
	Planktonic Foraminifera	2	2	–	–	–
	Molluscs	4	4	–	–	–
	Echinoderms[1]	3	2	1	–	–
	Tropical corals	11	11	–	–	–
	Coralline red algae	1	1	–	–	–
Photosynthesis[2]	Coccolithophores[3]	2	–	2	2	–
	Prokaryotes	2	–	–	1	–
	Seagrasses	5	–	–	–	–
Nitrogen Fixation	Cyanobacteria	1	–	1	–	–
Reproduction	Molluscs	4	4	–	–	–
	Echinoderms	1	1	–	–	–

Figure 1.1-21. Representative examples of measured impacts of ocean acidification on major groups of marine biota derived from experimental manipulation studies. From Doney and others (2009).

Among plants, some species are taking advantage of increasing levels of carbon dioxide in the atmosphere by increasing their rates of photosynthesis, although in general other limiting factors (water, nitrogen, phosphorous) temper this CO_2 fertilization effect (Reviewed in Hughes 2000). In addition, higher temperatures can stress metabolic processes in plants (Chaves and others 2011). Further, as observed along Florida's coast, salt water intrusion is causing reproductive failure and adult mortality among many coastal forest tree species (Ross and others 1994, Williams and others 2003).

Case Study - Physiologic response in sea turtles

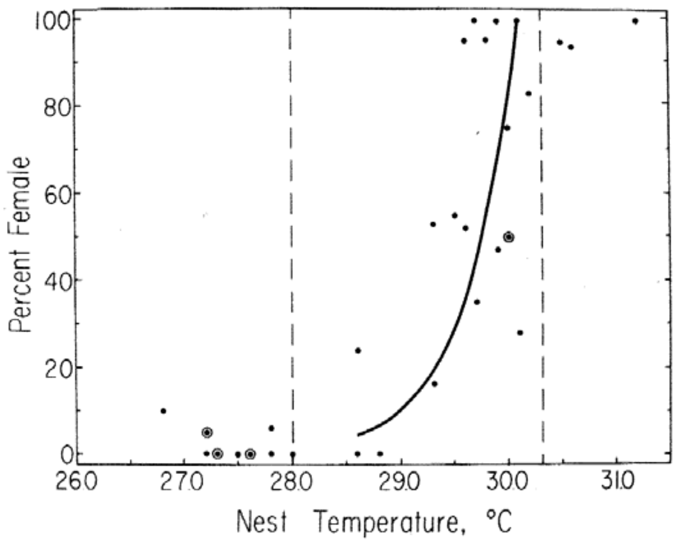


Photo: green sea turtle, www.franslanting.com, Graph: Standora and Spotila (1985).

The graph on the right shows the relationship between mean turtle nest temperature and the percent of female green sea turtle hatchlings produced in nests on a Costa Rican beach (Standora and Spotila 1985). In this study, temperatures below 28.0 C produced a maximum of 10% females while temperatures above 30.3 C produced a minimum of 90% females (Standora and Spotila 1985). Temperature-dependent sex determination are common among sea turtle species and is one reason that sea turtles are vulnerable to climate change (Poloczanska and others 2009). Higher temperatures in turtle nests are already leading to skewed sex ratios at a number of locations (Poloczanska and others 2009). With global temperature predictions of a 2^0C increase by 2100, sex ratio skew is predicted to become more widespread (Poloczanska and others 2009). Highly skewed ratios may lead to a shortage of males needed to sustain turtle populations. Scientists are currently debating the exact number of males needed to maintain healthy populations (Poloczanska and others 2009); however most are concerned that thresholds may be quickly crossed and that a crisis will occur for these highly imperiled species (Poloczanska and others 2009). Many other species, such as American Crocodiles, have temperature-dependent sex determination and may be similarly affected by climate change.

More information about this case study:
Poloczanska ES and others. 2009. Vulnerability of marine turtles to climate change. Advances in Marine Biology(56):151-211.

Distributional response

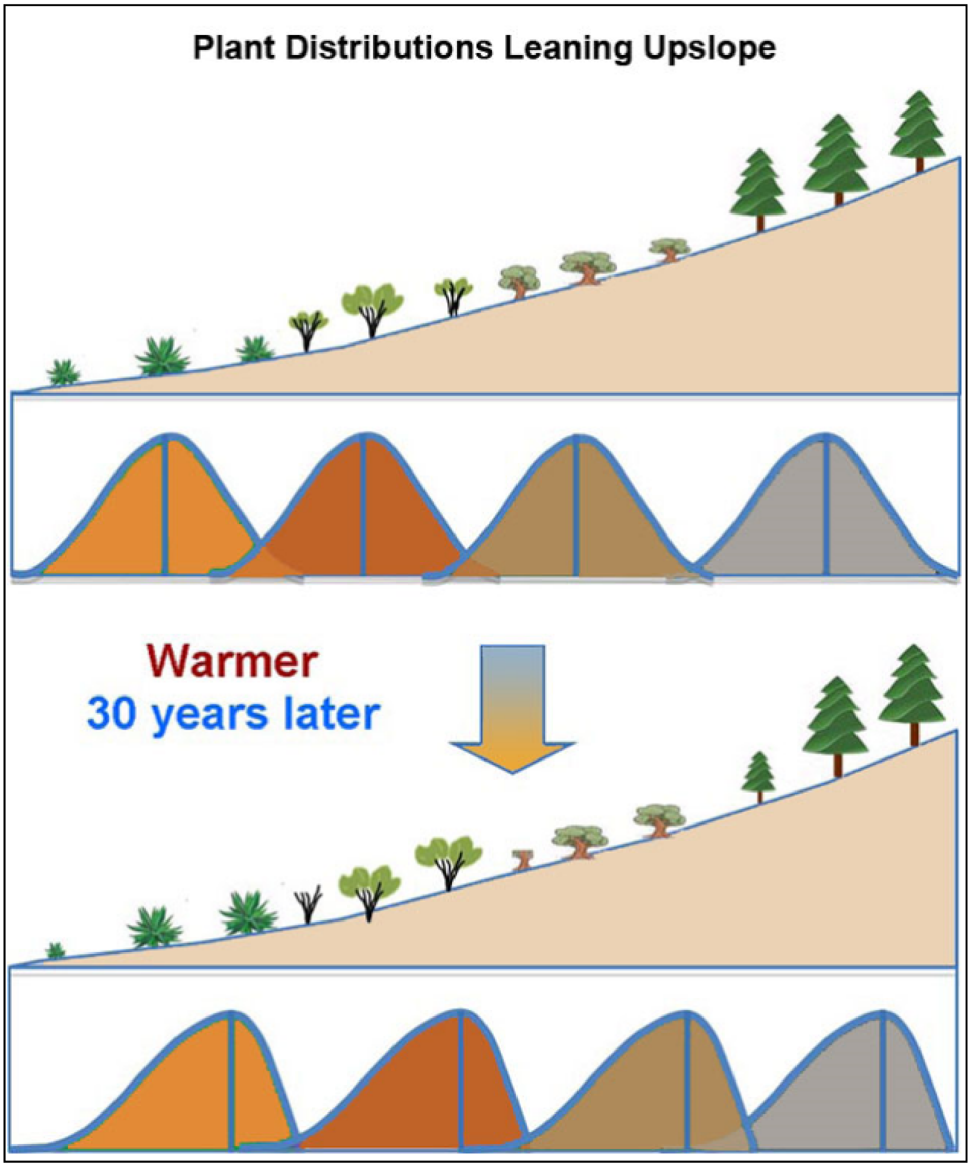


Figure 1.1-22. Upslope migration of the average position of plants on mountain slopes. From Breshears and others (2008).

Under warming temperatures, many species are expected to move upwards in elevation or towards the poles in order to follow their associated climates (Hughes 2000). A review of the trends in over 1,000 species revealed that species are moving poleward at an average rate of 6.1 km per decade (Parmesan and Yohe 2003). Other changes in the environment, such as changes in rainfall and seasonality will also induce movement. These shifts will lead to changes in species home ranges, distributions, migration routes, and species invasions. The frequency and magnitude of these changes depend on whether the species-specific climate niche is important to the sustainability of species (Wiens and others 2010) and that species can identify changes and move appropriately. Indeed this pattern is proving to hold true for many species. There have been observed changes in the distribution of butterflies, birds, and many other species (Reviewed in Visser 2008). Range shifts appear to be common among species that live in regions of extreme climate and among those capable of moving (Hughes 2000). Many upslope migrations have been observed among mountain zone plants as climate conditions move upslope (Figure 1.1-22).

In the Andes, trees are moving upslope at a rate of 2.5–3.5 vertical meters per year (Feeley and others 2011). Dramatic changes in the ranges of mammals (Maiorano and others 2011), birds (Stralberg and others 2009), invertebrates (King and others 2011), and others have been predicted around the world.

In Florida, sea grass communities are reorganizing their distributions as a result of tracking changes in freshwater availability (Herbert and others 2011). The distribution of mangroves (Figure 1.1-23) ebbs north and south along the Florida Peninsula determined by freeze cycles (Stevens and others 2006). However, if climate change causes winter freezes to become less common these native trees and their associated species may be able to move north replacing salt marsh on a more permanent basis (Stevens and others 2006). Changes in grasshopper species distributions along Florida's Atlantic coast have been observed resulting from phenological changes in salt marsh grass (Wason and Pennings 2008).

Figure 1.1-23. Mangrove. Photo: Katie Fuller.

Because species distributions are rapidly shifting under climate change (Solomon and others 2007, Rodder and Weinsheimer 2009, Murphy and others 2010), successful non-native species invasions will increase (Figure 1.1-24) (Walther and others 2009, Gold and others 2011). Successful invaders will outcompete native species and reduce biodiversity (Walther and others

2009). This negative influence will be magnified by the weakened state of many native species as they are stressed by climate changes (Walther and others 2009).

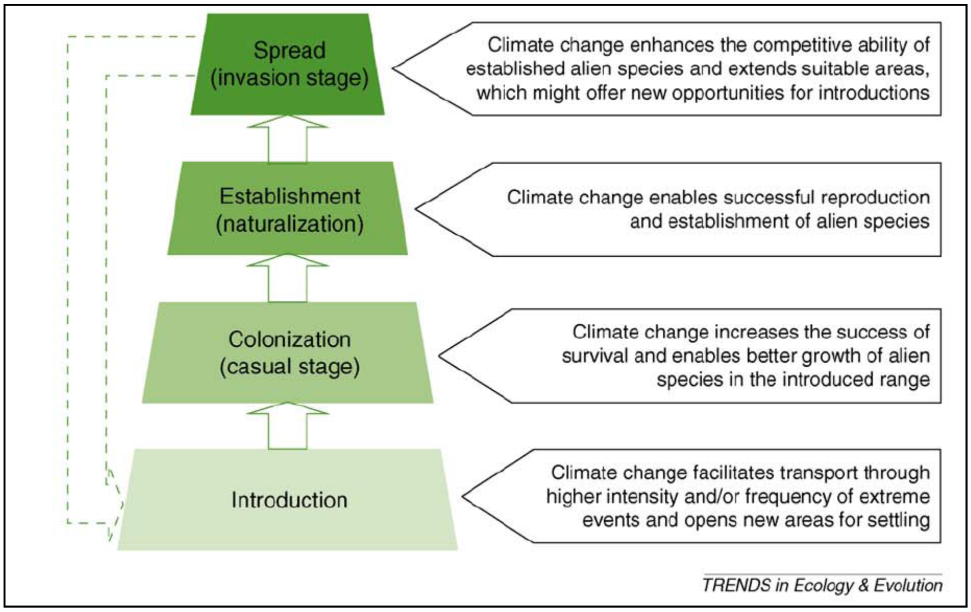


Figure 1.1-24. Influence of climate change on all the sequential transitions of a successful invasion process. From Walther and others (2009).

In Florida, non-native, invasive species are widespread. Many southern species are expanding north as temperatures rise (Walther and others 2009). It is estimated that 32.8% of all Florida plant species are non-native (Wunderlin and Hansen 2008), making it the second worst state for the number of nonnative plant species in the U.S. (Ward 1990). Hundreds of invasive wildlife species including reptiles, amphibian, avian, insect, and aquatic species have also established in Florida (Beck and others no date). Florida has the highest global number of invasive reptiles and amphibians (Krysko and others 2011).

Non-native, invasive species can cause widespread damage to Florida's native biodiversity through direct competition, spreading of disease, hybridization, predation, and other mechanisms. Warming air and water temperatures projected under climate change are expected to increase successful species invasions and subsequent spread (Walther and others 2009). For example, Cuban tree frogs (Figure 1.1-25) have spread across Florida from an introduction in the Keys in 1920's (Rodder and Weinsheimer 2009). The range of this species is expected to increase as a result of warming winters, leading to the spread across the entire state and beyond (Figure 1.1-26) in the next ten years (Rodder and Weinsheimer 2009).

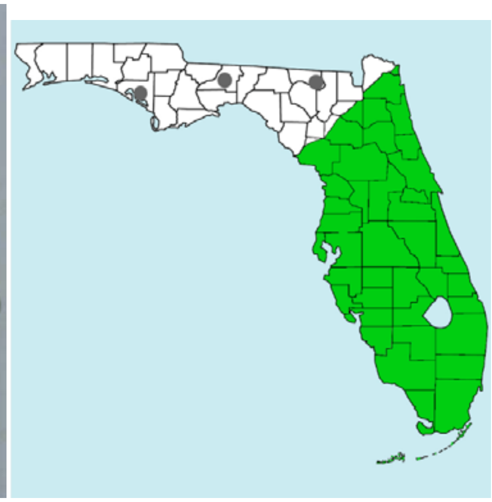


Figure 1.1-25. Cuban treefrog. Photo: Steve Johnson. 2010 distribution map. Map: Monica McGarrity.

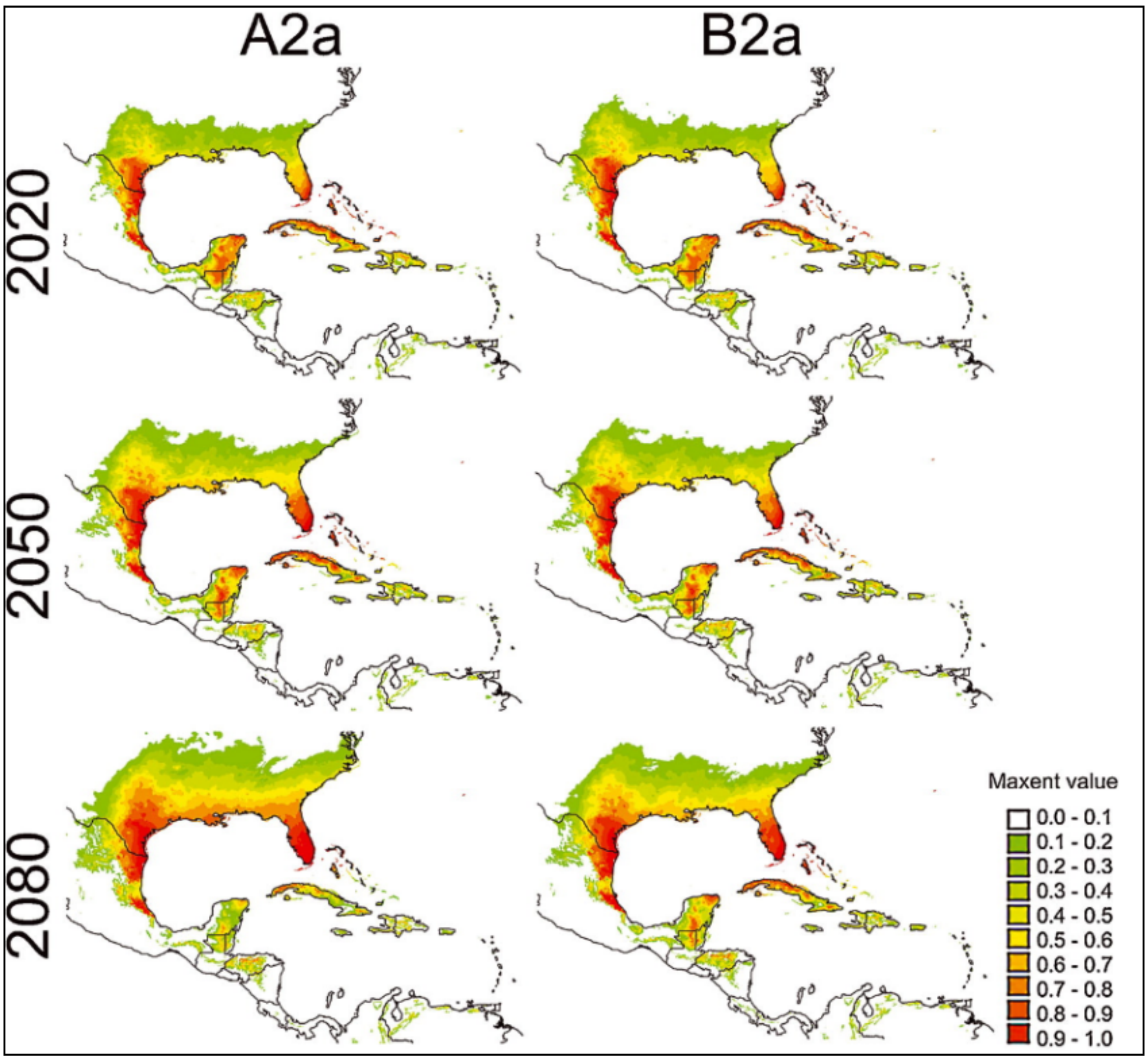


Figure 1.1-26. Maps of the potential distribution of Cuban tree frogs as expected for 2020, 2050 and 2080 assuming Intergovernmental Panel on Climate Change climate models A2a and B2a conditions. From Rodder and Weinsheimer (2009).

Cuban tree frogs outcompete native frogs for resources and also eat them, contributing to the decline of native Florida species (Rodder and Weinsheimer 2009, Johnson 2010). Another invasive species example is the Asian green mussel, which has successfully invaded South Florida and is advancing north with warming ocean temperatures (Urian and others 2011). Mayan cichlids, a freshwater fish, are also moving northward in Florida from an introduction in Florida Bay documented in the 1980's (Paperno and others 2008). In fact, many invasive fish species are established in Florida waters and more are expected with climate change (Idelberger and others 2011). There are many ways that fish and other wildlife species have been introduced to Florida; however, the exotic pet trade industry and release by pet owners is the largest source (Krysko and others 2011, FWC no date).

There are concerns about the expanding and expensive problem of invasive, non-native plant species in Florida. The Brazilian peppertree (*Schinus terebinthifolius*) is an invasive upland species that is prevalent across the state (Knight and others 2011). Originally introduced in South Florida from South America in the 1880's, it has escaped from cultivation and moved northward to the Florida/Georgia border. This range expansion in Florida exceeds the comparable latitude within the native range in the southern hemisphere (Mukherjee and others, in press). The Brazilian peppertree expansion in Florida is expected to continue and expand east into Texas and north into North Carolina (Mukherjee and others, in press). Old world climbing fern (*Lygodium microphyllum*) is another non-native, invasive species whose range is expanding along Florida's north-moving frost line (Knight and others 2011).

As many species distributions shift with climate change, the difference between "native" and "non-native" will be blurred. Range shifts in native species could be interpreted as invasions, potentially necessitating management action for the preservation of native biodiversity or a redefinition of what constitutes a native species. It will become more difficult to determine which species require management intervention and which are welcome changes. "Although this [challenge] cannot be an excuse to ignore current threats from alien species, plans to control them should consider the potential consequences that such control might also have for native species and ecosystems under climate change scenarios" (Walther and others 2009).

Phenology response

Changing patterns in climate are altering environmental cues that many species use to determine the timing of life cycle events (Hughes 2000). For example, leaf unfolding and flowering in many plants are associated with changes in air temperature (Menzel and Fabian 1999). Across thousands of species, there has been a documented advancement of the mean date of springtime wildlife activities by 2.3 days per decade (Parmesan and Yohe 2003). Arctic squirrels have been documented to come out of hibernation 9-13 days sooner than in the recorded past due to changes in snow melt (Sheriff and others 2011). Many bird species are changing their migration and breeding dates due to changing environmental cues (Goodenough and others 2010). Other examples are plentiful: the timing of vegetation development, spawning date in frogs and toads, return date of migrant butterflies, and egg hatching date in insects (Reviewed in Visser 2008). Unfortunately, phenological changes typically occur at the species level, often causing a mismatch in species interactions, such as predator-prey relationships, pollination, and competition (Hughes 2000). For example, some breeding birds have not been able to keep up with changes in the earlier springtime emergence of prey species, leading to reduced reproductive output (Goodenough and others 2010).

In Florida, some plant species have significantly delayed flowering due to later spring onset in Florida (Von Holle and others 2010). This response is in sharp contrast to the global trend for earlier flowering onset with increasing temperatures in the mid and upper latitudes. For example, the nonnative invasive tree Albizia (*Albizia lebbeck*) and native Sassafras (*Sassafras albidum*) have been recently observed to flower later (Figure 1.1-27) (Von Holle and others 2010). Delayed flowering is not widespread in Florida (Von Holle and others 2010), perhaps due to the complexity in temperature changes across the state (see above for more on temperature changes in Florida).

Figure 1.1-27. Sassafras, a tree found in Florida that is flowering later in response to climate change. Photo from Wikimedia commons.

This example displays the complex reaction among flora and fauna to changing seasonal cues under climate change. Von Holle and others (2010) suggest that Florida plants may have different reproductive cues that those in more northern climates. They postulate that the climate change-induced increase in the variability of the minimum temperature in the temperate-subtropical zone is the cause of delayed flowering in Florida plants. Some wildlife species, are matching global trends in advancing springtime activities. Green and loggerhead sea turtles median nest dates have become earlier over the last 20 years (Weishampel and others 2010).

Evolutionary response

Anthropogenic (and natural) climate change can also drive evolution and adaptation (Holt 1990). The changes in physiology, distribution, phenology discussed above may lead to rapid evolution in a species. Evolution is observed when the changes in a species, such as color or food choices, are heritable (Bradshaw and Holzapfel 2006), that is to say passed down genetically to decedents. These changes typically occur via phenotypic plasticity, which means that the expressed trait of a given gene (or set of genes) is flexible and can be expressed in many ways, such as color or breeding start date. However, variation only feeds evolution if one or few expressions of a gene translates into more reproductive success among those individuals with that expression. For example, Canadian red squirrels are reproducing earlier in the spring, thereby capitalizing on earlier spruce cone production (Réale and others 2003). Evolutionary change occurs in this species when the squirrels that reproduce earlier realized higher reproductive success due to more food availability that those that breed later, thus the genetic coding for this trait is passed to their offspring, leading to evolution in the species. It is crucial to realize that while selection for existing traits can occur relatively rapidly (e.g., several to 100's of generations), the emergence of novel traits that might be advantageous in a novel environment must rely on chance mutations which may take many hundreds of thousands of generations to occur. It is unclear and difficult to predict how many of today's species will have the ability to rapidly respond to climate change via evolution (Holt 1990) and some scientists speculate that it will be a minority (Williams and others 2008). Species with short generation times, large populations, and rapid population growth rates relative to climate change rates may have better chances for evolutionary adaptation. Climate change induced micro-evolution has been observed in color morphs in owls (Karell and others 2011), body sizes in lizards (Bell and others 2010), and phenological changes in mosquitoes, squirrels and birds (reviewed in Bradshaw and Holzapfel 2006). Most known changes have been related to seasonal timing, specifically season length or start (Bradshaw and Holzapfel 2006). In addition, there are more known evolutionary examples in northern latitudes, likely because seasonal changes are more extreme (Bradshaw and Holzapfel 2006). However, recent studies showing that tropical species may experience high levels of climate change impacts (Deutsch and others 2008) that could also lead to evolutionary adaptation by some species in the tropics as well.

Rapid adaptation in response to climate change does not ensure the long-term persistence of a species. Scientists studying the rapid change in the timing of springtime egg laying in birds found that while reproductive timing was evolving in response to earlier spring onset, it could not keep pace with changes in the availability of caterpillars, sending the entire population into decline (Nussey and others 2005).

Extinction

Polar bears (Durner and others 2011), sea turtles (Poloczanska and others 2009), pika (Beever and others 2011), golden frogs (Pounds and others 2006), harlequin frogs (Pounds and others 2006) are all species among a growing list that are predicted to go extinct as a result of climate change (Figure 1.1-28). Roughly a million species are thought to be at risk of extinction due to climate change (Thomas and others 2004).

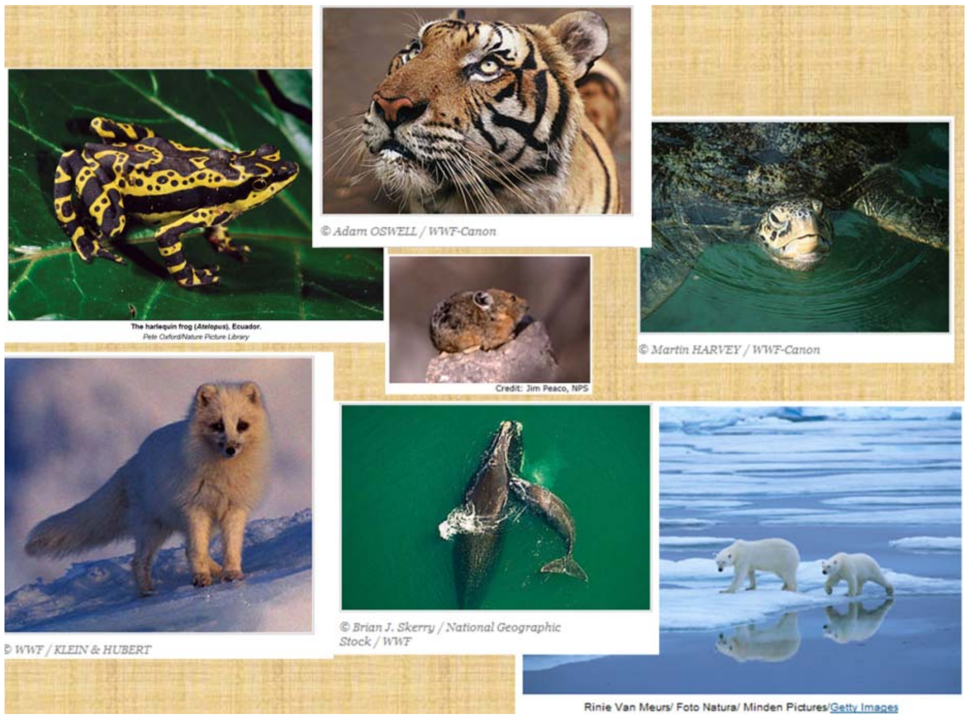


Figure 1.1-28. Species known to be at high extinction risk in part because of climate change. (clockwise from upper left: harlequin frog, Indochinese tiger, green sea turtle, polar bear, northern right whale, arctic fox and in the center: American pika.)

Because they are already in decline, species of current conservation concern are among the most imperiled by climate change (Pimm 2008). Florida Fish and Wildlife Commission has identified 1,033 species of greatest conservation need, of which 131 are state listed and 67 are federally listed endangered species (FWC 2011). The other 835 species are considered species of concern because they are rare, biologically vulnerable, keystone species or taxa of concern (FWC 2011). A more variable and changing environment, brought about under climate change will only aggravate stress on these vulnerable species. Climate change is considered one of the Florida Fish and Wildlife Conservation Commission’s greatest challenges in managing and conserving species of greatest conservation need (FWC 2011). In 2011, FWC revised the Florida State Wildlife Action Plan to incorporate climate change threats and needs.

"Climate change is placing immense pressure on the natural world, changing ecosystems and helping to drive a rising wave of extinctions that could end in the disappearance of one out of every four animals and plants species on the planet within the lifetimes of our children and grandchildren." - World Wildlife Fund, Available at: http://www.worldwildlife.org/climate/adaptation/species-impacts.html

There are a number of species life history characteristics that elevate extinction risk from climate change: ecothermic or "cold-blooded" species (Somero 2011), species with small ranges (Ohlemüller and others 2008), montane species (Engler and others 2011), tropical species (Deutsch and others 2008), high latitude species (Murphy and others 2010), species with small populations (Brattstrom 1970), island species (Maschinski and others 2011), species that live in extreme environments (Hughes 2000), marine species that use calcium carbonate (Doney and others 2009), endemic species (Maiorano and others 2011), coastal lowland species (Oetting and others 2010), and species with slow life history traits (Webb and others 2002). Many of these risk factors hold true for other anthropogenic stresses, such as habitat loss and not just climate change.

Because of the high number of endemic species and species of conservation concern, in combination with climate change threats, Florida is considered to have a very high number of species at risk of extinction due in part to climate change. These species include elkhorn coral (Figure 1.1-29), marine sea turtles, Key tree cactus, Key deer, Lower Keys marsh rabbit, Florida panther, Florida manatee, gopher tortoise, and a wide array of coastal species.

Figure 1.1-29. Elkhorn coral. Photo: www.diver_meg/Flickr.com.

Elkhorn coral represents a suite of coral reef species that are at great risk of extinction in part because of climate change (Burke and others 2011). The sensitivity of elkhorn coral is particularly worrisome as it functions as an ecosystem engineer, building structural habitat for all reef associated species (Burke and others 2011).

Because of Florida's extensive coastline and low topography, many species whose distributions concentrate in coastal habitats and therefore, are at high risk from rising sea levels (Figure 1.1-30).

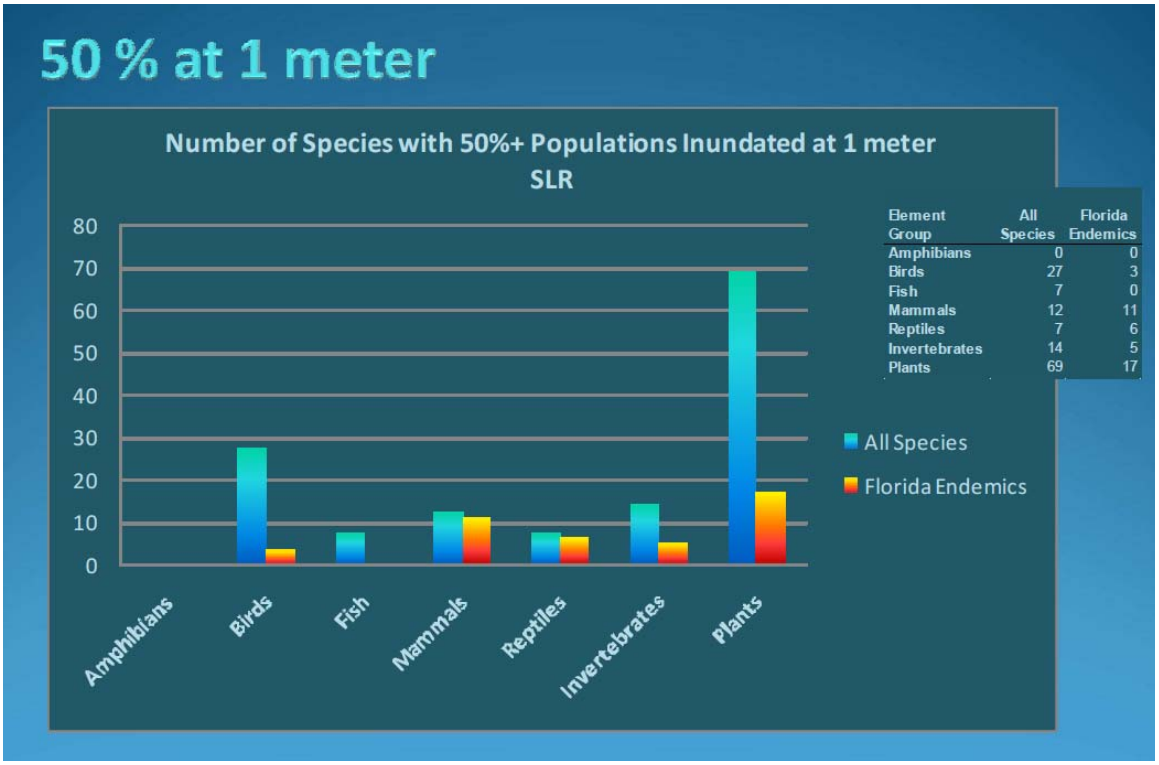


Figure 1.1-30. Number of Florida species with at least 50% of its population predicted to be inundated with a 1 meter sea level rise. From Oetting and others (2010).

Over 136 species, 42 of which are Florida endemics, are predicted to lose at least 50% of their population under a one meter sea level rise (Oetting and others 2010). Of course, higher sea level rise would increase the number of species affected.

> "climate change presents a significant threat to [Florida's] fish, wildlife, and natural ecosystems."- Florida Fish and Wildlife Commission 2011

Case study - Florida Keys Endemics at Risk

The Florida Keys have a large number of endemic species that are currently at high risk of extinction due to sea level rise and increased storm intensity (See Case Study 1.1-A). Salt water intrusion is the primary mechanism for habitat loss and change, leaving these species with no place to live. Evidence of the decline among rare species has already have been documented on the low-elevation islands of the Florida Keys. At risk species include Key tree cactus (*Pilosocereus robinii*); Big Pine partridge pea (*Chamaecrista lineata* var. *keyensis*); sand flax (*Linum arenicola*); Florida leafwing butterfly (*Anaea troglodyta f loridalis*); Key deer (*Oedocoileus virginianus clavium*); and Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*).

More information on this case study:

Maschinski J and others. 2011. Sinking ships: conservation options for endemic taxa threatened by sea level rise. Climatic Change 107(1-2): 147-167.

1.1.3. Special Topics

Synergism among biodiversity threats

The drivers of biodiversity loss do not act in isolation and multiple drivers often interact to magnify impacts (Pachauri and Reisinger 2007, Williams and others 2008, Secretariat of the Convention on Biological Diversity 2010). These interactions are likely to have large negative impacts on biodiversity (Williams and others 2008). For example, reduced freshwater inputs, storm impacts, and sea level rise interact to reduce oyster reefs along Florida's Big Bend coastline (Seavey and others 2011). Habitat fragmentation and changing climate regimes interact to limit the expansions of species (Walther 2010). For example, the endangered conifer *Torreya taxifolia*, found on Florida's panhandle, is limited by habitat fragmentation that is expected to make movement under a changing climate impossible (www.torreyaguardians.org). In addition, human migration away from Florida's heavily populated coastlines due to sea level rise could result in significant inland habitat loss and fragmentation further reducing the ability of native species to adapt to climate changes. The manner in which climate drivers act synergistically, including how humans adapt or manage themselves under changing climates, as well as changes in ecosystem processes will significantly influence biodiversity (Figure 1.1-31). Landscapes in Florida that are currently under greater levels of anthropogenic stress are at higher risk from the synergistic impacts of climate change. Coastal systems such as mangrove, salt marsh, oyster and coral reefs; agricultural landscapes; and low-lying islands are at particularly high risk (Pachauri and Reisinger 2007). Actions to protect valuable coastal property, such as construction of sea walls and bulkheads may exacerbate problems for coastal species by elimination coastal habitats and modifying littoral zones.

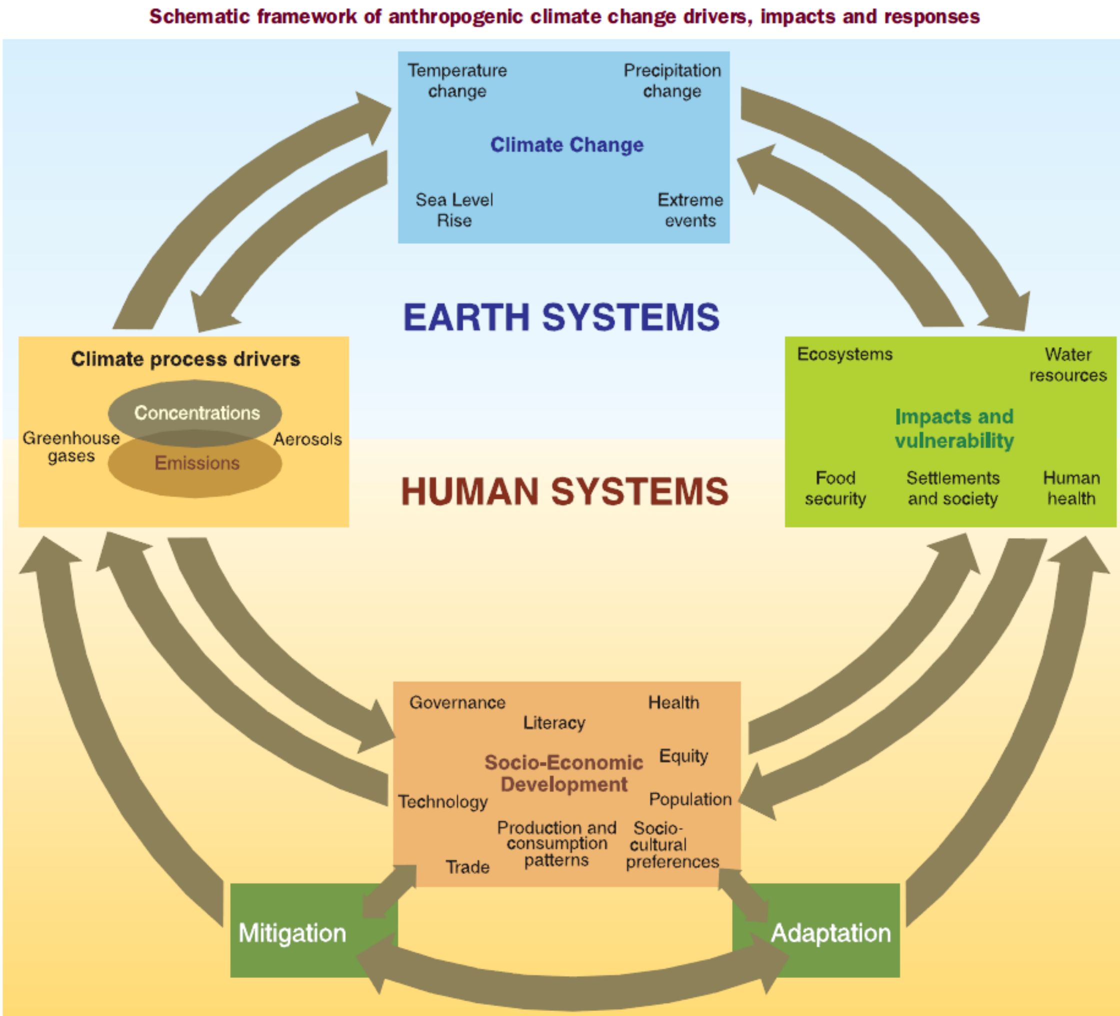


Figure 1.1-31. Framework of interactions between climate change, climate processes, impacts, and socio-economic development, with feedbacks between systems can occur along any of the green arrows. From Pachauri and Reisinger (2007).

> "No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future."- Williams and Jackson 2007

<u>No-analog ecological communities</u>

As individual species respond in unique ways to climate change, a reshuffling of ecological communities is likely. No-analog communities "result when species occur in combinations and relative abundances that have not occurred previously within a given biome" (Hobbs and others 2006). These no-analog communities are expected to alter biodiversity and ecological function (Hobbs and others 2006, Williams and Jackson 2007, Stralberg and others

2009, Wiens and others 2011). No-analog communities are expected to be more common in areas of large climate changes (Figure 1.1-32).

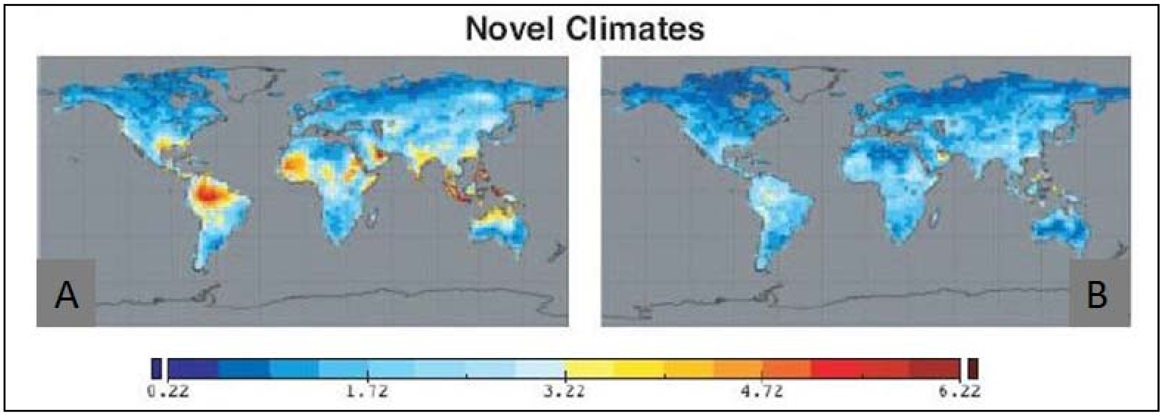


Figure 1.1-32. Analyses of Intergovernmental Panel on Climate Change climate-change scenarios (A2 and B1) suggest that climates with no modern analog may develop by the end of this century. From Williams and others (2007).

No-analog communities will not necessarily have negative consequences, but monitoring will be necessary to determine if desirable ecological services and biodiversity are maintained (Hobbs and others 2011). However, no-analog communities will be difficult to predict and plan for. This is because "most ecological models are at least partially parameterized from modern observations and so may fail to accurately predict ecological responses to these novel climates." (Williams and Jackson 2007) We discuss this challenge more in Chapter 2.1.

CHAPTER 2
2. Future Needs for Biodiversity Management and Conservation

> "We need to stand firm about the real complexity of biological systems and not let policy makers push us into simplistic answers..." - Camille Parmesan, quoted in The New York Times, April 4, 2011, article by Carl Zimmer.

Maintaining ecosystem resiliency is critical to ensure that Florida's biodiversity is able to cope with the inevitable changes associated with global climate change (Benson and Garmestani 2011, Mori 2011). Resilience is "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker and others 2004). Managing for resiliency in a changing climate does not necessarily imply that the current state or even the historic range of variability should be the end goal (Benson and Garmestani 2011). Rather, managing for resiliency aims to maintain ecological processes and functions that are critical to preserving biodiversity in the state of Florida.

Resiliency can be improved through Ecosystem Management (EM). In use since the 1980's, EM is a useful framework for managing the composition, structure, and function of natural ecosystems increasing resiliency (Meffe and others 2002, Grumbine 1994). EM is based on collaboratively established vision for future conditions that incorporates ecological, socioeconomic, and institutional needs (Figure 2-1).

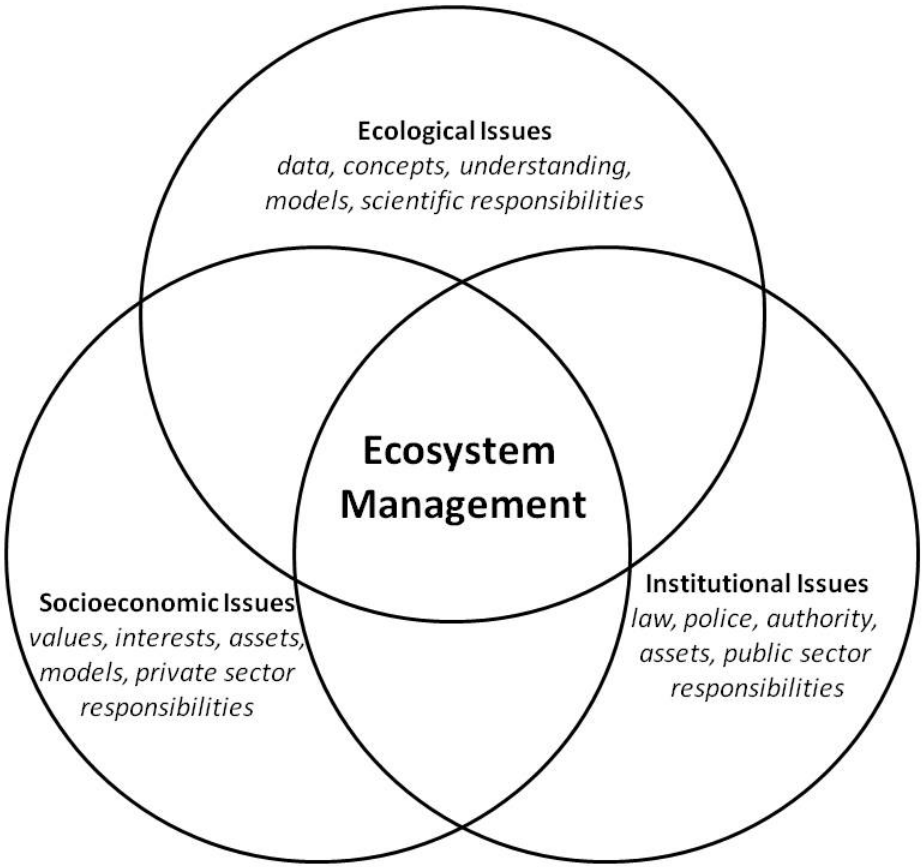


Figure 2-1.Three major contexts of ecosystem management. Adapted from Meffe and others (2002).

EM is not prescriptive in terms of the specific management actions, but is rather a framework for how to approach the integration of science, societal values, and management in a dynamic and flexible manner. Management dynamics and flexibility can be promoted through the use of Adaptive Management.

Adaptive management is an approach to natural resource management that emphasizes learning via treating management action as experiments; monitoring and evaluating the response to actions; and building management knowledge (Allen and others 2011, Meffe and others 2002). Adaptive management is a method for navigating what we know, as well as, what we don't in a learning framework to best inform and update management actions. Adaptive management in its most progressive form is called active adaptive management and it follows the format of a scientific experiment (Figure 2-2).

Figure 2-2. Active adaptive management cycle. From Conservation Measures Partnership (2007).

Active adaptive management begins with the conceptualization of a problem, in this case the threats to biodiversity stemming from climate change. This step needs to incorporate the viewpoints of both ecological and socio-economic stakeholders. The second step is devising an action plan(s), ideally outlining several management options with clearly defined goals and measurements of success. Several actions can be carried out at once to more quickly identify the best method for achieving goals. Clearly defining a monitoring plan aimed at examining the impact of actions is a critical component of step two. The implementation and monitoring of action is step three. Management can only be deemed a success or failure by carefully monitoring impacts of the action (Lawler 2009). Step four is a careful analysis of the monitoring data, followed by evaluation of results to redesign management actions for improved or further success. The final step is to document learning and share information so that progress can be achieved. This step should feed back into the first and thus, continue the iterative process of improving the management of biodiversity resiliency.

> Active adaptive management differs from scientific experimentation because the actions are conducted at a spatial scale relevant to management, represent real management options, and learning is directly relevant to future management decisions. It is most similar to scientific experimentation in that it requires rigorous design and analysis - Meffe and others 2002

Structured Decision Making is a form of active adaptive management that "brings transparency (by stating the objectives explicitly) and rigor (by developing models based on the best available science) to the decision process (Martin and others 2011). Structured decision making is useful because it provides a way to identify the optimal choice among several climate change scenarios and because it can also incorporate dynamic environmental situations, such as rising sea levels or air temperature (Martin and others 2011). Scenario building and comparison can not only incorporate multiple climate change trajectories but also explore how socio-economic and institutional factors will respond to a changing climate. Scenario comparison can be very useful in finding common ground and widely acceptable decisions in complex situations (Martin and others 2011, Vargas-Moreno and Flaxman 2011).

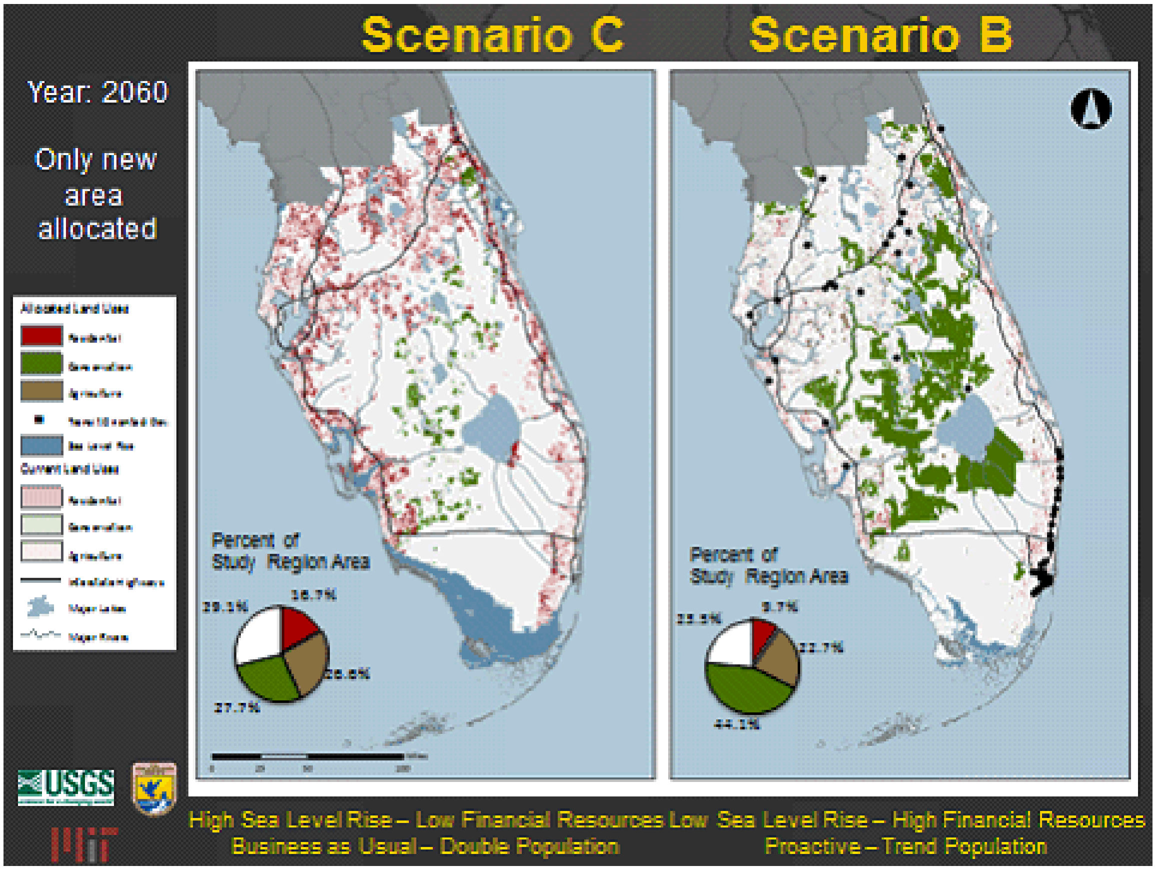


Figure: Snapshot of the output on the website: http://geoadaptive.com/everglades/mitse/bin-release/mitse.html for scenarios B and C. Scenario C being the best potential future with low sea level rise, a proactive government for conservation, good conservation funding and trend population development (A small amount less than doubling). This scenario is greatly different than B (High Sea Level rise, Business as usual government, low conservation funding and double population growth). The green lands represent potential future conservation needed to preserve critical ecosystems and landscape connectivity.

Most of the Florida's National Wildlife Refuges are located along the coast, where one meter of sea level rise is expected to result in significant inundation. In a joint effort between the U.S. Fish and Wildlife Service, U.S. Geological Service, and Massachusetts Institute of Technology, an assessment of the future distribution of species, habitats, and human development across a variety of different future scenarios for peninsular Florida is underway. Twenty-four scenarios were created by varying future levels of: climate change, shifts in planning approaches and regulations, population change, and variations in financial resources conservation.

These scenarios, or alternative futures, integrate the best available scientific information on climate change with local knowledge and expertise in order to create a suite of management-relevant scenarios for the region. Stakeholder-based scenarios were conceived not as blueprints for the future, but rather as learning tools for managing uncertainty. Three future time intervals were simulated for each scenario: 2020, 2040 and 2060. Each Alternative Future visualizes land use patterns and landscape transformations such as coastal inundation, urbanization, and infrastructure changes. Future changes in conservation lands are modeled and/or designed based on input from local experts and managers and using the best available ecological information and data. Conservation strategies were incorporated into the scenarios through using two state databases that identify lands of critical conservation importance of connectivity value.

In 2012, the scenarios will be extended to include the entire coastline in Florida and several more inland counties. This effort will inform the conservation planning effort under the Florida Beaches Habitat Conservation Plan. Additional elements will be added or improved in the scenario modeling, such as carbon sequestration and carbon accounting; more refined storm surge modeling; and species and habitats for the Florida Keys.

This scenario-based research investigation aims to better illustrate the challenges and future conditions decision-makers may need to consider in developing conservation strategies. The scenarios help managers understand the cumulative impacts of possible decisions across a range of scales and allow them to form partnerships they may need to better prepare for future changes. Once the simulations are complete, an online tool will also be available to aid decision-making by visualizing the scenarios and their potential impacts at the three time intervals. In short, the scenarios are intended to serve as learning and exploratory tools that enable conservation managers to better understand the different trajectories of change and the forces that shape them.

For more information:
Vargas-Moreno JC, Flaxman M. 2011. Participatory Climate change scenario and simulation modeling: Exploring Future Challenges in the Greater Everglades Landscape. Chapter 2 in Karl H, Scarlett L, Vargas-Moreno JC, Flaxman M(eds.). Restoring and Sustaining Lands. Springer, New York, New York.

2.1. Science Needs

"If ever there was a field in which policy ought to be guided by solid scientific knowledge, climate change is it." - Center for Urban and Environmental Solutions 2008

The application of active adaptive management to biodiversity conservation under climate change demands that science take a strong and direct role in management (Figure 1.3-2).

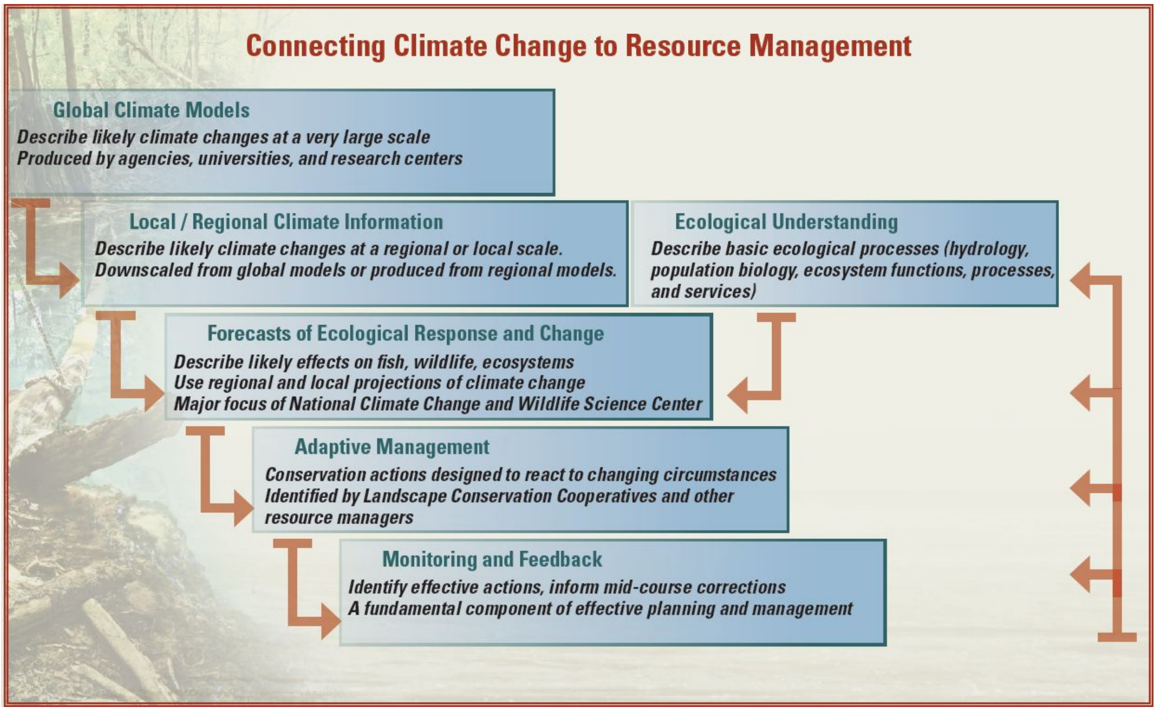


Figure 2.1-1. Integration of scientific information and application to conservation challenges raised by the Earth's changing climate as oulined by the National Climate Change and Wildlife Science Center. From USGS (2010).

Scientific research is a source for informing management strategeties and generating measurements of success. Improving application of research to biodiversity conservation under climate change could be strengthed via enhanced data quality and access, better ecological models, increased focus on broad patterns and trends, greater understanding of disturbance regimes and interacting drivers, and more focus on action-oriented research and monitoring programs.

<u>Climate models/physical drivers needs</u>

Having accurate climate models, built at a variety of spatial and temporal scales appropriate for assessment impacts on biodiversity in Florida, is essential to adequately assess the implications of climate change on biodiversity and develop management solutions. This topic is being addressed by Misra and others in the white paper entitled: *Climate scenarios: A Florida-*

centric view, so it will not be discussed further here (Available at: http://floridaclimate.org/docs/climate_scenario.pdf). However, updating abiotic data sets and increasing their availability to biologists and natural resource managers is a particular need that deserves highlighting. Data sets of particular interest in Florida include land cover maps, high precision elevation data (LiDAR) and hydrology models. Land cover maps should include human development scenarios under future climate conditions.

Biodiversity assessment needs

The measurement and predictions of impacts of climate change on biodiversity are very active fields of science. The methods of evaluation are rapidly evolving and constantly improving. Major areas for continued improvement include the further development of ecological models, especially species distribution and species interaction models; increased focus on general patterns and trends in climate change impacts on biodiversity; increased understanding of the changes in disturbance regimes under climate change; increased understanding regarding the interaction of climate change drivers; and improved efficiency and accessibility of monitoring data. To maximize usefulness of these assessments, standardized climate change scenarios should be used when possible.

Model improvement

Ecological modeling is one of the more comprehensive and flexible methods for predicting changes to biodiversity under future climate change scenarios (McMahon and others 2011). Species distribution modeling is commonly used to assess impacts on biodiversity (Thomas and others 2004, Schwartz and others 2006, Mateo and others 2011). This type of model has improved our understanding of potential trajectories of biodiversity under climate change. However, these models have also been highly criticized (Mateo and others 2011). The United Nation's Intergovernmental Panel on Climate Change specifically identified the failure of species distribution (specifically climate-envelope models and dynamic global vegetation models) to incorporate the range of processes known to influence species distributions (Solomon and others 2007).

Model improvement can be accomplished by incorporating a greater range of climate data and species interactions (Davis and others 1998, Williams and others 2007, Mateo and others 2011). Models that predict species ranges under changing climate conditions (species distribution models) typically incorporate contemporary observations to associate a species with a set of climate conditions and track them into the future. However, using only present day information may fail to predict ecological responses to the unique climates of the future (Williams and others 2007). Species may be able to adapt to future climates in novel ways that are not seen in today's data (Williams and Jackson 2007). Scientists should focus testing the robustness of models to climate conditions outside modern experience (Williams and others 2007). Model improvement could also be made by refocusing models to highlight sensitivity of species to climate changes instead of distribution prediction. Paleoecological information could be used more often to expand the range of the variation (Dawson and others 2011, McMahon and others 2011). Including species interactions is another way to improve prediction accuracy of future changes. Unfortunately, species interactions are often unknown or very complex and thus difficult to include for most species. In general, improved models will depend upon model development that incorporates biotic variables more effectively (Davis and others 1998). However, progress is likely as scientists are investigating methods for incorporating interactions

(Meier and others 2011), species traits (Syphard and Franklin 2010), physiologically based models (Kearney and Porter 2009), and abiotic interactions (Araujo and Luoto 2007).

Increased focus on general patterns and trends

While significant progress has been made to identify broad trends in the response of species to climate change (Parmesan and Yohe 2003, Chen and others 2011), more work is needed, especially in the areas outside of phenology and migration. Parmesan and others (2011) state that

> "It is rarely possible to attribute specific responses of individual wild species to human-induced climate change. This is partly because human forcing of the climate is only detectable on large spatial scales, yet organisms experience local climate. Moreover, in any given region, species' responses to climate change are idiosyncratic, owing to basic differences in their biology. A further complication is that responses to climate are inextricably intertwined with reactions to other human modifications of the environment."

Another reason to focus on broad trends and patterns is that a species-by-species approach will be extremely time consuming in a world with at least nine million species (Sweetlove 2011). This is not to say that species-specific approaches will not be extremely useful in some cases, and evaluation of likely responses of individual species may be valuable for species that are highly sensitive to impact, those with state and federal listing status, and those that serve as keystone species, whose sustainability positively facilitates the persistence of other species.

Improved understanding of disturbance regimes

The UN's Intergovernmental Panel on Climate Change identified the "neglect of changing disturbance regimes" as a critical science need (Solomon and others 2007). Climate change will alter many disturbance regimes and may move systems in novel and perhaps unexpected directions (Turner 2010, Westerling and others 2011). Shifting disturbance regimes is likely to produce dramatic changes in ecosystems (Turner 2010). For example, the wildfire regime in Europe is currently changing, fires are now negatively affecting larger areas than they did historically, leading to changes in impacts of wind and pests that are having lasting impacts on forest systems (Seidl and others 2011). In Alaska, climate-driven increases in size and frequency of fire in the tundra is significantly increasing carbon loss and may accelerate atmospheric greenhouse gas accumulation (Mack and others 2011). Turner (2010) recommends that science address: "disturbances as catalysts of rapid ecological change, interactions among disturbances, relationships between disturbance and society, especially the intersection of land use and disturbance, and feedbacks from disturbance to other global drivers."

Improved understand of interacting drivers

The UN's Intergovernmental Panel on Climate Change Fourth Assessment Report states that one of the critical challenges to identifying impacts of climate change on biodiversity is a lack of understanding of interaction among biodiversity drivers, especially interactions involving land management (Solomon and others 2007). This need will be especially great as humans adapt in novel ways to a changing climate. In Florida, human migration, increased use and production of biofuels, shifts in agricultural land use, and changes in water use are expected under climate change and will interact to influence biodiversity. Effective management of biodiversity requires an understanding of these feedbacks. For example, scientists have found that resiliency of Australian coral reefs to climate change impacts is directly tied to the level of recreational and commercial fishing pressure in the area (Salt 2009). This interaction results from a climate change driven algae bloom among reefs, which kills coral when left unchecked. Reducing fishing puts coral reefs in a more resilient position to adapt to other climate changes, such as increased bleaching. This example emphasizes the connections between climate change and other human drivers of biodiversity and the need to make holistic assessments of biodiversity changes over time.

Biofuels. Photo: Wikimedia Commons.

Biofuels are a new priority in the efforts to reduce the use of fossil fuels. Unfortunately, the production of biofuels may threaten biodiversity (Groom and others 2008). Corn was an early biofuel option for the production of ethanol; however, recent criticism over its production methods, net emissions, and costs are decreasing its popularity (New York Times 2011). More recently, biofuels made from plant wastes or grown from non-food related crops are gaining attention (Times 2011). Many biofuels, such as oranges, tobacco, and sugar cane have been proposed and are under development in Florida. Determining the best biofuels for Florida is not an easy task because each has its own set of costs and benefits. For example, proposed species such as Jatropha and castor beans have the potential to become invasive (Gordon and others 2011). Two studies provide guidance in biofuel evaluation. Scharlemann and Laurance (2008) recommend a standardized approach to the comparison of greenhouse gas emissions and overall environmental impact of all the various biofuels to enable more effective cost/benefit analysis. Groom and others (2008) offer three guidelines for reducing biofuel production threats to biodiversity: 1) biofuel resources should be grown with biodiversity-friendly agricultural practices, 2) the land area needed to grow sufficient quantities of the resource should be minimized, and 3) biofuels that can sequester carbon should be given high priority.

More information:

Groom MJ and others. 2008. Biofuels and biodiversity: Principles for creating better policies for biofuel production. Conservation Biology 22(3): 602-609

Improved efficiency and accessibility of monitoring data

One of the greatest needs in the science of assessing impacts of climate change to biodiversity is long-term monitoring data. The analysis of long-term data is critical to identification of patterns of change among species and communities (Hughes 2000). The National Science Foundation has recognized this need and is actively developing the National Ecological Observation Network (NEON) project, the nation's first continental-scale ecological observatory. This observatory will include 62 sites across the United States aimed at gathering continental-scale data for a 30-year time period. Information collected will include land cover, climate change variables, invasive species and biodiversity data. The information gathered from this project will help scientists to observe climate change impacts across spatial and temporal scales. Florida is fortunate to have a permanent NEON observatory located within the state, at the University of Florida's Ordway-Swisher Biological Station located outside Melrose and a 5 year site at the Disney Wilderness Preserve near Poinciana. Another long-term data monitoring project called the Florida Coastal Everglades Long-Term Ecological Research Network, was initiated in 2000. This program is gathering data on hydrology, climate, and human activities with the aim of identifying changes in the Florida Coastal Everglades (FCE LTER 2011). Archbold Biological Station may possess the longest time series dataset for scrub habitat in Florida as monitoring began there in the 1930's (www.archbold-station.org). While these efforts and others like them are extremely valuable, they do not fill all long-term data required for a clear assessment of impacts of climate change on biodiversity in Florida. Data gaps include poor geographic coverage of monitoring sites in some high-diversity biomes, including grasslands, coastal and marine systems; key taxonomic and functional groups, such as, soil microbial, and many invertebrate communities (McMahon and others 2011).

Improved data accessibility and standardization of protocols would facilitate wider use in the scientific community and advance our understanding of the impacts of climate change. Data accessibility is critical as not every scientist has the good fortune of working in association with a long-term monitoring program. Enhancing access to the data from these programs would promote multiple assessments, repeatability, and improved adherence to the scientific process of discovery. The scientific discovery process relies on transparency in data, methodology, and analysis. Further, the broad scale nature of global climate change impacts requires that multiple data set sources be integrated to increase the spatial or temporal scale of analysis. Standardization of monitoring methodology, such as that implemented by the NEON project, will improve the compatibility of data.

"We need to give nature the opportunity to respond" - Dr. Pearson, quoted in The New York Times, April 4, 2011, article by Carl Zimmer.

Case Study - Designing monitoring plans for adaptive management

Photo: Wikimedia Commons

Eyre and others (2011) proposed a framework for adaptive management monitoring of Australian rangeland that is informative to monitoring Florida ecosystems in the face of climate change. Their framework applies a hierarchical approach:

1. Targeted monitoring; involving localized field-based monitoring of target species, addressing specific management questions.
2. Surveillance monitoring; involving broad-scale, field-based sampling of multi-taxa and a set of habitat and condition attributes.
3. Landscape-scale monitoring; providing regional to national-scale intelligence on habitat quality and trends in threats to or drivers of biodiversity, with data obtained using systematic ground-based and remote methods.

The framework aims to provide information on the response of biodiversity to management actions that is relevant to regional, state and national jurisdictions. The characteristics of the framework addresses many of the pitfalls that often stall biodiversity monitoring: clarification of the desired outcomes and management requirements; a strong collaborative partnership that oversees the administration of the framework and ensures long-term commitment; a conceptual model that guides clear and relevant question-setting; careful design and analysis aimed at addressing the set questions; timely and relevant communication and reporting; and, regular data analysis and review, providing an adaptive mechanism for the framework to evolve and remain relevant.

More information/Adapted from:

Eyre TJ, Fisher A, Hunt LP, Kutt AS. 2011. Measure it to better manage it: a biodiversity monitoring framework for the Australian rangelands. The Rangeland Journal 33: 239–253

2.2. Management Needs

Active adaptive management is widely recommended for addressing the management of biodiversity in the face of global climate change in Florida (CUES 2008) and elsewhere (Heller and Zavaleta 2009, Mawdsley and others 2009, Allen and others 2011, Benson and Garmestani 2011). One of the greatest challenges to the application of active adaptive management is that it advovcates that managers become more experimental and flexiable. A flexible and experimental approach can be fostered through improved data management, taking action despite scientific uncertainity, increasing public outreach, enhanced partnership building, enhanced definitions of biological significance, and improved institutional acceptance of ecosystem dynamics. There are also several specific strategies that can be implemented to promote the conservation of biodiversity in the face of climate change, which are discussed below.

Data/information management

Management can be improved with improved access to data and importantly, scientific interpretations of data for management needs. As mentioned above, science needs more standardized long-term data and better access to data. Natural resource management should recognize the importance of data to the adaptive management process and support data collection through funding, logistical assistance, and data management. Further, the review and dissemination of scientific research needs to be enhanced to ensure that all stakeholders involved in the management process have the most up-to-date information and strategies for conserving Florida's biodiversity.

Taking action in spite of uncertainty

Science will not be able to keep pace with demands of management and will never completely understand all aspects of biodiversity impacts from climate change. Adaptive management is specifically designed to allow for management decisions in the face of uncertainty and incomplete knowledge. This is what is meant by the experimental approach. Adaptive management is a means to a clearer understanding of management actions and direction. In addition, Meffe and others (2002) present several ideas for dealing with uncertainty. First, employ as many people as possible to think holistically about biodiversity impacts from climate change. Second, develop ecological models that directly inform management and uncertainty. Third, allow for buffers in management decisions. Fourth, make sure monitoring is in place before actions are carried out to allow for attribution of changes to action and knowledge with which to inform management redirection.

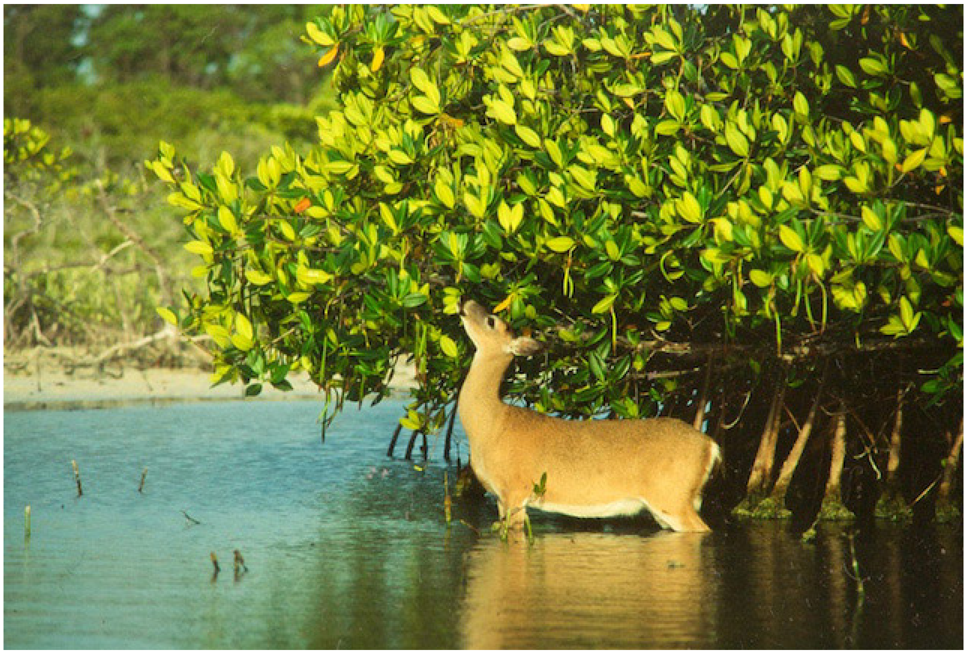


Photo: Bill Keogh

The Key deer, a subspecies of the white tailed deer, is the smallest deer race in North America. This federally endangered species eats a variety of plant species, especially red mangrove, on low-lying islands of the Florida Keys. Listed as an endangered species in 1967, the population is estimated to be 500-700 individuals and is considered stable under current conditions. Among the many threats to the population's long-term viability is sea level rise, which will impact the distribution, abundance, and availability of limited freshwater wetlands that are critical for survival (USFWS 2010). Translocation has been considered as an option to increase the resiliency of this species. Efforts in the early 2000's that used holding pens to accumulate deer into their new areas for 3-6 months were deemed successful after an eight month period. The success of these efforts suggests that pending the availability of suitable habitat, assisted migration could be a viable option for this species. It would be ideal to keep deer in the original historic range to reduce the risk of adverse species interactions with other species in the translocation areas. There is evidence to suggest that habitat does exist on islands in the Florida Keys that is not fully used by deer (Watts and others 2008). There may also be opportunities for moving key deer to other Caribbean islands if no local deer and suitable habitat is available. Of course, an assessment of the potential impact of deer on local species would be necessary before such actions could be recommended.

More information:
Parker ID, Watts DE, Lopez RR, Silvy NJ, Davis DS, McCleery RA, Frank PA. 2008. Evaluation of the efficacy of Florida key deer translocations. Journal of Wildlife Management 72(5): 1069-1075.

Public outreach/ values

Despite overwhelming scientific consensus, the public continues to lag in its acceptance and understanding of climate change. In 2010, 29% of 1,000 respondents in a nationwide survey said that they believed that climate change was an unproven theory and 49% believe that science has serious doubts about climate change (Virginia Commonwealth University 2010). Many Americans believe that science is not trustworthy when it comes to reporting about climate change (Borick and others 2011). Further, while many Americans believe that wildlife and natural resources will suffer negative impacts from climate change, they do not believe that there is connection between the health of natural resources and the quality of their own live or those of other Americans in their lifetime (Leiserowitz and others 2011). Management can and will suffer because the public does not support or understand the reasons for climate change action.

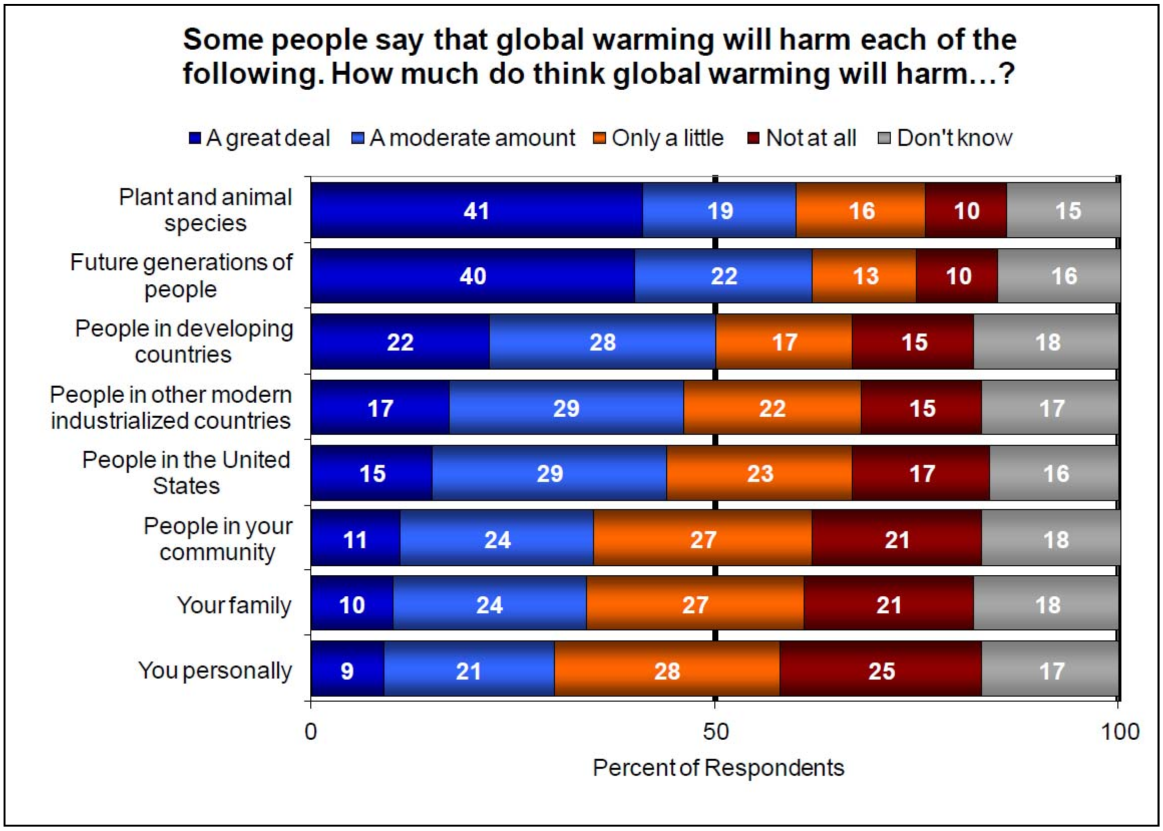


Figure 2-1. Survey results from a Yale University study of 1,000 Americans regarding the question on the relative harm to people and natural resources from global warming. From Leiserowitz and others (2011).

Fortunately, Floridians are more likely than the average American citizen to believe that climate change is happening and believe it is having important impacts on Florida's biodiversity (Leiserowitz and Broad 2009). Floridians also believe that the government should be doing more to address threats from climate change (Leiserowitz and Broad 2009). Managers should capitalize on the interests of Florida's citizens in climate change. For effective management to be carried out in an experimental format, the public will need to understand active adaptive management and support specific actions. Managers can facilitate this by requiring public reporting by scientists, public data repositories to promote transparency, and creating more opportunity for citizens to be participants in monitoring programs and the ecosystem management process.

Partnership building

Because climate change will influence the spatial distribution of species, partnerships across agency, political, and land ownership lines will need to be enhanced (Griffith and others 2009, Heller and Zavaleta 2009). For example, the California State Legislature created the San Francisco Bay Restoration Authority. This authority facilitates across agencies to protect marshes and wetlands in the San Francisco Bay area in part because of threats from climate change. State and national level agencies are in the best position to facilitate such cooperative efforts (Griffith and others 2009).

Conserving all of biodiversity

Biodiversity conservation frequently focuses on species hotspots, which are places of especially high number of species (Hodgson and others 2009). The conservation of biodiversity would benefit from a holistic approach that focuses are regions that represent the range of biological units (e.g., ecosystems, genes, ecosystem processes) that contribute to biodiversity (see Figure 1.0-1). While it makes sense to ensure that places with a large number of species, especially endemics, are conserved, in the long run, species will move and they will move at different rates (Parmesan and Yohe 2003, Hodgson and others 2009). This diversity of movement direction and rates may lead to the cooling of particular species hotspots. Rather than just focusing on areas with high numbers of species, it is important to protect a balanced portfolio of biodiversity's component features to ensure long-term persistence of a wide variety of natural systems (Hodgson and others 2009).

Accepting dynamic systems

Two traditional conservation principles that are likely to reduce biodiversity conservation effectiveness under a changing climate are 1) "maintain existing or past community composition," and 2) use "permanently fixed conservation targets (e.g., 10% of given habitat in a preserve)" (Hodgson and others 2009). Both of these principles assume that ecological communities function as a stable unit and that stability is good for conservation. However, ecological communities are dynamic in nature and ecological disturbances are often responsible for generating and maintaining biodiversity (Reviewed in Turner 2010). The response of species to climate change tends to occur at an individual level and not at the level of ecological communities (Hodgson and others 2009). This individual shifting allows for the reshuffling of ecological communities and thus creates the opening for biodiversity building and maintenance. Because of the important role of disturbance dynamics to biodiversity, management should resist trying to maintain the status quo of a landscape or ecosystem. This is especially challenging in light of endangered species legislation as it calls for the maintenance of individual species. Thus, careful evaluation of when and where to attempt to maintain existing communities is required.

Management recommendations for managing dynamic ecosystem change induced by climate change:

- "Management objectives may have to be reconsidered more frequently than under more stable conditions."
- "The set of potential actions may also have to be adapted over time as conditions change."
- "(System) models have to account for the nonstationarity of the modeled system processes."- Martin and others 2011

Strategies for promoting biodiversity

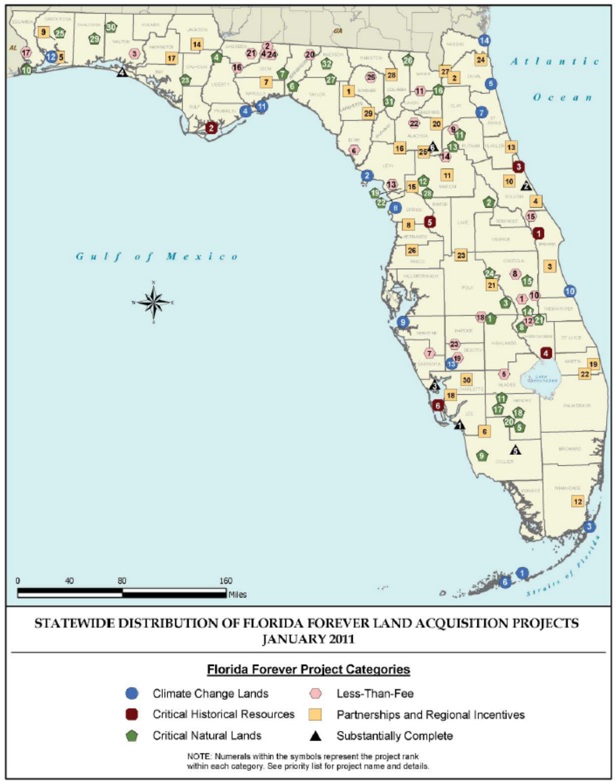
There are several strategies for promoting biodiversity in the face of global climate change that should be highlighted for management consideration. Many of the strategies focus on managing for expected changes in species distributions. Strategy development should reach beyond these spatial considerations and include species interaction and temporal needs. The strategies outlined here are not meant to serve as an exhaustive list, but as a baseline for innovation.

State policy proposals for promoting biodiversity

1) Permanently establish the Florida Forever Program through constitutional amendment with a dedicatedrevenue source;
2) Extend and expand support for the Century Commission's Critical Lands/Waters Identification Project, the Florida Natural Area Inventory, and the Cooperative Conservation Blueprint;
3) Develop a comprehensive research and practitioner training program in climate change adaptive management;
4) Develop a climate protection and adaptation strategy for the Florida Keys;
5) Expand and permanently fund the Florida Coastal Ocean Observing System, and the Florida Oceans and Coastal Resources Council;
6) Establish a cap-and-trade policy;
7) Reassess Florida's beach management strategies, including devising a plan for relocating some beach developments, where retreat is the optimal choice.

Adapted from: Center for Urban and Environmental Solutions 2008

A basic starting place for any natural resource conservation strategy is the protection of high quality habitat, as it is considered both fundamental and highly effective (Hodgson and others 2009, Hodgson and others 2011). In addition, this strategy is considered a low risk, with little chance for unintended negative consequences (Lawler 2009). "Retaining as much high quality natural and semi-natural habitat as possible should remain the key focus for conservation, especially during a period of climate change." (Hodgson and others 2011) Since habitat area is critical to maintaining biodiversity, the promotion of land conservation is prudent. It is important to keep in mind that in the face of the habitat changes that climate change will bring, preserves cannot be static and management strategies need to focus on ways to expand their holdings. "Species will not be able to survive where they are or shift their distributions to new climatically suitable areas unless there is sufficient habitat" (Hodgson and others 2009).



Florida Forever's 2011 land acquisition priority plan. Climate change adaptation/mitigation priorities shown as blue circles. From FDEP (2011).

Florida Forever is a state program for land acquisition and natural resource management. Overseen by the Florida Department of Environmental Protection, it is one of the most ambitious conservation and recreation land acquisition programs in the United States. The focus of the land acquisition program is to preserve critical natural lands. The program prioritizes land purchases with best available science, ranking them in terms of functional landscape-scale natural systems, intact large hydrological systems, significance for imperiled natural communities, and corridors linking large landscapes (FDEP 2011). In 2008, climate change mitigation/ adaptation value was added to the ranking criteria. This category prioritizes "lands where acquisition or other conservation measures will address the challenges of global climate change, such as through protection, restoration, mitigation, and strengthening of Florida's land, water, and coastal resources"(FDEP 2011). This new "Climate Change Lands" category is aimed at acquiring lands to sequester carbon, provide habitat, protect coastal lands or barrier islands. It has a special focus on providing sea level rise migration corridors.

More information:

Florida Department of Environmental Protection (FDEP) 2011. Florida Forever Five Year Plan. May 2011. Prepared for the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida. Available at:
http://www.dep.state.fl.us/lands/FFAnnual/FINAL%20REPORT%20FF%20-%20May2011.pdf

Increasing or restoring species migration corridors is the most widely promoted climate change adaptation strategy in the scientific literature (Heller and Zavaleta 2009, Hodgson and others 2009). The popularity of this recommendation stems from the concern over expected range shifts. The use of agricultural and urban lands for corridors; the removal of dispersal barriers, such as roads and culverts; decreasing the distances between reserves; creating buffer zones around reserves; longitudinal orientation of corridors; protecting riparian habitat and railway lines in cities; creating corridors that connect coastal and inland habitats; and habitat restoration are all actions under the broad goal of increasing movement options for species (Heller and Zavaleta 2009). Fortunately, Florida does have a history and head start in migration corridor conservation and protection in the Florida Ecological Greenways Network and related programs and initiatives. This network should be supported and enhanced.

Related to the promotion of migration corridors is assisted migration. Assisted migration calls for human intervention in facilitating movement of species in the case where migration corridors do not exist or the species lacks the ability to move on its own (Appell 2009). The recommended methodology for assisted movement of species is to mimic their natural dispersal characteristics as closely as possible which typically includes moving individuals from the leading edge of their current distribution northward (Vitt and others 2009). The use of this strategy is considered especially desirable where human land use has isolated a species from potential dispersal pathways (Vitt and others 2009). However, assisted migration is controversial because of concerns raised over the effectiveness, cost and the potentially negative impacts on other species in the relocation area (Appell 2009, Lawler 2009). While scientists should carefully evaluate risks and managers should monitor the ethical and legal validity of such intervention, this strategy can be an effective tool for preventing species extinction (Sax and others 2009, Schwartz and others 2009) in more extreme situations.

Case Study - Assisting the migration of a rare Florida tree

Photo: Constance Toops

The Florida torreya (*Torreya taxifolia*) is the world's most endangered conifer (The Nature Conservancy 1997). Native only to a 65-kilometer length of the Apalachicola River in the Florida Panhandle, the species began to decline in the 1950s, probably because of fungal pathogens, and is thought to be "left behind" in a habitat refuge that has prevented its migration northward. While scientists debate the reasons why this species cannot make its own migration north in the face of climate change, The Torreya Guardians (a private citizens group), are attempting “assisted migration” for the species. The group has been cultivating and planting individual trees north, into North Carolina and Georgia, since the 1990's. The group’s actions to assist the migration of this endangered tree has generated much controversy. Many scientists do not believe that this particular species should be moved because they argue that more locally-based methods for increasing torreya populations exist and would be more effective (Schwartz 2005). In addition, scientists worry that assisted migration puts individuals at the transplantation site at risk for new diseases, pests, and other unintended consequences. However, not assisting these trapped species puts them at high risk for extinction. Many ecologists recommend careful use and study of this climate change management tool.

Adapted from/more information:

Appell D. 2009. Can assisted migration save species from global warming? Scientific American March 3, 2009. Available at: http://www.scientificamerican.com/article.cfm?id=assited-migration-global-warming

Another strategy for biodiversity conservation in the face of climate change is to reduce other anthropogenic threats to biodiversity (Parmesan and Yohe 2003, Heller and Zavaleta 2009, Hodgson and others 2009). This is another management strategy with low risk of unintended negative impacts (if at all) (Lawler 2009). The mitigation of other threats, such as invasive species, habitat fragmentation, and pollution will serve to decrease the level of additional stress on species from climate change (Parmesan and Yohe 2003). Often, the impacts from these other threats and how to manage them are better understood than climate change impacts and thus, will provide more conservation value for the dollar (Hodgson and others 2009). "In some instances, mitigating known threats other than climate change may be sufficient to permit a population to persist, even if the local climate has deteriorated." (Hodgson and others 2009) For example, along Florida's coast there is growing scientific evidence that freshwater input is important to the resilience of several wetland ecosystems (Williams and others 2003, Seavey and others 2011), thus restoring freshwater hydrology may decrease or slow impacts from sea level rise. In another example, reducing the threat of invasive species in South Florida is likely to relieve pressure on native species, thereby increasing the chance that they can adapt to changing hydrological regimes and sea level rise (Steve Johnson, University of Florida, personal communication).

Whatever actions are taken, they should begin today and be carefully integrated into a framework of adaptive and ecosystem management. Ecological systems are changing and time is of the essence in the maintenance of biodiversity and ecosystem function (Heller and Zavaleta 2009).

> "Humans have adapted to changing climatic conditions in the past, but in the future, adaptations will be particularly challenging because society won't be adapting to a new steady state but rather to a rapidly moving target."-Karl and others 2009

Florida has the largest number of established non-indigenous herpetofaunal species in the USA. Despite current state laws that make it illegal to release any non-indigenous animal in Florida without first obtaining a permit from state, enforcement is difficult, and no person has ever been prosecuted for the establishment of a non-indigenous animal species in Florida. Because current state and federal laws have not been effective in curtailing the ever-increasing number of illegal introductions, laws need to be modified and made enforceable. At the very least, those responsible for introductions should be held accountable for clean up of those species for which they are responsible. Lastly, the creation of an Early Detection / Rapid Response program would serve to quickly identify newly found introduced species for eradication attempts. Many Cooperative Invasive Species Management Areas (CISMAs) in Florida include Early Detection/Rapid Response as one of their goals. Public/private partnerships provide for joint efforts to track and remove early problematic species on both public and private lands, thus leveraging funding and manpower

Adapted from/more information:

Krysko K and others. 2011. Verified non-indigenous amphibians and reptiles in Florida 1986 through 2010: Outlining the invasion process and identifying pathways and stages. Zootaxa 3028: 1-64.

CHAPTER 3
3. Economic Opportunities

Figure 3-1. Vintage Florida postcard,. Photo from Wikimedia commons.

Numerous direct economic benefits are associated with conserving Florida's natural resources, such as tourism, recreation, and fisheries (Figure 3-1). In addition, Florida's biodiversity and natural systems provide significant ecosystem services including freshwater filtration and storage, timber production, pollination, carbon storage, and a reduction in the effects of climate change (TNC 2009b). Climate change is anticipated to reduce or eliminate some of these ecosystem services resulting in a net negative effect (Mooney and others 2009). Implementing strategies to mitigate impacts on Florida's ecosystems is recommended to reduce biodiversity loss, as well as maintain vital ecosystem services and economic benefits for Florida's citizens. As previously mentioned, adaptive management can be cost effective way to reduce the negative impacts of climate change on Florida's natural systems.

Florida's tourism industry contributes approximately $65 billion annually to the economy (Visit Florida 2011) and natural resources are one of the major attractions for visitors. Recreational activities such as hiking and nature viewing provide approximately $1 billion annually through the Florida State Park System (FWC 2005). In a given year, Florida's fishing industry can create more than 500,000 jobs, $12.7 billion in wages, and $3.1billion towards state revenues (National Ocean Economics Program 2004).

Florida's coast provides approximately $11 billion annually in coastal protection from storms, with coastal wetlands serving as "horizontal levees" against hurricanes (TNC 2009b). Mangrove forests block wave action via their trunk and root systems during storm surges (Dahdouh-Guebas 2006). In South Florida, the Everglades function as major carbon sink, offsetting CO_2 atmospheric emissions, and are a major freshwater source for the state (Mulkey and others 2008).

As detailed in earlier sections, climate change is currently affecting natural systems in Florida, and these effects are expected to intensify. As conservation management resources are often severely limited (Lawler 2009), efficiency is critical. To increase efficiency, individual projects should be prioritized by weighing the effects of climate change on the ecosystem in conjunction with the value of the ecosystem, species or populations (Lawler 2009). The use of active adaptive management to maintain Florida's critical ecosystems will benefit both humans and biodiversity. For example, preserving and/or restoring coastal wetlands and mangrove forests will mitigate the negative effects of sea level rise on human systems. In another example, maintaining hydrological flows and therefore the wetland habitats of the Everglades can provide valuable freshwater and carbon storage for human benefit. Effective adaptive management aimed at minimizing negative climate change impacts can only be achieved by funding land acquisition (including easements), restoration, and others methods of habitat protection, as well as monitoring programs, scientific analysis, ecological modeling and the full process of the adaptive management experimental learning process. Creative new financial incentives to landowners should be explored and developed in an adaptive management framework. Such funding is likely to increase the overall efficiency of conservation and maintenance of ecosystem services by prioritizing actions with the greatest success and benefit to both humans and biodiversity.

CHAPTER 4

4. Administrative Challenges to Biodiversity Management and Conservation

There are several administrative challenges that currently inhibit the effectiveness of adaptive management. Challenges can be broadly categorized as logistical, communication, attitudinal, institutional, conceptual, and educational (Jacobson and others 2006).

Logistical barriers include a lack of funding, time, goals and staff to implement adaptive management (Jacobson and others 2006). Lack of funding and staff often cited as a barrier to management progress (Jantarasami and others 2010). Monitoring and analysis is often the largest cost of the adaptive management process. Scientists and managers need work together to develop lower-cost monitoring programs with a focus on methodology that could be carried out by citizens and stakeholder groups (Keith and others 2011). In addition, ill-designed programs may waste money through monitoring "things that are irrelevant or insensitive to system response, at levels of precision that are unnecessary" (Keith and others 2011). Again, careful design can improve efficiency.

Time concerns are also critical in addressing climate change impacts. Climate changes are happening at a rapid pace and are expected to accelerate (Solomon and others 2007). Management, stakeholders, and science will need to work together to aggressively experiment with management innovations. Large government agencies often find change difficult (Jantarasami and others 2010) and tend to try one new idea at a time (Keith and others 2011). Multiple management strategies will need to be addressed simultaneously to optimize implementation and to keep up with biodiversity needs.

Communication barriers include a need for external collaborative partnerships, improved stakeholder support and communication, improved scientific communication with managers (Jacobson and others 2006). Keith and others (2011) reviewed a number of strategies for building more cooperation among stakeholders including building a hierarchy of management objectives, economic incentives for cooperation, and ongoing negotiation among stakeholders. Stakeholder involvement early in the management process and improved education for all parties can alleviate some conflict.

Attitudinal barriers include a lack of stakeholder respect for each other's opinions and values, a lack of faith in the process, and lack of value in monitoring programs. One reason managers and scientists often misunderstand each other is due to self-serving behavior. "Scientists often oversell their ability to model and predict policy consequences, and sometimes use policy demands to pursue discovery goals that may never be applied to decision making" (Keith and others 2011). Conversely, managers often ignore scientific uncertainty in order to simplify communication with stakeholders and then blame the scientific community for failure (Keith and others 2011). Unfortunately both actions cause misunderstanding and mistrust of both science and adaptive management. The lack of support and value of monitoring programs is a significant barrier as adaptive management relies on scientific evaluation (Meffe and others 2002).

Institutional barriers include the culture of stakeholder groups, lack of team building support, lack of flexibility within institutional mandates. Stakeholder groups, even those with institutions, often are not formed in a collaborative framework, which is helpful for group learning in adaptive management (Jacobson and others 2006). Allen and others (2011) suggest arenas in which management can focus on building collaborations to increase adaptive management effectiveness: (1) assessment teams, made up of stakeholders across sectors in a social-ecological system; (2) non-governmental organizations, which create an arena for trust-building, learning, conflict resolution and adaptive co-management; and (3) the scientific community, which acts as a "watchdog," as well as a facilitator, for adaptive management.

Conservation legislation can also form an institutional barrier, hindering active adaptive management for climate change impacts on biodiversity. This is due to the single-species and specific location and/or habitat focus of many laws, especially endangered species and wilderness legislation at both the federal and state levels (Jantarasami and others 2010). State and federal agencies need to update interpretation and implementation of these laws to incorporate a dynamic approach to climate change management.

Finally, conceptual and educational barriers include a lack of clear understanding of adaptive management and the steps of the process, as well as a lack of training in associated disciplines. Adaptive management is relatively new and thus is not consistently defined (Jacobson and others 2006). The relative youth of the adaptive management process also leads to a lack of understanding among stakeholders that is needed to effectively pursue this management framework (Jacobson and others 2006).

> "I can tell you with assurance that global, sweeping, concerted actions is needed now, there is no time to waste" - UN Secretary-General Ban Ki-Moon. 2007. Chemical and Engineering News 85(48):7

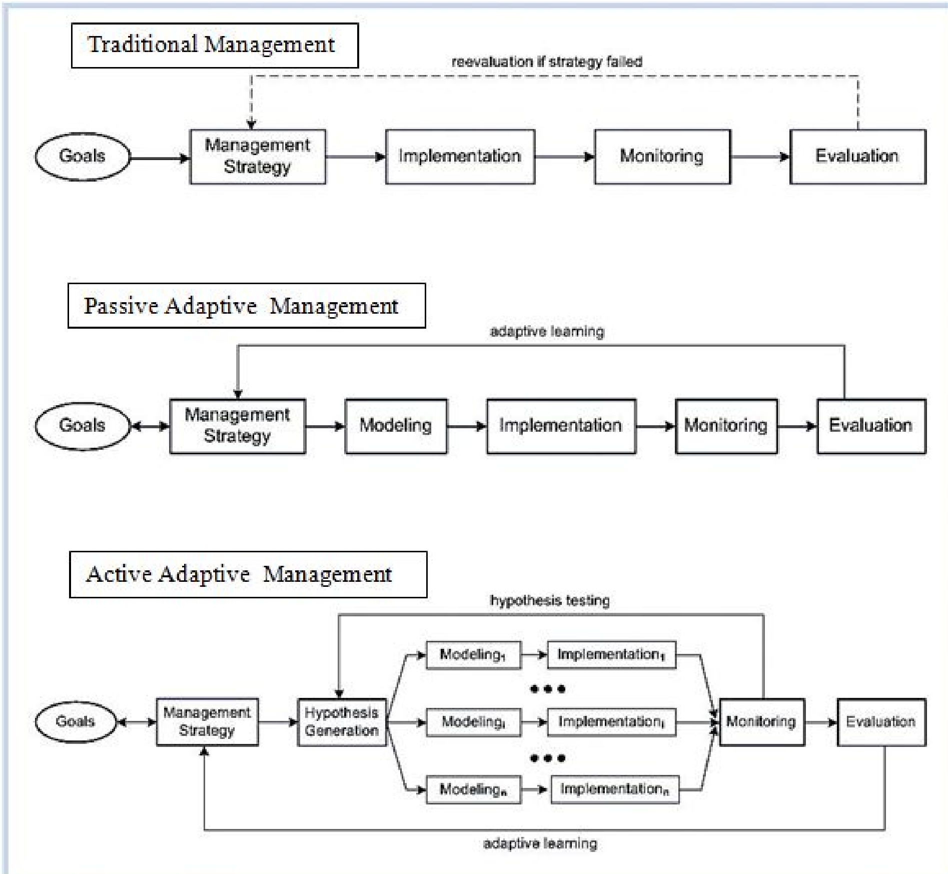


Figure from Linkov and others (2006).

Based on a review of 100 case studies, Walters (2007) found that most adaptive management programs have failed. Failure stemmed from a lack of experimental approach and serious problems with monitoring programs if implemented at all. Walters (2007) identifies three main reasons for widespread difficulties in adaptive management programs:

1) Lack of monitoring resources needed to carry out large-scale experiments;
2) Unwillingness by decision makers to admit and embrace uncertainty in making policy choices; and
3) Lack of leadership in the form of individuals willing to do the hard work needed to plan and implement new and complex management programs.

The most important of these three issues has been lack of leadership to carry out the complicated administrative steps involved in moving a new management vision into actual field practice. The single most important component that proponents of adaptive management must learn to do in the future is to learn how to identify and nurture such leaders.

Adapted from:

Walters CJ 2007. Is adaptive management helping to solve fisheries problems? Ambio 36(4): 304-307.

CHAPTER 5
5. Conclusions

Florida has abundant and unique biological resources that are expected to be negatively affected by global climate change. In fact, Florida is at particularly high risk for climate change impacts because of its low topography, extensive coastline, and the frequency of large storm events. Climate change is already making large sweeping changes to Florida's landscape, especially along the coasts. The drivers of this change are both physical and biological in nature. Changes in air and water temperature, freshwater availability, salt water intrusion, ocean acidification, natural disturbance regime shifts (e.g., fire, storms, flood), and loss of land area have already been observed in Florida. Florida's average air temperature has increased at a rate of 0.2 - 0.4^{0}C per century over the past 160 years and is expected to increase around another 5^{0}C by 2100. Rainfall in Florida has generally increased by 10% over the last 120 years, and more frequent heavy precipitation events are expected in the future. Both globally and in Florida, ocean pH has been lowered 0.1 unit since the pre-industrial period and another 0.3–0.5 pH unit drop is predicted by 2100. Many of Florida's disturbances regimes such as algae blooms, wildfires, hypoxia, storms, droughts and floods, diseases, pest outbreaks are already showing signs of change. Finally, Florida's sea level is currently rising at 1.8-2.4 mm per year and may rise by another meter by 2100.

> "Florida faces some of the most direct, immediate, and severe effects from climate change as beach and sea interact in more than one thousand miles of treasured coastline" - Center for Urban and Environmental Solutions 2008

Florida's biodiversity is already responding to climate change through changes in physiology, distribution, phenology, and extinction. Physiological stress is being observed among marine species through increased pathogens and in reduced rates of calcification, photosynthesis, nitrogen fixation, and reproduction brought on by increased acidity. Northward movement is becoming more common as a result of temperature shifts. Unfortunately, for Florida species movement brings increased risk for invasions by non-native species, such as the Cuban treefrog. Turtle nesting and tree flowering dates are starting to shift earlier in time to keep pace with increasing temperatures in Florida. Climate change also brings elevated extinction risks for Florida's numerous endemic species and species of conservation concern.

Maintaining species and ecosystem resiliency is critical to conserving Florida's biodiversity, and active adaptive management can serve as a framework to achieve this goal. The application of adaptive management demands that science take a leading role in management. As we have outlined here, the scientific research needs are to improve ecological modeling methodology and application; focus more on general climate change impacts patterns and trends; improve the understanding of disturbance regimes and the interactions of climate drivers; and enhance monitoring programs. Resource management can have a leading role, especially in embracing an experimental and flexiable approach. Support is also needed for managers to improve data management and infrastructure; embrace and work openly with uncertainity, engage in more climate change related public outreach; and reach out to other management agencies across political and bureaucratic boundaries. Management and science together need to promote the conservation of habitat; create migration corridors;; consider the use of assisted migration and other adaptation strategies; reduce other anthropogenic threats to biodiversity and promote stragety development that is both creative and experimental.

Fortunately, there are numerous agencies, institutions, and scientists in Florida that can facilitate both improved scientific research and management of climate change impacts on biodiversity. Federal programs such as the White House's Interagency Climate Change Adaptation Task Force and the Department of Interior's Landscape Conservation Cooperatives are being implemented to enable holistic adaptive management across state borders. Within Florida, The Fish and Wildlife Commission, Water Management Districts, and Florida Oceans and Coastal Council should continue to work across county and habitat borders with Florida research scientists and non-profit organizations to promote active adaptive management approaches to protecting biodiversity. These local, state and federal partners and resources are listed in Appendix 2.

Numerous direct economic benefits are associated with conserving Florida’s natural resources, such as tourism, recreation, and fisheries. In addition, Florida’s biodiversity and natural systems provide significant ecosystem services and aesthetic values that benefit all the citizens of Florida. To develop effective active adaptive management in Florida, several administrative challenges need to be addressed such as current interpretation of legislation, lack of funds, stakeholder conflict, self-serving behavior, and the pace of change. "The challenge to researchers is to shift their focus from discovery to the science of implementation, while managers and policy-makers must depart from their socio-political norms and institutional frameworks to embrace new thinking and effectively utilize the wealth of powerful new scientific tools for learning by doing" (Keith and others 2011). Structured and transparent decision making can unlock these options for science and management to effectively address Florida's biodiversity conservation in the face of climate change.

CHAPTER 6

6. Literature Cited

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Appendix 1- Lists of Species of Conservation and Management Concern

A1.1. FWC Managed Species List

American Alligator
American Crocodile
Bald Eagle
Black Bear
Freshwater Turtles (18 species)
Gopher Tortoise
Manatee
Florida Panther
Sea Turtles
Waterfowl (including Mottled Duck, Wood Duck, 20 species of Winter and Migratory Waterfowl, Mallard)
White-tailed Deer

A1.2. FWC Nonnative Species List

(known to be "established" and breeding in Florida)

Mammals:

House Mouse
Black Rat
Norway Rat
Nine-banded Armadillo
Coyote
Red Fox
Sambar Deer
Pallas Mastiff Bat
Rhesus Monkey
Mexican Red-billed Squirrel
Vervet Monkey
Squirrel Monkey
Elk
Nutria
Capybara
Gambian Pouch Rat
Feral Cats

Birds:

Scarlet Ibis
Muscovy Duck
Purple Swamphen
White-winged Dove
Chestnut-fronted Macaw
Budgerigar
Monk Parakeet
Hill Myna

Reptiles:

Red-eared slider
Spectacled Caiman
African Redhead Agama
Giant Ameiva
Brown Anole
Hispaniolan Green Anole
Puerto Rican Crested Anole
Largehead Anole
Bark Anole
Knight Anole
Cuban Green Anole
Jamaican Giant Anole
Brown Basilisk
Oriental Garden Lizard
Rainbow Lizard
Giant Whiptail

Mexican Spinytail Iguana
Black Spinytail Iguana
Tokay Gecko
Tropical House Gecko
Common House Gecko
Mediterranean Gecko
Indo-Pacific Gecko
Green Iguana
Northern Curlytail Lizard
Red-sided Curlytail Lizard
Butterfly Lizard
Many-lined Grass Skink
Giant Day Gecko
Texas Horned Lizard
Ocellated Gecko
Ashy Gecko
Nile Monitor
Common Boa
Burmese Python
Brahminy Blind Snake
Amphibians:
Cuban Treefrog
Giant Toad
Greenhouse Frog
Coqui
Fish:
Black Acaria
Butterfly Peacock
Jaguar Guapote
Spotted Tilapia
Blue Tilapia
Clown Knifefish
Mayan Cichlid
Suckermouth Catfish
Brown Hoplo
Common Carp
Midas Cichlid
Swamp Eel
Bullseye Snakehead
Grass Carp
Oscar
Walking Catfish
Piranha
Lionfish
+ may species of plants

A1.3. Florida's Endangered and Threatened (Imperiled) Species List

Common Name	Scientific Name	Status
FISH		
Atlantic sturgeon	*Acipenser oxyrinchus*	SSC
Blackmouth shiner	*Notropis melanostomus*	ST
Bluenose shiner	*Pteronotropis welaka*	SSC
Crystal darter	*Crystallaria asprella*	ST
Gulf sturgeon	*Acipenser oxyrinchus [=oxyrhynchus] desotoi*	FT
Harlequin darter	*Etheostoma histrio*	SSC
Key silverside	*Menidia conchorum*	ST
Lake Eustis pupfish	*Cyprinodon hubbsi*	SSC
Okaloosa darter	*Etheostoma okalossae*	FE
Rivulus	*Rivulus marmoratus*	SSC
Saltmarsh topminnow	*Fundulus jenkinsi*	SSC
Shortnose sturgeon	*Acipenser brevirostrum*	FE
Smalltooth sawfish	*Pristis pectinate*	FE
Southern tessellated darter	*Etheostoma olmstedi maculaticeps*	SSC
AMPHIBIANS		
Florida bog frog	*Lithobates okaloosae*	SSC
Frosted flatwoods salamander	*Ambystoma cingulatum*	FT
Georgia blind salamander	*Haideotriton wallacei*	SSC
Gopher frog	*Lithobates capito*	SSC
Pine barrens treefrog	*Hyla andersonii*	SSC
Reticulated flatwoods salamander	*Ambystoma bishopi*	FE
REPTILES		
Alligator snapping turtle	*Macrochelys temminckii*	SSC
American alligator	*Alligator mississippiensis*	FT(S/A)
American crocodile	*Crocodylus acutus*	FT
Atlantic salt marsh snake	*Nerodia clarkii taeniata*	FT
Barbour’s map turtle	*Graptemys barbouri*	SSC
Bluetail mole skink	*Eumeces egregius lividus*	FT
Eastern indigo snake	*Drymarchon corais couperi*	FT
Florida brownsnake1	*Storeria victa*	ST
Florida Keys mole skink	*Eumeces egregius egregius*	SSC
Florida pine snake	*Pituophis melanoleucus mugitus*	SSC
Gopher tortoise	*Gopherus polyphemus*	ST
Green sea turtle	*Chelonia mydas*	FE
Hawksbill sea turtle	*Eretmochelys imbricata*	FE
Kemp’s ridley sea turtle	*Lepidochelys kempii*	FE
Key ringneck snake	*Diadophis punctatus acricus*	ST
Leatherback sea turtle	*Dermochelys coriacea*	FE
Loggerhead sea turtle	*Caretta caretta*	FT
Peninsula ribbon snake1	*Thamnophis sauritus sackenii*	ST

Red rat snake1	*Elaphe guttata*	SSC
Rim rock crowned snake	*Tantilla oolitica*	ST
Sand skink	*Neoseps reynoldsi*	FT
Short-tailed snake	*Stilosoma extenuatum*	ST
Striped mud turtle1	*Kinosternon baurii*	ST
Suwannee cooter	*Pseudemys suwanniensis*	SSC

BIRDS

American oystercatcher	*Haematopus palliatus*	SSC
Audubon's crested caracara	*Polyborus plancus audubonii*	FT
Bachman's wood warbler	*Vermivora bachmanii*	FE
Black skimmer	*Rynchops niger*	SSC
Brown pelican	*Pelecanus occidentalis*	SSC
Burrowing owl	*Athene cunicularia*	SSC
Cape Sable seaside sparrow	*Ammodramus maritimus* mirabilis	FE
Eskimo curlew	*Numenius borealis*	FE
Everglade snail kite	*Rostrhamus sociabilis plumbeus*	FE
Florida grasshopper sparrow	*Ammodramus savannarum* floridanus	FE
Florida sandhill crane	*Grus canadensis pratensis*	ST
Florida scrub-jay	*Aphelocoma coerulescens*	FT
Ivory-billed woodpecker	*Campephilus principalis*	FE
Kirtland's wood warbler	*Dendroica kirtlandii*	FE
Least tern	*Sterna antillarum*	ST
Limpkin	*Aramus guarauna*	SSC
Little blue heron	*Egretta caerulea*	SSC
Marian's marsh wren	*Cistothorus palustris marianae*	SSC
Osprey	*Pandion haliaetus*	SSC
Piping plover	*Charadrius melodus*	FT
Red-cockaded woodpecker	*Picoides borealis*	FE
Reddish egret	*Egretta rufescens*	SSC
Roseate spoonbill	*Platalea ajaja*	SSC
Roseate tern	*Sterna dougallii dougallii*	FT
Scott's seaside sparrow	*Ammodramus maritimus peninsulae*	SSC
Snowy egret	*Egretta thula*	SSC
Snowy plover	*Charadrius alexandrinus*	ST
Southeastern American kestrel	*Falco sparverius paulus*	ST
Tricolored heron	*Egretta tricolor*	SSC
Wakulla seaside sparrow	*Ammodramus maritimus juncicola*	SSC
White-crowned pigeon	*Patagioenas leucocephala*	ST
Whooping crane	*Grus americana*	FE(XN)
White ibis	*Eudocimus albus*	SSC
Worthington's marsh wren	*Cistothorus palustris griseus*	SSC

Wood stork	*Mycteria americana*	FE

MAMMALS

Anastasia Island beach mouse	*Peromyscus polionotus phasma*	FE
Big Cypress fox squirrel	*Sciurus niger avicennia*	ST
Caribbean monk seal	*Monachus tropicalis*	FE
Choctawhatchee beach mouse	*Peromyscus polionotus* Allophrys	FE
Eastern chipmunk	*Tamias striatus*	SSC
Everglades mink	*Neovison vison evergladensis*	ST
Finback whale	*Balaenoptera physalus*	FE
Florida black bear3	*Ursus americanus floridanus*	ST
Florida mastiff bat	*Eumops glaucinus floridanus*	ST
Florida mouse	*Podomys floridanus*	SSC
Florida panther	*Puma [=Felis] concolor coryi*	FE
Florida salt marsh vole	*Microtus pennsylvanicus dukecampbelli*	FE
Gray bat	*Myotis grisescens*	FE
Gray wolf	*Canis lupus*	FE
Homosassa shrew	*Sorex longirostris eonis*	SSC
Humpback whale	*Megaptera novaeangliae*	FE
Indiana bat	*Myotis sodalis*	FE
Key deer	*Odocoileus virginianus clavium*	FE
Key Largo cotton mouse	*Peromyscus gossypinus allapaticola*	FE
Key Largo woodrat	*Neotoma floridana smalli*	FE
Lower Keys rabbit	*Sylvilagus palustris hefneri*	FE
North Atlantic right whale	*Eubalaena glacialis*	FE
Perdido Key beach mouse	*Peromyscus polionotus trissyllepsis*	FE
Red wolf	*Canis rufus*	FE
Rice rat	*Oryzomys palustris natator*	FE1
Sanibel Island rice rat	*Oryzomys palustris sanibeli*	SSC
Sei whale	*Balaenoptera borealis*	FE
Sherman's fox squirrel	*Sciurus niger shermani*	SSC
Sherman's short-tailed shrew	*Blarina carolonensis shermani*	SSC
Southeastern beach mouse	*Peromyscus polionotus niveiventris*	FT
Sperm whale	*Physeter catodon [=macrocephalus]*	FE
St. Andrew beach mouse	*Peromyscus polionotus peninsularis*	FE
West Indian manatee	*Trichechus manatus*	FE

INVERTEBRATES

CORALS		
Elkhorn coral	*Acropora palmate*	FT
Pillar coral	*Dendrogyra cylindricus*	ST
Staghorn coral	*Acropora cervicornis*	FT
CRUSTACEANS		
Black Creek crayfish (Spotted royal crayfish)	*Procambarus pictus*	SSC
Panama City crayfish	*Procambarus econfinae*	SSC
Santa Fe Cave crayfish	*Procambarus erythrops*	SSC
Squirrel Chimney Cave shrimp	*Palaemonetes cummingi*	FT
INSECTS		
American burying beetle	*Nicrophorus americanus*	FE
Miami blue butterfly	*Cyclargus thomasi bethunebakeri*	ST
Schaus' swallowtail butterfly	*Heraclides aristodemus ponceanus*	FE
MOLLUSKS		
Chipola slabshell (mussel)	*Elliptio chiplolaensis*	FT
Fat threeridge (mussel)	*Amblema neislerii*	FE
Florida treesnail	*Liguus fasciatus*	SSC
Gulf moccasinshell (mussel)	*Medionidus penicillatus*	FE
Ochlockonee moccasinshell (mussel)	*Medionidus simpsonianus*	FE
Oval pigtoe (mussel)	*Pleurobema pyriforme*	FE
Purple bankclimber (mussel)	*Elliptoideus sloatianus*	FT
Shinyrayed pocketbook (mussel)	*Lampsilis subangulata*	FE
Stock Island tree snail	*Orthalicus reses*	FT

List Abbreviations:
FWC = Florida Fish and Wildlife Conservation Commission
FE = Federal Endangered
FT = Federal Threatened
ST = State Threatened
SSC = State Species of Special Concern
F(XN) = Federally listed as an experimental population in Florida
FT(S/A) = Federally Threatened due to similarity of appearance

A1.4. FWC Priority Habitats

Coral reef
Softwater Stream
Sandhill
Spring and Spring Run
Scrub
Submerged Aquatic Vegetation

Appendix 2- Resources for Biodiversity Management

Taking an adaptive, ecosystem-based management approach to preserve biodiversity in the face of climate change will require a broad scale effort, undertaken at all levels of management. Federal, state, and local resources will be called upon to gather information, educate private and public sectors, promote proactive management ideas and tools, carry out actions, and evaluate progress.

Fortunately, there are numerous agencies, institutions, and scientists addressing biodiversity needs in Florida and beyond that can be utilized to assist management in the face of climate change. The challenge is identifying who is doing what and how the various sources of information and support can work together. Ultimately, meeting the needs of biodiversity in the face of a rapidly changing climate will require the collaboration of biodiversity management agencies at every level of government and across a wide array of scientists and policy specialists.

"I am persuaded that global climate change is one of the most important issues that we will face this century. With almost 1,200 miles of coastline and the majority of our citizens living near that coastline, Florida is more vulnerable to rising ocean levels and violent weather patterns than any other stat...Florida will provide not only the policy and technological advances, but eh moral leaderships, to allow us to overcome this monumental challenge." - Governor Charlie Crist at his July 2007 Serve to Preserve Summary on Global Climate Change.

A2.1. Federal Agencies

National Fish, Wildlife and Plants Climate Adaptation Strategy

The National Fish, Wildlife, and Plants Climate Adaptation Strategy is currently being developed with input from a broad range of federal, state, and tribal partners, with active engagement with non-government organizations, industry groups, and private landowners. This effort is the result of a congressional mandate passed in 2010 to develop a national strategy for dealing with climate change. It is chaired by U.S. Fish and Wildlife Service, National Ocean and Atmospheric Administration, and New York Division of Fish, Wildlife, and Marine Resources.

Website: http://www.wildlifeadaptationstrategy.gov/index.php

Contact:
Office of the Science Advisor
Attn: National Fish, Wildlife, and Plants Climate Adaptation Strategy
U.S. Fish and Wildlife Service

4401 N. Fairfax Drive, Suite 222
Arlington, VA 22203

Interagency Climate Change Adaptation Task Force

Co-chairs of the Climate Adaptation Task Force include White House Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA). This group is comprised of over 200 federal agency staff. The group issues recommendations to President Obama for how Federal Agency policies and programs can better prepare the United States to respond to the impacts of climate change.

Website: http://www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation

U.S. Global Change Research Program

The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes in the global environment and their implications for society. The mission of this program is to build a knowledge base that informs human responses to climate and global change through coordinated and integrated federal programs of research, education, communication, and decision support.

Website: http://www.globalchange.gov

Contact:
U.S. Global Change Research Program
Suite 250
1717 Pennsylvania Ave, NW
Washington, DC 20006

The US Global Change Research Information Office

A program within the USGCRP, this office provides access to data and information on climate change research, adaptation/mitigation strategies and technologies, and global change-related educational resources on behalf of the various US Federal Agencies that are involved in the US Global Change Research Program.

Website: http://www.gcrio.org/

Contact:
U.S. Global Change Research Information Office
Suite 250, 1717 Pennsylvania Ave, NW
Washington, DC 20006.

NOAA Regional Integrated Sciences and Assessment (RISAs)

Within the Climate Program Office of NOAA, the RISA program supports research that addresses complex climate sensitive issues of concern to decision-makers and policy planners at a regional level. RISA research team members work closely with natural resource managers and land planners, nongovernmental organizations and the private sector within each region to advance new research on how climate variability and change will impact the environment, economy, and society, and develop innovative ways to integrate climate information into decision-making. Research topics include fisheries, water, wildfire, agriculture, public health and coastal restoration. Team members are primarily based at universities though some of the team members are based at government research facilities, non-profit organizations or private sector entities. In Florida, The Florida Climate Institute, Southeast Climate Consortium are RISA-sponsored institutions.

Website: http://www.climate.noaa.gov/cpo_pa/risa

Contact:
Adam Parris
Program Manager
Regional Integrated Sciences and Assessment
ph: (301) 734-1243
fax: (301) 713-0518

Landscape Conservation Cooperatives (LLC)

A Department of Interior agency, each of the twenty-one LCC's will be guided by a steering committee with members from resource management and science agencies (federal, state, tribal and local). Nongovernmental organizations, universities, industry and others may contribute to the cooperative effort and may be part of the steering committee in some LCCs. LCC products may include resource assessments, climate model applications to appropriate scale, vulnerability assessments, inventory and monitoring protocols, and conservation plans and designs.

LCCs are to collaborate with academia, other Federal agencies, local and state partners, and the public and will coordinate with CSCs and RISAs in their regions. LCCs can be a particularly useful resource for states as they revise their State Wildlife Action Plans. States could use the products generated by LCCs to identify priority resource management issues, gaps in scientific knowledge, data sharing needs and strategies for adaptation to climate change and other large-scale landscape stressors. Florida is covered by three LCC units: Peninsular Florida (most of peninsular Florida), The South Atlantic (North Florida), and Gulf Coastal Plains and Ozarks (Florida Panhandle)

Website:
http://peninsularfloridalcc.org

Contact:
Tim Breault, Coordinator, Peninsular Florida Landscape Conservation Cooperative
U.S. Fish and Wildlife Service
620 South Meridian Street, Mail Stop 2
Tallahassee, FL 32399-1600

Phone: (850) 617-9415
timothy_breault@fws.gov

Climate Science Centers (CSC)

A Department of Interior agency, the eight Regional Climate Science Centers provide scientific information, tools and techniques that land, water, wildlife and cultural resource managers can apply to anticipate, monitor and adapt to climate and ecologically-driven responses at regional-to-local scales. CSCs deliver basic climate-change-impact science to Landscape Conservation Cooperatives within their respective regions, including physical and biological research, ecological forecasting, and multi-scale modeling. CSCs prioritize their delivery of fundamental science, data and decision-support activities to meet the needs of the LCCs. This includes working with the LCCs to provide climate-change-impact information on natural and cultural resources and to develop adaptive management and other decision-support tools for managers. In addition, CSCs will coordinate with RISAs and anticipate using model results and projections produced by RISA-supported scientists. Florida is in the Southeast Climate Science Center, housed at North Carolina State University.

Contact:
Sonya A. Jones
DOI Southeast Climate Science Center
Telephone: 770-409-7705
e-mail: sajones@usgs.gov

National Climate Change and Wildlife Science Center

A Science Center within the U.S. Geological Survey, it will work with the Landscape Conservation Cooperatives and Climate Science Centers to 1) implement partner-driven science to improve understanding of past and present land use change, 2) develop relevant climate and land use forecasts, and 3) identify lands, resources, and communities that are most vulnerable to adverse impacts of change from the local to global scale. The Center will support research and monitoring initiatives of carbon, nitrogen, and water cycles, and their effects on ecosystems. In addition, they will provide tools for managers to develop, implement, and test adaptive strategies, reduce risk, and increase the potential for ecological systems to be self-sustaining, resilient, and adaptable to environmental changes.

Website: http://nccwsc.usgs.gov

Contact:
U.S. Geological Survey
National Climate Change and Wildlife Science Center
12201 Sunrise Valley Drive, MS 300
Reston, VA 20192

National Integrated Drought Information System (NIDIS)

National Oceanic and Atmospheric Administration runs this information service is aimed at improving the nation’s capacity to proactively manage drought-related risks, by providing those affected with the best available information and tools to assess the potential impacts of drought, and to better prepare for and mitigate the effects of drought. U.S. Drought Portal is an interactive system to: provide early warning about emerging and anticipated droughts; assimilate and quality control data about droughts and models; provide information about risk and impact of droughts to different agencies and stakeholders; provide information about past droughts for comparison and to understand current conditions; explain how to plan for and manage the impacts of droughts; provide a forum for different stakeholders to discuss drought-related issues.

Website: www.drought.gov

Contact:
NOAA's Earth Systems Research Laboratory
325 Broadway
Boulder, Colorado

Climate Change and Water Working Group

This working group is a Joint effort by principal water resources management agencies and the earth science data collection agencies of the U.S. government. The group works with Federal and non-Federal research programs to find ways for their programs to assist in implementing the research plan and to generate collaborative research efforts across members of the water management and scientific communities to close these gaps.

Website: http://www.esrl.noaa.gov/psd/ccawwg

Contact: See website

National Phenology Network (NPN)

The USA National Phenology Network (USA-NPN) monitors the influence of climate on the phenology of plants, animals, and landscapes. The USA National Phenology Network brings together citizen scientists, government agencies, non-profit groups, educators and students of all ages to monitor the impacts of climate change on plants and animals in the United States. The Florida network is being managed by George R. Kish, from USGS Tampa Office (gkish@usgs.gov). The Florida network held a Florida Phenology Workshop in 2009, information can be found at http://www.usanpn.org/node/5971

Website: www.usanpn.org

Contact:
USA National Phenology Network
National Coordinating Office
1955 E. Sixth St., Tucson, AZ 85721
Phone: (520) 626-3821

A2.2. State Agencies

Florida Oceans and Coastal Council

Coordinated through Florida State's Department of Environmental Protection, the Council was created by the 2005 Florida State Legislature through The Oceans and Coastal

Resources Act. The Council is charged each year with developing priorities for ocean and coastal research and establishing a statewide ocean research plan. The Council also coordinates public and private ocean research for more effective coastal management.

The Council is comprised of three non-voting members and fifteen voting members appointed by the Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission and Department of Agriculture and Consumer Services.

Website: http://www.dep.state.fl.us/oceanscouncil

Contact:
Rebecca Prado
(850)245-2103
Rebecca.Prado@dep.state.fl.us

Florida Department Environmental Protection's Florida Forever Program

Florida Forever is the state's current blueprint for conserving our natural resources. The Florida Forever program conserves Florida's natural and cultural heritage, provides urban open space, and manages the land acquired by the state. The program has adopted a Climate Change Lands project that targets lands vulnerable under climate change through protection, restoration, mitigation, and strengthening of Florida's land, water, and coastal resources. This project includes lands that provide opportunities to sequester carbon, provide habitat, protect coastal lands or barrier islands, and otherwise mitigate and help adapt to the effects of sea-level rise.

Website: http://www.dep.state.fl.us/lands/fl_forever.htm

Contact:
Florida Forever
3900 Commonwealth Boulevard
Tallahassee, Florida
Phone: 850-245-2555

Florida Fish and Wildlife Commission (FWC)

There are several special initiatives programs with in Florida Fish and Wildlife Commission that will address climate change impacts. Wildlife 2060, Coastal Wildlife, Landowner Assistance, Wildlife Legacy, Cooperative Conservation Blueprint, and Florida Bird Conservation Initiative all incorporate or have the potential to incorporate climate change impacts on Florida's biodiversity in a positive manner.

Contact:
Florida Fish and Wildlife Commission
620 S. Meridian St.
Tallahassee, FL
32399-1600
(850) 488-4676

Wildlife 2060

This program focuses on wildlife habitat loss as a result of human development - urban and agricultural. This program does discuss climate change, especially how it will impact coastal areas- especially the balance between this change and ever growing human populations along the coast. This program and associated report could be expanded to discuss and prepare for ways in which climate change will influence human development and therefore anticipate hot spots of pressure on wildlife habitat.

Website: http://myfwc.com/conservation/special-initiatives/wildlife-2060

Coastal Wildlife Conservation Initiative

A FWC-led, multi-agency strategy to address coastal issues that affect wildlife and their habitats while considering human needs. It has the broad goal of ensuring the long-term conservation of native wildlife in coastal ecosystems throughout Florida in balance with human activities. The program's goal is "ensuring the long-term conservation of native wildlife in coastal ecosystems throughout Florida in balance with human activities." The strategies championed in this program can all incorporate climate change impacts, especially in light of the coastal nature of Florida's landscape. The education and outreach programs, regulation organization, and identification of threats to wildlife and habitats under this program can all have a climate change component.

Website: http://myfwc.com/conservation/special-initiatives/cwci

Landowner Assistance Program

A valuable tool by which climate change education, impact preparation and mitigation, restoration, and other actions can be taken. This program could be used to target those habitat types that are most vulnerable to climate change impacts.

Website: http://myfwc.com/conservation/special-initiatives/lap

Florida Bird Conservation Initiative

This program is a voluntary public-private partnership that seeks to promote the sustainability of native Florida birds and their habitats. Though this program has a narrow focus in comparison to other FWC, birds can be used throughout Florida as measures of climate change impacts. This program has already begun address climate change needs through several publications, listed on their website.

Website: http://myfwc.com/conservation/special-initiatives/fbci

State Wildlife Action Plan

Florida's State Wildlife Action Plan is an action plan for conserving all of the state's wildlife and vital natural areas for future generations. It outlines what native wildlife and habitats are in need, why they are in need and, most importantly, what actions FWC deem warranted. The plan is revisited every five years and in 2011-2015 the plan will be revised. The focus of the revision is 1) revising our Species of Greatest Conservation Need (SGCN) list, 2) writing and incorporating a chapter on climate change, 3) revising our approach to conserving freshwater habitats, 4) incorporating information on the first five years of Action Plan implementation, and, 5) reducing redundancy, and reorganizing to improve clarity and readability. The draft chapter addressing climate change can be found at: http://myfwc.com/media/1489165/CC_adaptation_chapter_compiled_072811.pdf

Website: http://myfwc.com/conservation/special-initiatives/fwli/action-plan

Cooperative Conservation Blueprint (CCB)

The CCB is a process that builds agreement between government and private interests to use common priorities as the basis for statewide land-use decisions. The purpose of the CCB is to help to conserve the most vital working landscapes and natural habitats while maintaining a sustainable economy and agriculture opportunities. A public-private partnership will create, publish on-line, and maintain a centralized GIS application of common priorities. The CCB will help to guide future land use planning decisions and recommend market-based incentives that encourage conservation.

Website: http://myfwc.com/conservation/special-initiatives/fwli/taking-action/blueprint

Climate Change Program

The FWC created the Climate Change Team that includes a five-member Steering Committee and five employee workgroups. The workgroups will develop and lead agency goals and objectives in each of these key areas: adaptation, research and monitoring, communication and outreach, policy, and opportunity and operations. Key areas of focus for the working groups are: 1) Identifying present and future climate change impacts to Florida's fish and wildlife communities; 2) Exploring ways for Florida's fish and wildlife communities to adapt to climate change; 3) Identifying ways to minimize climate change impacts on Florida's fishing and hunting resources; 4) Developing actions to mitigate climate change impacts to imperiled fish and wildlife species in Florida; 5) Taking steps that will reduce our agency's carbon footprint, improve energy and operational efficiency, and reduce our operational costs; 6) Creating internal and external communication and outreach opportunities.

Website: http://myfwc.com/conservation/special-initiatives/climate-change

A2.3. County and Town Programs

Water Management Districts

Florida has five water management districts: Northwest Florida Water Management District, Suwannee River Water Management District, St. Johns River Water Management District, South Florida Water Management District and Southwest Florida Water Management District. The districts develop water management plans for water shortages in times of drought and to acquire and manage lands for water management purposes under the Save Our Rivers program. Regulatory programs delegated to the districts include programs to manage the consumptive use of water, aquifer recharge, well construction and surface water management. Each district is addressing climate change impacts on water supplies in unique ways; however, recent changes in district management have put the future of these programs on hold in several districts.

Website: www.dep.state.fl.us/secretary/watman

In 2011, major changes were made to the Growth Management Act, which previously required Florida's 67 counties and 411 municipalities to adopt Comprehensive Plans that guide future growth and development. While plans are still required the entire program and oversight of the plans are in flux. It remains unclear as to the usefulness of these plans in preparing for climate change. Currently, preparation for climate adaptation is an optional part of the community Plans. Information can be found at: http://www.dca.state.fl.us/

A2.4. National Non-profits

Union of Concern Scientists (UCS)

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world. UCS combines independent scientific research and citizen action to develop innovative, practical solutions and to secure responsible changes in government policy, corporate practices, and consumer choices. including climate change, energy, transportation, sustainable agriculture, and scientific integrity in the federal government.

Website: www.ucsusa.org

Contact:
2 Brattle Square
Cambridge, MA 02138-3780

Defenders of Wildlife

Defenders of Wildlife is a national, non-profit membership organization dedicated to the protection of all native animals and plants in their natural communities. Defenders of Wildlife focuses on the accelerating rate of extinction of species and the associated loss of biological diversity, and habitat alteration and destruction. They have several projects in Florida, notably they are assisting FWC with the climate change impacts sections for the revision of the State Wildlife Action Plan.

Website: www.defenders.org

Contact:
1130 17th Street, NW
Washington, DC 20036
Phone: 1-800-385-9712

Environmental Defense Fund

The Environmental Defense Fund was established in 1967 as a nonprofit organization dedicated to protecting the environmental rights of all people, including future generations. It achieves that goal by linking science, economics and law to create innovative, equitable and cost-effective solutions to urgent environmental problems. The Environmental Defense Fund participated in the 2008 Climate Summit held by FWC.

Website: www.edf.org

Contact:
257 Park Avenue South
New York, NY 10010
Phone: 212- 505-2100

National Wildlife Federation

This nonprofit organization's work focuses on three major areas that are important to the future of America's wildlife: confronting global warming, protecting and restoring wildlife habitat, and connecting with nature. participated in the 2008 Climate Summit held by FWC. They have representatives on the ground in Florida to address global warming.

Website: www.nwf.org

Contact:
Steve Murchie
National Wildlife Federation
941-441-7035
MurchieS@nwf.org

The Nature Conservancy (TNC)

The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. TNC operates a Florida Chapter that focuses on four themes: freshwater habitat, marine, the Northern Everglades, and longleaf pine forest. Climate change is among the impacts TNC is addressing in their work on these four themes.

Website: www.nature.org

Contact:
The Nature Conservancy in Florida
222 S. Westmonte Drive
Suite 300

Altamonte Springs, FL 32714
Phone: 407-682-3664

National Resources Defense Council (NRDC)

NRDC works on a broad range of issues as we pursue our mission to safeguard the Earth; its people, its plants and animals, and the natural systems on which all life depends. As an institution, global warming is a focal areas of their work. In 2001, they published *Feeling the Heat in Florida : Global Warming on the Local Level*, which can be found on their website, listed below.

Website: www.nrdc.org/globalwarming/florida/flainx.asp

Contact:
Natural Resources Defense Council
40 West 20th Street
New York, NY 10011
Phone: 212-727-2700

National Audubon Society

Audubon's Mission is to conserve and restore natural ecosystems, focusing on birds, other wildlife, and their habitats for the benefit of humanity and the earth's biological diversity. The Florida chapter is addressing climate change as a part of its conservation efforts. They wrote a report outlining Florida needs, available at:
www.audubonofflorida.org/PDFs/Audubon_climatechange.pdf

Website: www.audubon.org

Contact:
Florida State Office
444 Brickell Avenue, Suite 850
Miami, FL 33131

EcoAdapt

EcoAdapt strives to make climate change adaptation capacity and resources more accessible. One of their focal projects is Climate Adaptation Knowledge Exchange , which is a joint project of Island Press and EcoAdapt. It is aimed at building a shared knowledge base for managing natural systems in the face of rapid climate change, and includes a large database of adaptation case studies, reports, and tools, as well as links to federal, state, and local adaptation plans.

Website: http://ecoadapt.org

Contact:
EcoAdapt
P.O. Box 11195
Bainbridge Island, WA 98110
Phone: 206-201-3834

The Pew Center on Global Climate Change

This center brings together business leaders, policy makers, scientists, and other experts to bring a new approach to a complex and often controversial issue. The Center's mission is to provide credible information, straight answers, and innovative solutions in the effort to address global climate change. In Florida, The Pew Center is support smart grid conversions, such as that undertaken by Florida Power and Light.

Website: http://www.pewclimate.org

Contact:
Pew Center on Global Climate Change
2101 Wilson Blvd.,
Suite 550
Arlington, VA 22201

National Ecological Observatory Network (NEON)

The National Ecological Observatory Network collects data across the United States on the impacts of climate change, land use change and invasive species on natural resources and biodiversity. NEON, Inc. is an independent 501(c)(3) corporation created to manage large-scale ecological observing systems and experiments on behalf of the scientific community.
National Ecological Observatory Network (NEON) is a large facility project managed by NEON, Inc. and funded by the National Science Foundation.

NEON has partitioned the U. S. into 20 ecoclimatic domains, each of which represents different regions of vegetation, landforms, climate, and ecosystem performance. Data will be collected from strategically selected sites within each domain and synthesized into information products that can be used to describe changes in the nation's ecosystem through space and time. The data NEON collects and provides will focus on how land use, climate change and invasive species affect biodiversity, disease ecology, and ecosystem services. These data and information products will be readily available to scientists, educators, students, decision makers, and the public. The Southeast Domain covers most of Florida- excluding South Florida- and is hosted by the University of Florida's Ordway-Swisher Biological Station. South Florida is within the Atlantic Neotropical Domain, which is hosted by Guánica Forest, Puerto Rico

Website: www.neoninc.org

Contact:

1685 38th St., Suite 100
Boulder, CO 80301
Phone: (720) 746-4844

A2.5. State and local Non-profits

Gulf of Mexico Alliance

The Gulf of Mexico Alliance is a partnership of the states of Alabama, Florida, Louisiana, Mississippi, and Texas, with the goal of significantly increasing regional collaboration to enhance the ecological and economic health of the Gulf of Mexico. The five U.S. Gulf States have identified six priority issues that are regionally significant and can be effectively addressed through increased collaboration at local, state, and federal levels: Water Quality; Habitat Conservation and Restoration; Ecosystem Integration and Assessment; Nutrients & Nutrient Impacts; Coastal Community Resilience; Environmental Education. Each of these areas of focus includes aspects of climate change.

Website: www.gulfofmexicoalliance.org

Contact:
Gulf of Mexico Alliance
1141 Bayview Avenue
Biloxi, MS 39530
Phone: 228-523-4014

Sea Turtle Conservancy

Corporation is a Florida-based, not-for-profit corporation founded in 1959 to ensure the survival of sea turtles within the wider Caribbean basin and Atlantic. It accomplishes that mission through research, education, training, advocacy and the protection of the natural habitats that sea turtles depend upon.

Website: www.cccturtle.org

Contact:
4424 NW 13th St.
Suite B-11
Gainesville, FL 32609
Phone: 352-373-6441

Our Florida. Our Future.

This program is run by the Collins Center, which was established in 1988 as a statewide nonprofit organization to seek out creative, non-partisan solutions to Florida's toughest issues. This multi-year effort to envision the future of Florida and includes three major thrusts: develop a scenario planning process, engage at least 4 million Floridians in this discussion, and support both the scenarios and the civic engagement efforts with appropriate research, data collection and policy papers.

Website: http://www.ourfloridaourfuture.org

Contact: see website

Florida Climate Alliance

The Florida Climate Alliance is a website forum dedicated to fostering state leadership in mitigating and adapting to the challenge of global warming. The Alliance is a part of the Southeast Coastal Climate Network, which consists of Southeast coastal organizations working towards climate solutions from Louisiana to Maryland. Their site is a meeting place that provides members of Florida Climate Alliance with a shared calendar, discussion forums, member profiles, photo gallery, file storage and more. The host organization for the Florida Climate Alliance is the Southern Alliance for Clean Energy.

Website: http://floridaclimatealliance.groupsite.com

Conservancy of Southwest Florida

The Conservancy of Southwest Florida is dedicated to conserving the environment. To achieve our mission, we employ a multidisciplinary approach. Members of our environment policy team promote sound environmental policies based on the best technical, legal, and scientific information. Our staff biologists research the issues negatively affecting our environment, while our naturalists interpret the information through a variety of educational programs.

Website: www.conservancy.org

Contact:
Conservancy of Southwest Florida
1450 Merrihue Drive
Naples, Florida 34102
Phone: 239-262-0304

A2.6. Academic Institutions and Scientists

In addition to the resources listed below, many academic researchers at Florida's universities are studying various aspects of climate change, biodiversity, and land use; these individual efforts are too numerous to list here.

Florida Sea Grant

Sea Grant uses academic research, education and extension to create a sustainable coastal economy and environment. We are a partnership between the Florida Board of Education, the National Oceanic and Atmospheric Administration and Florida's citizens, industries, and governments. Florida Sea Grant's extension, education and outreach programs are done in partnership with the University of Florida's IFAS Extension and coastal counties of Florida. One of their focal areas is coastal impacts from climate change.

Website: www.flseagrant.org

Contact:
PO Box 110400
Gainesville, FL 32611-0400
Phone: 352-392-5870

The Florida Climate Institute (FCI)

FCI is a multi-disciplinary network of national and international research and public organizations, scientists, and individuals concerned with achieving a better understanding of climate variability and change. The FCI was initially founded in 2010 by the University of Florida and the Florida State University and is supported by the two Universities' Affiliated Colleges, Centers and Programs.

Website: http://www.floridaclimateinstitute.org

Contact:
Carolyn Cox
Coordinator, Florida Climate Institute
Agricultural and Biological Engineering
University of Florida
PO Box 110570
Gainesville, FL 32611

Southeast Climate Consortium

This consortium includes University of Alabama-Huntsville, University of Georgia, University of Florida, University of Miami, Auburn University, Florida State University, North Carolina State University, and Clemson University. The mission of the Southeast Climate Consortium is to use advances in climate sciences, including improved capabilities to forecast seasonal climate and long-term climate change, to provide scientifically sound information and decision support tools for agricultural ecosystems, forests and other terrestrial ecosystems, and coastal ecosystems of the Southeastern USA. As a multidisciplinary, multi-institutional team, the SECC conducts research and outreach to a broad community of potential users and forms partnerships with extension and education organizations to ensure that SECC products are relevant and reliable.

Website: http://seclimate.org

Contact:
Keith Ingram, Coordinator
University of Florida
Department of Agricultural and Biological Engineering
283 Frazier Rogers Hall , PO Box 110570
Gainesville, FL 32611

Florida Climate Center (FCC)

FCC is a public service unit of the Florida State University Institute of Science and Public Affairs. Home of the State Climatologist, David Zierden, and the State Climatologist Emeritus and noted El Niño expert, James J. O'Brien, the Florida Climate Center provides climate data and information for the state of Florida. The center serves to provide climate data, information, and services for the United States. Affiliated with the National Climatic Data Center (NCDC) in Asheville, NC and the Southeast Regional Climate Center (SERCC) in Columbia, SC, the Florida Climate Center should be the first stop for climate data and information for citizens, organizations, educational institutions and private businesses in the state of Florida. We seek to serve the state of Florida by providing: 1) Climate Data: Historical weather observations for weather stations throughout the state of Florida. We are able to provide data for most stations from 1948-present. 2) Climate Information: Long-term historical averages for various stations, climate divisions, and the entire state. 3) Extreme Events: Information and analyses on extreme events such as storms, freezes, droughts, floods and hurricanes. 4) Special Analysis**:** With his vast knowledge of El Niño, La Niña and climate variability, the State Climatologist and staff can offer expert insight into Florida's climate trends. 5) Outreach: Inform and educate the people of Florida about current and emerging climate issues.

Website: http://coaps.fsu.edu/climate_center/index.shtml

Contact:
The Florida Climate Center
Center for Ocean-Atmospheric Prediction Studies (COAPS)
Florida State University
2035 E. Paul Dirac Dr.
223 R.M. Johnson Bldg.
Tallahassee, FL 32306-2840
(850) 644-3417

Rosenstiel School of Marine and Atmospheric Science (RSMAS)

A one of the World's leading academic oceanographic and atmospheric research institutions, RSMAS research interests encompass virtually all marine-related sciences. Climate change science and impact assessment is infused across all divisions of RSMAS.

Website: http://www.rsmas.miami.edu

Contact:
The Rosenstiel School of Marine and Atmospheric Science
4600 Rickenbacker Causeway
Miami, FL 33149-1098

Florida Center for Environmental Studies

A state university research center established in 1994 by the Regents of the State University System of Florida. Mission of the Center is to collect, analyze, research and promote the use of scientifically sound information concerning tropical and subtropical freshwater, estuarine and coastal ecosystems. The role of the center is to facilitate productive research, information and training relationships within Florida Atlantic University and among Florida's universities and state, national and international agencies, including both the public and private sectors. Their Climate Change program focuses on South Florida impacts and

Website: http://www.ces.fau.edu

Contact:
Florida Center for Environmental Studies
5353 Parkside Drive, Building SR
Jupiter, FL 33458