



A Guide to Climate Change Adaptation for Conservation

Resources and Tools for Climate Smart Management of Florida's Fish and Wildlife Species and Their Habitats

Version 1

Florida Fish and Wildlife Conservation Commission

2016

A GUIDE TO CLIMATE CHANGE ADAPTATION FOR CONSERVATION

RESOURCES AND TOOLS FOR CLIMATE SMART MANAGEMENT OF FLORIDA'S FISH AND WILDLIFE SPECIES AND THEIR HABITATS

Florida Fish and Wildlife Conservation Commission

April 10, 2016

Cover Photographs

Top: Cape Sable, Florida (CNES. SPOT Satellite Imagery.)
Upper Middle: Florida Mouse (Florida Fish and Wildlife Conservation Commission)
Middle: Florida Scrub Jay (Florida Fish and Wildlife Conservation Commission)
Lower Middle: Flatwoods Salamander (Florida Fish and Wildlife Conservation Commission)
Bottom: Coral Reef (National Park Service)

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This adaptation guide aimed to capture the needs of managers and was structured to align with the planning processes they use and technical expertise they possess. Managers know their systems and can identify the processes and attributes that are most critical to maintaining functional habitats and viable populations. They are most concerned with ecological impacts from climate change that would affect these features in a way that would make it difficult to achieve conservation and management goals. Therefore, they are most interested in identifying adaptation strategies that can reduce the impact of those consequences on conservation and management goals. With these needs in mind, this adaptation guide outlined a catalog of climate impacts, ecological consequences and associated adaptation strategies to inform management decisions, along with guidance and support for how to use it. It is the hope of everyone who was involved in the creation of this guidance document that it will be useful to managers and conservationists, particularly as a toolkit and guide for climate adaptation strategy development. In keeping with an adaptive strategy, it is the expectation of those involved that the content in and format of this guide will be continually refined to better meet the needs of the conservation and management community in Florida.

Acronym	Description
AR4	IPCC’s Fourth Assessment Report
AR5	IPCC’s Fifth Assessment Report
FWC	Florida Fish and Wildlife Conservation Commission
EEZ	Exclusive Economic Zone (Denoting Sovereignty Over Marine Resources)
IPCC	Intergovernmental Panel on Climate Change (United Nations Panel)
NGO	Non-governmental Organization
RCPs	Representative Concentration Pathways
SHCA	Strategic Habitat Conservation Areas
SIVVA	Standardized Index of Vulnerability and Value Assessments
SLAMM	Sea Level Affecting Marshes Model
SLR	Sea Level Rise
SWAP	State Wildlife Action Plan

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1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) is a leading global authority of multi-disciplinary experts that has produced a series of documents summarizing the current knowledge, including the driving forces, expected impacts, and steps that can be taken to adapt to climate change. The Fourth and Fifth Assessment Reports of the IPCC (2007 & 2014) concluded that the southeast region of North America will be vulnerable to changes in temperature, rainfall, and other environmental parameters that are projected to occur during the next century. These climatic changes are expected to impact Florida's fish and wildlife across all terrestrial, freshwater, and marine habitats. When combined with other stressors, the impacts to Florida's natural resources may decrease the long term viability of species and the ecosystems they inhabit. Such impacts would, in many cases, be compounded with existing pressures on these natural resources, which may already be substantial.

There is increasing scientific consensus about the predicted impacts from climate change, which is supported by a growing catalog of documented current changes that are consistent with the projections. Nevertheless, there remains uncertainty about the localized impacts of future climate change and about how individual species and ecosystems will respond. Despite these inherent uncertainties, there are actions that can be implemented to help minimize or offset the predicted consequences.

This adaptation guide provides a starting point from which to address the predicted impacts of climate change on Florida's fish, wildlife, and ecosystems. The guide is intended to help the development of adaptation strategies that would be implemented by the Florida Fish and Wildlife Conservation Commission (FWC) and other natural resource management agencies and groups interested in managing natural resources in a changing climate. Florida's fish and wildlife resources are an important component of the economy, with wildlife viewing contributing $4.9 billion, hunting and freshwater fishing bringing in $3.3 billion, and saltwater fishing contributing $7.6 billion to the economy (FWC 2014).

The need for this guide was recognized after 2007, when FWC formally adopted a Climate Change Resolution and when it hosted the summit "Florida's Wildlife: On the front line of climate change". The summit assembled wildlife and climate change experts to identify key research needs and to develop ideas to address climate change impacts on wildlife as part of FWC's comprehensive climate change strategy. Following the summit, FWC created an internal Climate Change Team (Team) of agency staff members that was comprised of a steering committee and four working groups (Figure 1.1). Together Team members work to ensure that agency staff at all levels have the opportunity to provide input, to become involved in efforts to identify climate change impacts to Florida's fish and wildlife resources, and to develop actions to address them. It is expected that this guide will provide the tools to better integrate these adaptation actions and tasks into broader policies and programs, serving as a toolkit to help FWC better address the predicted impacts of climate change on Florida's fish, wildlife, and the ecosystems where they occur and derive necessary resources.

An additional step was to partner with the Defenders of Wildlife (Defenders) to collaborate with the FWC Climate Change Working Groups. A two-pronged approach was developed that incorporated information from both a top-down perspective using climate projections and ecosystem-level threat assessments and a bottom-up perspective based on site-specific management needs and opportunities for climate change adaptation. The working groups of FWC's Climate Change Team took primary responsibility for compiling the information needed to achieve the first element of this approach through the development of this adaptation guide. The second element will be more process-based to apply this information into existing planning processes to account for expected future climate changes and the uncertainty surrounding those changes.

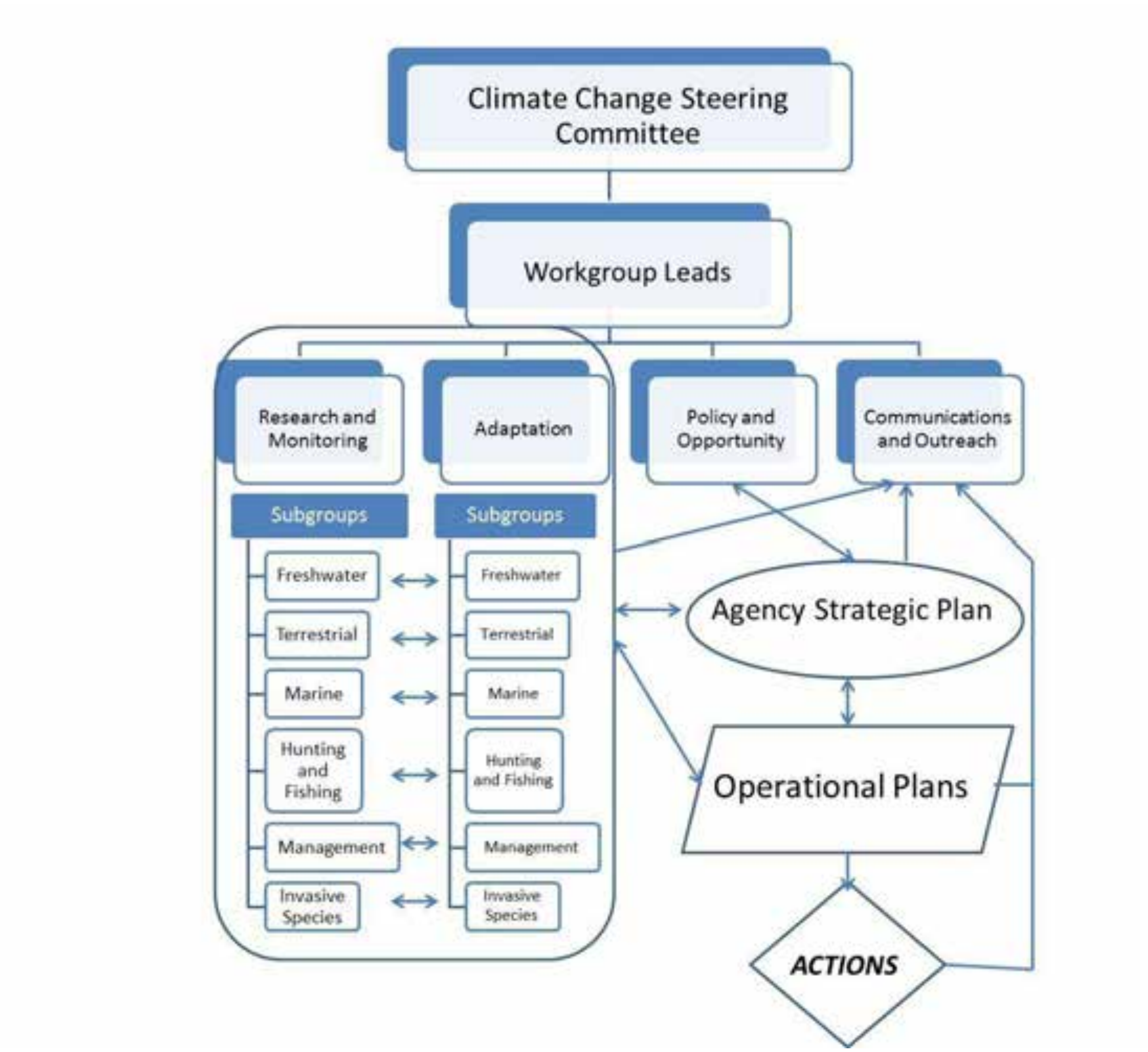


Figure 1.1 A graphical representation of the organization of the FWC Climate Change Team and links between elements of the team that are expected to lead to actions. Figure from Paukert et al. In Press.

The objectives of this adaptation guide are to:

- Provide a path by which natural resource researchers, biologists, managers, planners and policy makers can access sound foundational climate science and adaptation information.
- Identify possible ecological consequences of expected climatic changes on species and ecosystems and assess the associated compounding effects of existing stressors.
- Provide adaptation strategies that aim to increase the resiliency of species and ecosystems.
- Identify critical data gaps and highlight potential research and monitoring needs that lead to development of appropriate adaptation strategies.
- Adapt area management and species conservation plans to incorporate the projected impacts of climate change using current biological knowledge and accepted ecological principles.
- Facilitate and improve coordination to implement proposed adaptation strategies to better address projected impacts from climate change on fish and wildlife species in Florida; include researchers, regulatory and resource management agencies and policy makers.
- Incorporate climate change into long range planning efforts agency-wide.

While exact change can't be modeled with complete certainty, future planning should manage for change rather than with the expectation that current conditions will persist. Managing for persistence may be appropriate under some conditions, while managing to facilitate change will be appropriate under other conditions. Goals and operating activities may need to be adjusted to account for changing environments. There are three common management approaches; resistance, resilience and realignment (see side box for definitions). The selected approach should reflect the degree of anticipated impacts, costs and value of the resource(s) in questions (societal, ecological and economic) (Stein *et al*. 2014).

RESISTANCE – actions are intended to forestall impacts to species or systems, maintain status quo

RESILIENCE – actions designed to improve the capacity of a system to return to desired conditions after disturbance, to maintain some level of functionality

REALIGNMENT – activities that facilitate the transition of ecosystems to new functional states

Glick *et al.* 2011

The mission of FWC is to manage fish and wildlife resources for their long-term well-being and the benefit of people. To meet this mission in a century, it will be essential to incorporate climate change into long term planning and management activities moving forward. This adaptation guide lays out a series of strategies intended to maximize the capacity of species and ecosystems to adapt to anticipated impacts of climate change in Florida, some that can be implemented to complement ongoing activities. It is not the intent of this plan to describe in detail specific processes that may be required at a local scale to implement the suggested actions and tasks. The adaptation section is meant to serve as a menu of potential activities that can be selected from that are most suitable to management goals. It is hoped that the proposed adaptation strategies can be further refined or modified with new data so it will remain continually useful to natural resources managers and those interested in conservationists. Looking forward and planning for the conditions of the future will be essential, simply continuing to plan based on historic conditions may not be successful. Many of our natural communities and species have adapted to climate change impacts previously, but now must do so with non-natural barriers such as buildings, roads and other hazards related to sharing the built environment.

2 HOW TO USE THIS GUIDE

This guide is designed to provide natural resource managers the tools for developing adaptation strategies and actions using robust science. Managing the environment and protecting natural resources from climate change is at a critical juncture and is a need that will become more important with time. This adaptation guide is designed as a resource for developing and implementing climate change adaptation strategies for the species, communities, and managed lands of Florida. It is a toolkit designed to aid with the management of climate adaptation, rather than a handbook with step-by step instructions of specific actions.

This guide follows a set of cause-and-effect relationships (steps) that explain the causes (drivers) of climate change, assess the predicted impacts on various systems and communities, and recommend strategies to minimize vulnerability. This set of steps begins with the drivers of climate change, which are then downscaled into more localized and measurable climatic shift projections. Local climate shifts are expected to have impacts on various natural and human systems, and, in turn, those impacts are expected to have significant consequences for the components of each of those systems (e.g. wildlife, people, etc.). Finally, those consequences will be addressed with specific management strategies that enable the components of the system to adapt to climate change or help mitigate the consequences. These steps are illustrated in the Climate Change Impact Flow Diagram (Figure 2.1) and the organization of the guide follows this structure. Definitions for terms used in these steps are included at the end of section.

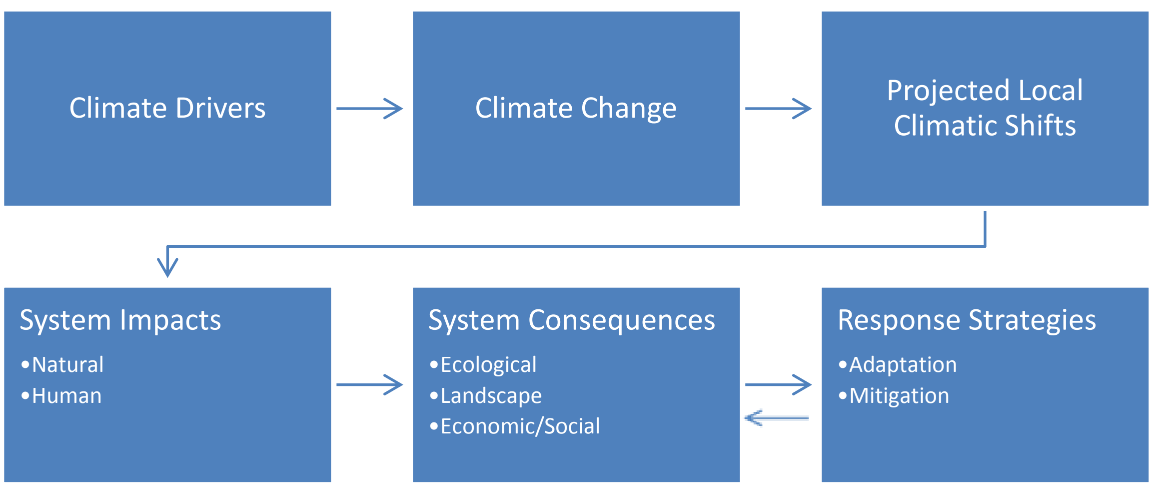


Figure 2.1. Climate Change Impact Flow Diagram. This flow chart illustrates the flow from the drivers of climate change, to the measurable climatic shifts projected to take place, to the impacts those shifts will have on various systems, to the consequences of impacts within various systems, to the response strategies (adaptive or mitigative) that are most relevant to those consequences.

Each of these steps appear in the adaptation guide and are the focus of multiple sections (e.g. impacts or consequences). This guide is designed for diverse users at multiple levels of complexity, therefore readers have a range of options to choose from to better understand climate change, its impacts, and potential adaptation strategies in the full context presented here. Readers with an existing knowledge of climate change or who are more interested in the researching the impacts and strategies relevant to their region or system(s) are encouraged to utilize the tabs in the document to find the sections that are most relevant to them, Table 2.1 has a quick reference to sections of the guide based on specific information of interest. Each section is well delineated, listed in the table of contents, and described below. Thus, this adaptation guide is designed to suit the needs of a broad audience and can be utilized for a variety of purposes.

Table 2.1. Quick section reference based on topics of interest.

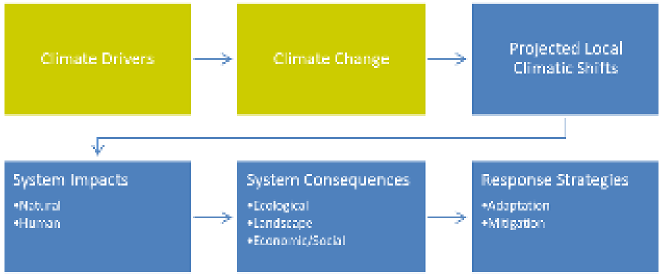
I am interested in learning more about:	
climate change	Section 3
climate change in Florida	Section 4
ecological consequences of climate change	Section 5
possible impacts of specific habitats	Section 6
vulnerability assessments	Section 7
adaptation options	Section 9
supplementary tools to aid my decisions	Section 10

To ensure optimal use of this guide, an outline of the adaptation guide sections is shown below utilizing the impact flow diagram (Figure 2.1). This will allow the reader to easily locate relevant climate change relationships associated with various climate drivers, impacts, or adaptation strategies.

Sections of the guide:

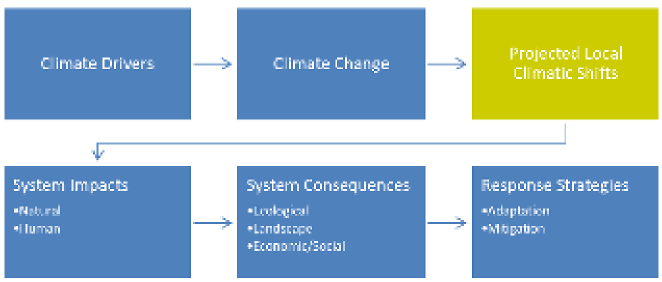
0. Table of Contents
1. Introduction
    a. Tab Title: Introduction
    b. Description: this section provides a brief of the process that is being followed and the objectives of this guide.
2. How To Use This Guide
    a. Tab Title: Using the Guide
    b. Description: This section provides a brief summary of the guide’s structure and a layout to help the reader quickly find relevant and helpful information.

3. The Science of Climate Change



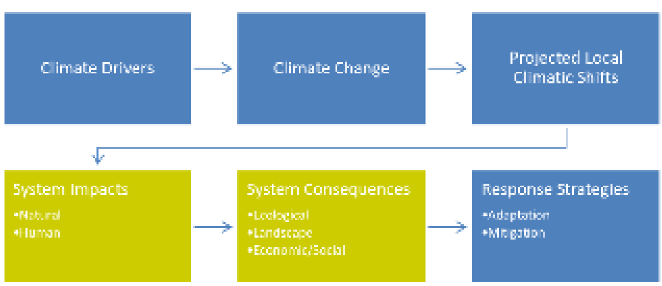
   a. Tab Title: Climate Science
   b. Description: This section provides an overview of the current scientific consensus on climate drivers and climate change at a global scale. It provides references and a summary of the predictions published by the Intergovernmental Panel on Climate Change (IPCC).

4. Projected Climatic Shifts In Florida



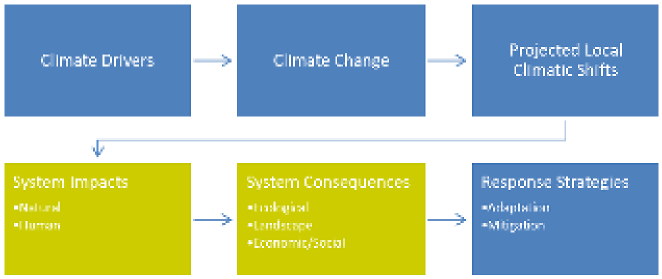
   a. Tab Title: Climate Projections
   b. Description: This section summarizes down-scaled climate change projections for Florida. Changes include SLR, land and water surface temperatures, and precipitation patterns.

5. Impacts and Consequences of Climate Change In Florida



   a. Tab Title: Statewide Impact
   b. Description: Climate change impacts and consequences are broadly statewide. Relational graphics that tie these various changes to the variety of impacts and consequences they precipitate. This section is useful for considering the potential range of impacts from specific climatic changes.

6. Impacts and Consequences of Climate Change On Florida's Habitats and Communities

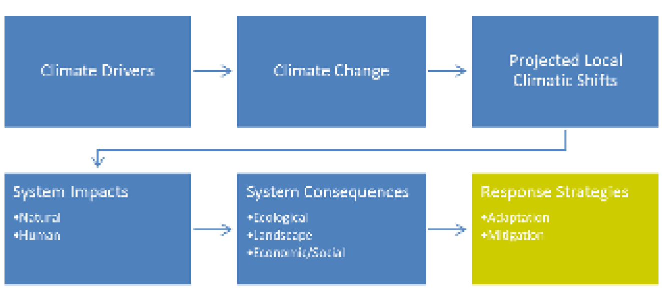


   a. Tab Title: Impact on Communities
   b. Description: This section organizes the climate change impacts and consequences for each of Florida's habitats and communities, providing a summary profile for each, and includes tables outlining the most important consequences.
   c. Example Table: Beach/Surf Zone

Climatic Shift	Ecological Consequence	Example Species
Sea level rise - Inundation	• Erosion • Distribution of habitat • Loss of habitat • Reduced populations	Shorebirds Diamondback terrapin, Cedar key mole skink, sea turtles Beach mice
Increased intensity of storms	• Spread of invasive species • Loss of habitat/habitat degradation	Species dependent upon trees/vegetation for nesting/refugia
Flood	• Increased mortality • Altered community structure • Change in population trends	

7. Vulnerability Assessments
   a. Tab Title: Vulnerability
   b. Description:

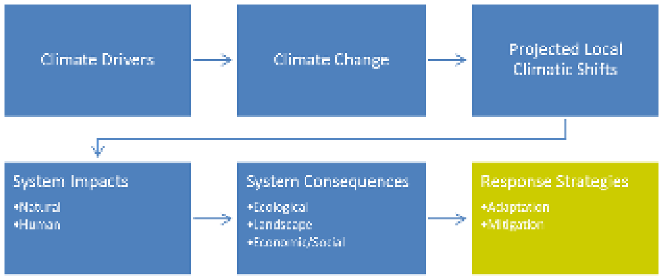
8. General Climate Change Adaptation Strategies



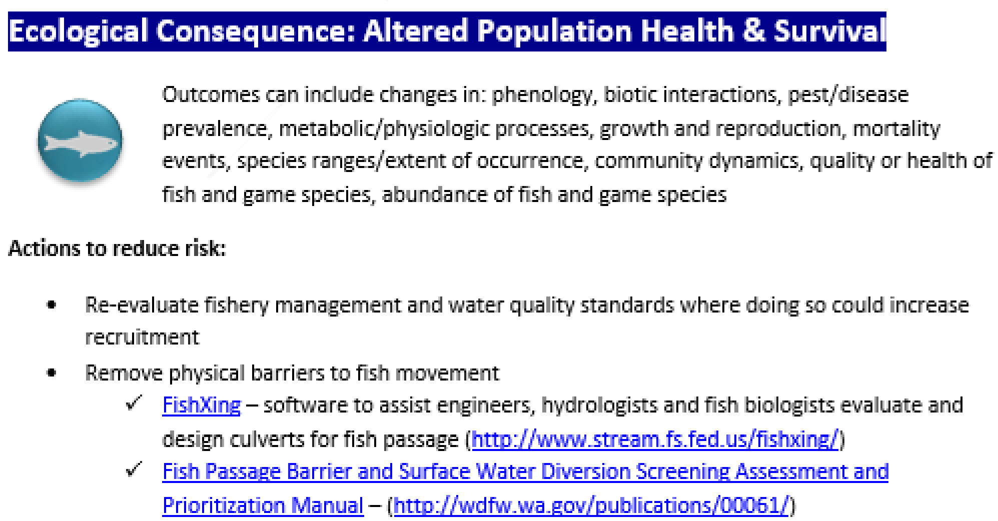
   a. Tab Title: General Adaptation

   b. Description: This section outlines broad principles for climate change adaptation that are likely to apply to some regions and communities in Florida. These principles could be considered general advice for developing and enacting climate change adaptation strategies.

9. Climate Change Adaptation Strategies For Habitats and Communities



   a. Tab Title: Community Adaptation
   b. Description: This section takes those broad principles for adaptation and applies them to the habitats and communities in Florida. Adaptation strategies are outlined for various groupings of similar habitats, termed coarse filters in this guide, correlating to the impacts and consequences each are likely to face. Some strategies have links to resources, examples or case studies.
   c. Example Layout:



Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: phenology, biotic interactions, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, species ranges/extent of occurrence, community dynamics, quality or health of fish and game species, abundance of fish and game species

Actions to reduce risk:

- Re-evaluate fishery management and water quality standards where doing so could increase recruitment
- Remove physical barriers to fish movement
  - ✓ FishXing – software to assist engineers, hydrologists and fish biologists evaluate and design culverts for fish passage (http://www.stream.fs.fed.us/fishxing/)
  - ✓ Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual – (http://wdfw.wa.gov/publications/00061/)

10. Additional Resources For Climate Change Adaptation
   a. Tab Title: Adaptation Resources
   b. Description: This final content-based section provides an extensive list of climate change adaptation and mitigation resources, some of which were used to design this guide. These resources span a variety of approaches, locations, and scales but all provide a unique and useful way to incorporate climate change into conservation and management decisions. We highly recommend consulting some of these resources, to complement the information presented throughout the adaptation guide.

11. Literature Cited
    a. Tab Title: Works Cited
12. Appendices
    a. Tab Title: Appendices

These sections can be found by using the marked tabs on the right hand side of the page. For a more detailed listing of the tools, habitats, resources, or strategies mentioned throughout this document, please consult the Table of Contents (pages i – iii). Using either of these two organization structures will allow quicker access to important and relevant information. For clarity, the key terms and definitions used are shown in Table 2.2.

Table 2.2. Key terms used throughout this guide and their definitions.

Term	Description
Climate Drivers	Human or natural phenomena that influence the climate system and trigger climatic changes
Major Climatic Changes	Projected trends in the climate system that may impact aspects of the natural and anthropogenic world
Measurable Climatic Shifts	Specific, often directional, and localized changes to the climate system that are tied to major climatic changes
Climate Projections	Specific predictions (with ranges of values) describing the scale of measurable climatic changes and shifts
Climate Change Impacts	Expected effects on natural or anthropogenic systems as a result of measurable climatic shifts
Ecological Consequences (attributes, processes, species)	Changes to the ecology of communities and species as a result of climate change impacts
Landscape Consequences	Changes to the ecology of landscapes as a result of climate change impacts
Economic/Social/Cultural Consequences	Changes to the human society, culture, and values as a result of climate change impacts
Adaptation Strategies	Methods aimed at preparing for or adjusting to the consequences and impacts of climate change
Mitigation Strategies	Methods aimed at minimizing the consequences and impacts of climate change

The following confidence terms are based on their use in the IPCC reports. For more information, please consult uncertainty guidance documentation provided by the IPCC (https://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf).

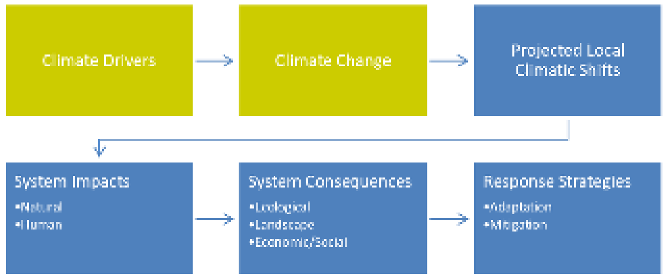
Term	**Likelihood of the outcome**
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

The following terms have been used to indicate the assessed likelihood, and typeset in italics:

Term*	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms (extremely likely: 95–100% probability, more likely than not: >50–100% probability, and extremely unlikely: 0–5% probability) may also be used.

3 THE SCIENCE OF CLIMATE CHANGE



According to the IPCC's Fifth Assessment Report (frequently identified as AR5; IPCC 2014), an accumulation of scientific evidence indicates a consistently strong relationship between cumulative carbon dioxide and other greenhouse gas (GHG) emissions and an expected global temperature change through 2100. The future climate will be influenced by warming caused by the confluence of anthropogenic GHG emissions and natural climate variability. Anthropogenic GHG emissions are driven by a variety of factors including human population size, energy use, economics, regulations and land use patterns. The drivers, along with effects from potential changes to climate and environmental policy, are represented within the AR5 report in several climate change scenarios that collectively encompass a set of vastly different temperature and climate predictions (IPCC 2014).

Four new scenarios, called Representative Concentration Pathways (RCPs) were defined in AR5 and estimate total radiative forcing (watts per square meter, W/m^2) they predict by the year 2100 relative to 1750: 2.6 W/m^2 for RCP2.6, 4.5 W/m^2 for RCP4.5, 6.0 W/m^2 for RCP6.0, and 8.5 W/m^2 for RCP8.5. The RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6), and one scenario with very high greenhouse gas emissions (RCP8.5) (IPCC 2014). RCPs are based on a combination of integrated assessment models, simple climate models, atmospheric chemistry and global carbon cycle models. While the RCPs span a wide range of total radiative forcing values, they do not cover the full range of known and potential emissions, particularly for aerosols (see Figure 3.1). For the RCP6.0 and RCP8.5 scenarios, radiative forcing does not peak by year 2100 but continues increasing; for RCP4.5 it stabilizes by 2100, and for RCP2.6 it has already peaked and declined (IPCC 2014).

Projected climate change impacts described in the IPCC's Fourth Assessment Report (AR4), were based on RCPs and are similar in both patterns and magnitude, but there are key differences. The overall spread of projections for the high RCPs is narrower than for comparable scenarios used in AR4 and projections of SLR in AR5 are larger than in the AR4, primarily because of improved modeling techniques (IPCC 2007 and 2014).

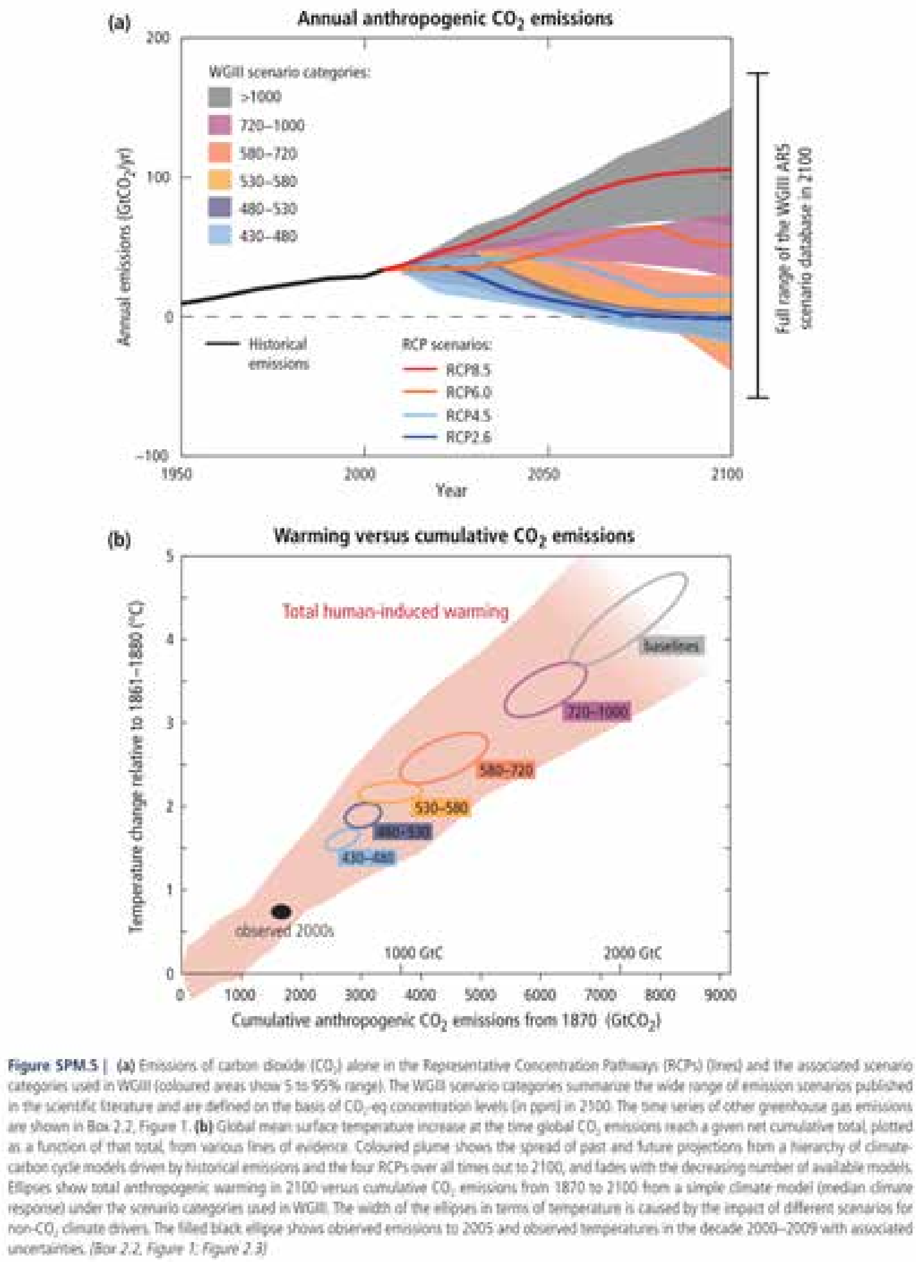


Figure 3.1. Disparate emissions scenarios (and some resulting temperature ranges) associated with each RCP. Figure reproduced from IPCC 2014, with original caption.

Each RCP in AR5 incorporates a different global mean surface temperature projections. The projected increase of global mean surface temperature by 2081–2100 relative to 1986–2005 is likely to be 0.3-1.7°C (RCP2.6), 1.1- 2.6°C(RCP4.5), 1.4-3.1°C(RCP6.0) and 2.6-4.8°C (RCP8.5) (IPCC 2014). Global surface temperature change by the end of the 21st century (2081–2100) is likely to exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (high confidence). Warming is likely to exceed 2°C for RCP6.0 and RCP8.5 (high confidence), more likely than not to exceed 2°C for RCP4.5 (high confidence), but unlikely to exceed 2°C for RCP2.6 (medium confidence). Warming is unlikely to exceed 4°C for RCP2.6, RCP4.5 and RCP6.0 (high confidence) and is about as likely as not to exceed 4°C for RCP8.5 (medium confidence) (Figure 3.2). It is virtually certain that as global mean temperatures increase there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales. It is also very likely that heat waves will occur with a higher frequency and duration while, occasional cold winter extremes will continue to occur (IPCC 2014).

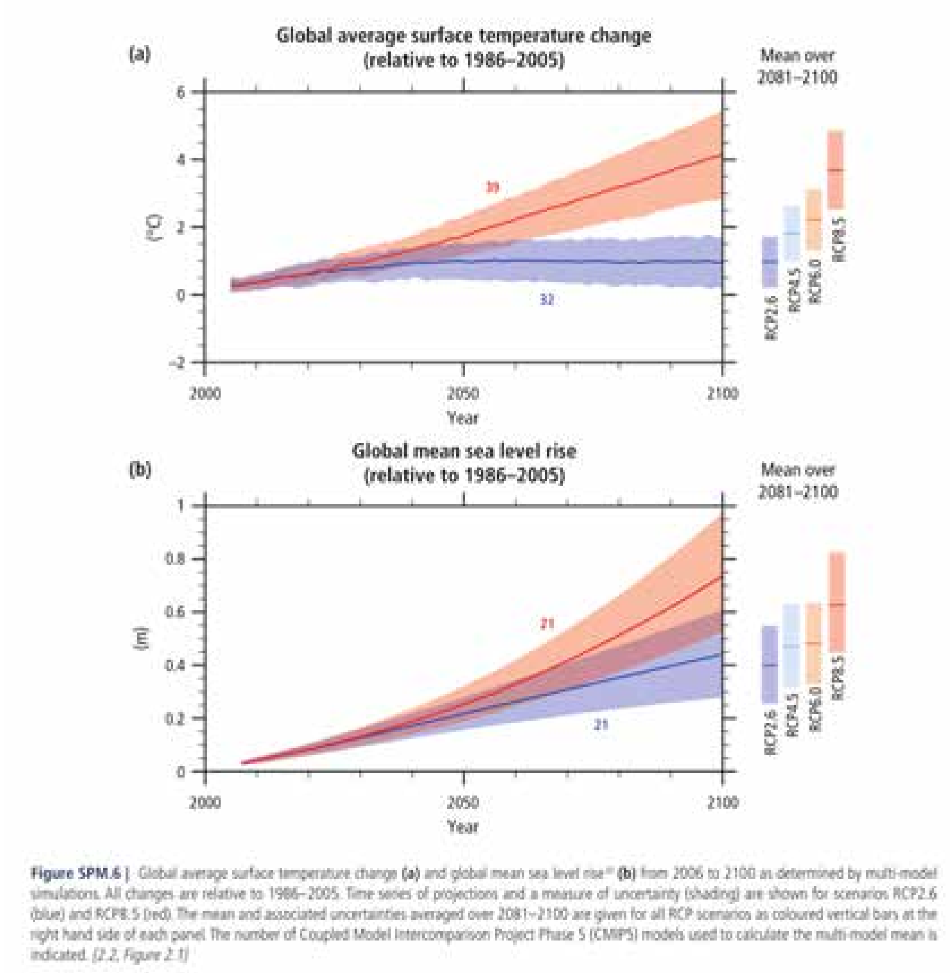


Figure 3.2. Disparate global warming and SLR scenarios associated with each RCP. Figure reproduced from IPCC 2014, with original caption.

These potential temperature and precipitation changes will not be uniform across the earth's surface. Various regions (e.g. high latitudes) are predicted to experience far more warming than others (e.g. tropical latitudes). Drier mid-latitude and subtropical regions are projected to receive less rainfall, while wetter mid-latitude regions are expected to have an increase in precipitation (IPCC 2014) (Figure 3.3). Extreme precipitation events are expected to increase in frequency and intensity over most land masses (IPCC 2014).

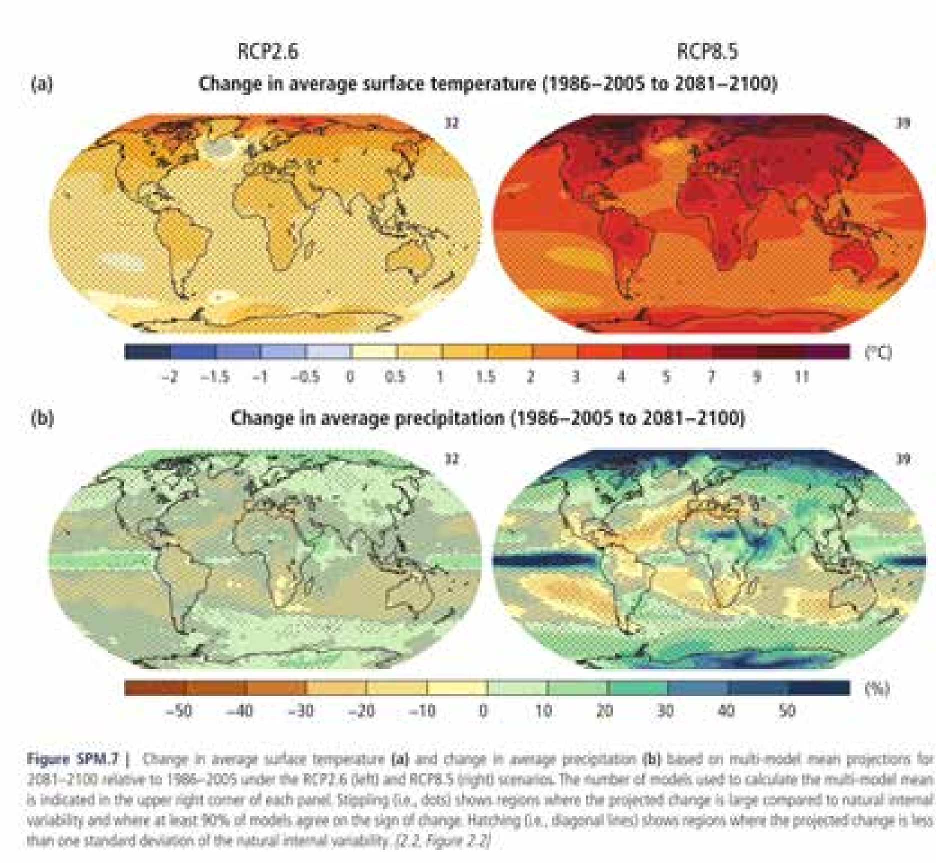


Figure 3.3. Geospatial variations in surface temperature and precipitation projections with RCP2.6 and 8.5. Figure reproduced from IPCC 2014, with original caption.

Oceanic warming and SLR are expected as a result of rising GHG levels and temperatures. Ocean warming is projected to be most pronounced in the surface waters of tropical and Northern Hemisphere subtropical regions. Estimates of ocean warming by the end of the 21st century are 0.6°C (RCP2.6) to 2.0°C (RCP8.5) for the top one hundred meters and 0.3°C (RCP2.6) to 0.6°C (RCP8.5) at a depth of about 1000 m (IPCC 2014).

Global mean SLR for 2081–2100 relative to 1986–2005 will likely be between 0.26- 0.55 m (RCP2.6), 0.32-0.63 m (RCP4.5), 0.33-0.63 m (RCP6.0), and 0.45-0.82 m (RCP8.5) (medium confidence) (IPCC 2014). For RCP8.5, the rise by 2100 is 0.52-0.98 m, with a rate during 2081 to 2100 of 8-16 mm/yr (medium confidence) (IPCC 2014). These ranges are derived from CMIP5 (Coupled Model Intercomparison Project, Phase 5) climate projections in combination with process-based models and literature assessment of glacier and ice sheet contributions. (Table 3.1 and Figure 3.3)

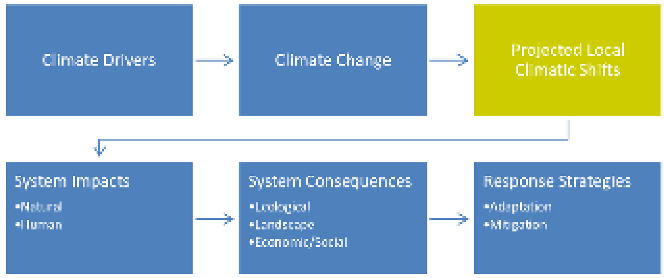
Table 3.1. Projected changes to surface air temperatures and sea levels for each RCPs. Table reproduced from IPCC 2014, with original caption.

Table SPM.2 | Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005. [12.4; Table 12.2, Table 13.5]

		2046–2065		2081–2100	
	Scenario	**Mean**	***Likely* range**[c]	**Mean**	***Likely* range**[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range**[d]	**Mean**	***Likely* range**[d]
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Changes in the earth's climatic system are projected to affect most surface areas but these effects will not be ubiquitous across the world's continents and oceans. The main changes expected for North America include rising temperatures, regional increases or decreases in precipitation, rising sea levels, and changes in the frequency and severity of extreme weather events. These broad trends also apply to Florida.

4 PROJECTED CLIMATIC CHANGES IN FLORIDA



Each major change to the earth's climate is associated with a range of possible local changes in any given area, referred to throughout this guide as measurable climatic shifts. These measurable climatic shifts are influenced by climatic change and can vary greatly by location and are often associated with particular predictions of drivers (Table 4.1). In the coming century, projections indicate that few other states will be impacted by climate change as severely as Florida, the following section summarizes possible climatic changes based on projections.

To predict these climatic shifts and assess the impacts, coarse scale temperature and precipitation change models can be downscaled from global climate models (GCM) to project regional climatic trends via a variety of tools: e.g., https://toolkit.climate.gov/tools. Climate Wizard, a tool jointly developed by the Nature Conservancy, University of Washington and the University of Southern Mississippi, can project a variety of general climatic changes for Florida (or any state) over the next century and can then be downloaded in commonly utilized geospatial formats (Girvetz *et al*. 2009). The following summary of climatic shifts for the state are derived from Climate Wizard, using ensemble climate models. These models allow for consideration of uncertainty in the climate system by using multiple parallel calculations simultaneously in the modeling process. This method leads to a more statistically robust general model set (for a specific listing of models included in Climate Wizard, see Appendix 1). Various available tools may result in different outputs or could be more appropriate for different projects, regions or scales. Other user tools are discussed in Section 10.

Climate Wizard can report outcomes based on three of the emission scenarios (A2, A1B, and B1) outlined in the IPCC's AR4 report (IPCC 2007), representing a range of emission/development predictions. The more extreme A2 scenario reflects minimal policy changes and continued heterogeneous economic development, with little international cooperation. The more moderate A1B scenario reflects a balanced development pattern (including sustainable energy), while the more ecologically-centric B1 scenario reflects more intense mitigation and harmonious economic development. As of early 2016, Climate Wizard had not yet been updated to reflect the new RCPs outlined in the AR5 and is still using scenarios from AR4 (Figure 4.1). Updated modifications to the models should be consulted in the future to determine how statewide and regional outputs may change.

Comparing this figure to those from the previous section will highlight the differences between the historical projections in AR4 and today's current projections.

Table 4.1. Major climatic changes and measurable climate shifts that may affect Florida.

Major Climatic Changes	**Potential Measurable Climatic Shifts**
Sea Level Rise (SLR)	Inundation or Saturation
	Salinity Shifts
Changes in Precipitation	Changes in Amount of Rainfall – Increase
	Changes in Amount of Rainfall – Decrease
	Changes in Duration – Longer/Shorter Wet Periods
	Changes in Duration – Longer/Shorter Dry Periods
	Changes in Timing During the Year
Changes in Air Temperature	Increased Average Summer Temperature
	Decreased Minimum Winter/Spring Temperature
	Changes in Temperature Extremes
	Changes in Diurnal Temperature Ranges
Changes in Extreme Events	Increased Intensity of Storms
	Floods
	Droughts
Changes in CO2	Changes in Air Chemistry
	Changes in Water Chemistry

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

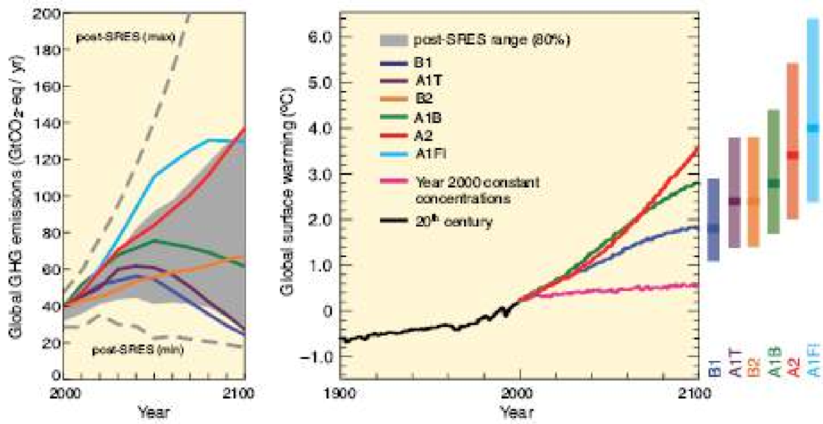


Figure SPM.5. Left Panel: Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (coloured lines) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. Right Panel: Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999. {Figures 3.1 and 3.2}

Figure 4.1. Disparate emissions scenarios (and some resulting temperature ranges) associated with each scenario. Figure is reproduced from IPCC 2014, with original caption.

According to the selected emission scenarios and the ensemble of climatic circulation models, annual average temperatures across the state are projected to markedly increase toward the end of the century. These departures from the 1961-1990 average temperatures are projected to be more severe in the northern portions of the state, gradually decreasing in severity to the south across the three emission scenarios with differing levels of intensity. As the emission scenario becomes more severe, so does the projected departure from historic average temperatures (Figure 4.2). When these scenarios are examined seasonally, a similar north-south trend remains and substantial warming is predicted to occur in every season. However, the warming in the fall and winter is substantially less than in the spring and summer. When monthly averages are modeled, the picture becomes more complex with central Florida occasionally surpassing northern Florida in warming projections. Nevertheless, the same general trend remains. To examine monthly departure models, consult Appendix 1.

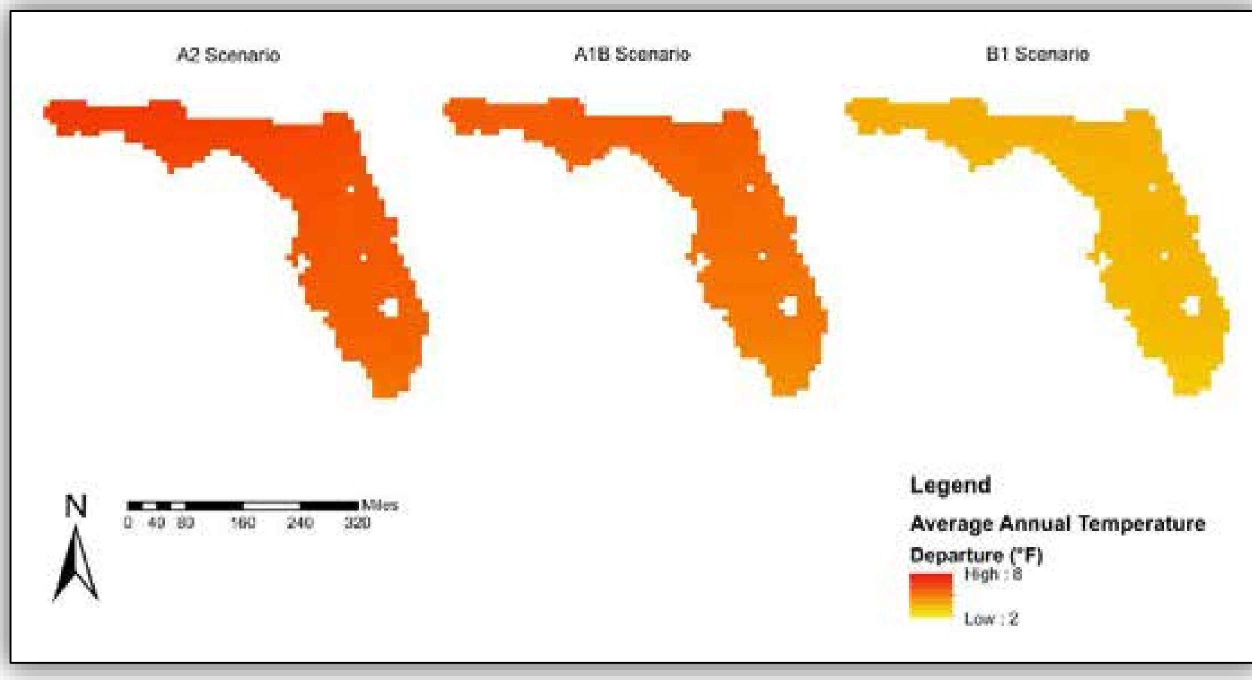


Figure 4.2. Temperature projections from the Climate Wizard showing three scenarios with more intense warming occurring in north Florida in every model and a gradient of decreasing warming intensity to the south (from Girvetz et al. 2009).

Predicting departures from annual average precipitation is more complex than projecting changing temperatures, more advanced downscaled precipitation models for Florida are being researched. These models will be of higher resolution and should more accurately determine the climate drivers and their effects. Using the Climate Wizard application on the same three emission scenarios and circulation models, some precipitation trends can be observed. There is a latitudinal pattern in the precipitation projections, with north Florida expected to have a slight to moderate increase in precipitation, although this increase is most pronounced in the moderate A1B emission scenario. Contrastingly, south Florida is projected to experience a moderate decrease in precipitation, which is pronounced under the A2 scenario. Central Florida, however, appears largely unchanged where the respective increases and decreases in precipitation converge (Figure 4.3).

Seasonally, these annual trends hold true with the exception of the fall. In the fall, precipitation is projected to increase throughout most of the state. The most pronounced disparity between precipitation predictions for north and south Florida occur in the summer and winter. Trends on monthly projections are more difficult to discern. South Florida is still projected to witness fewer monthly precipitation increases and more monthly precipitation decreases than northern Florida, accounting for less precipitation overall. To examine monthly departure models, consult Appendix 1.

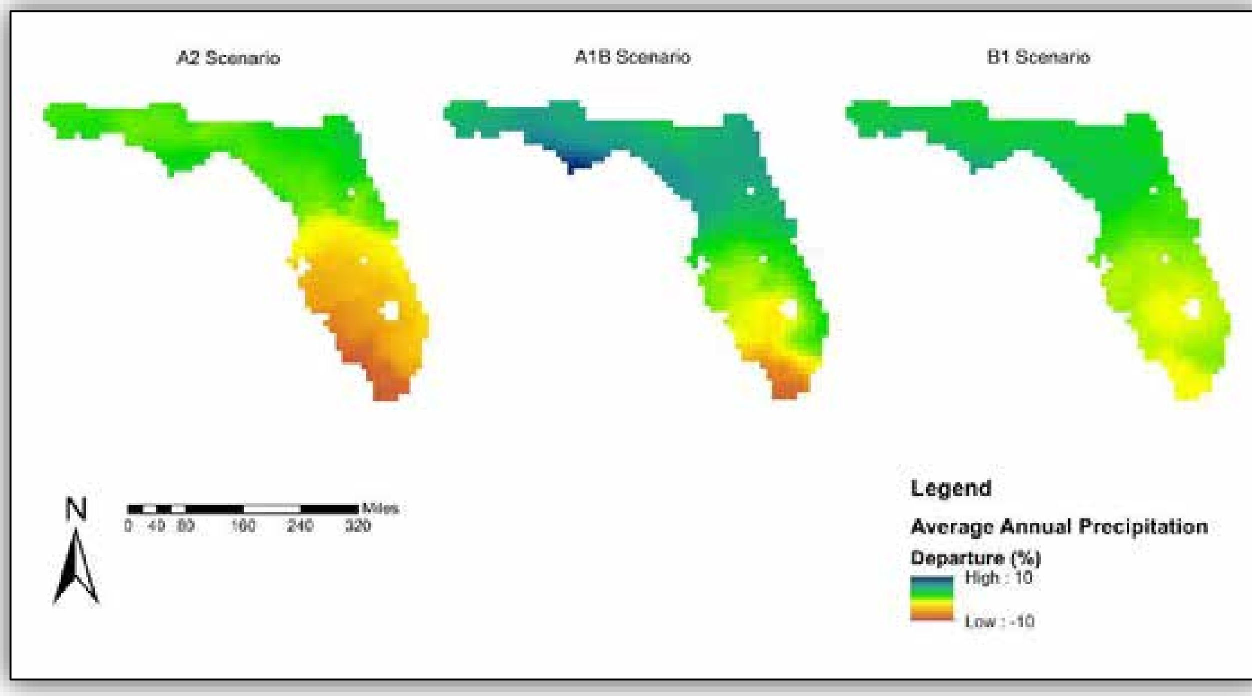


Figure 4.3. Precipitation trends for north and south Florida, showing an increase and decrease in precipitation, respectively (from Girvetz et al. 2009).

While the future projected shifts in temperature across Florida are greater than natural variability, the projected precipitation changes may not be differ greatly from the natural variability for much of Florida and that these precipitation projections should be seen as likely possibilities and not significant trends. Summaries of projected for these measurable climatic shifts for Florida can be found in Table 4.2. Climate models are still evolving (particularly precipitation models), especially at these finer scales.

Table 4.2. Summaries of projected measurable climatic shifts for Florida. The citation numbers refer to the works cited section of this guide.

Climatic Changes	Region of Florida	Climate Projections (For Measurable Shifts)	Citation
Air temperature*	Statewide	According to a moderate emissions scenario, the average annual surface air temperature in Eastern North America (25°N – 50°N and 85°W – 50°W) will increase 6.5°F (14.2°C) by the end of the 21st century (2080 – 2099). Warming is expected under all seasons, with the greatest warming in the summer months. The number of days with temperatures greater than 90 °F (32.2 °C) will increase across the southeast.	1 (pg 13), 5

Air temperature*	Panhandle	Average annual temperature projected change: +3.5°F by 2050; (Summer increase +4°F) +5.2°F by 2080; (Summer increase +5.8°F)	2
	North Peninsula	Average annual temperature projected change: +3.4°F by 2050; (Summer increase +3.7°F) +5.0°F by 2080; (Summer increase +5.5°F)	2
	Central	Average annual temperature projected change: +3.1°F by 2050; (Summer increase +3.5°F) +4.7°F by 2080; (Summer increase +5.1°F)	2
	South	Average annual temperature projected to increase: +2.9°F by 2050; (Summer increase +3.1°F) +4.3°F by 2080; (Summer increase +4.6°F)	2
Precipitation*	Statewide	Droughts more frequent and last longer, precipitation more often occurs in heavy downpours. Precipitation changes are dependent on the emission scenario, but generally predict increases in the panhandle and northern peninsula and decreases in South Florida. Under the highest emission scenario, precipitation would decrease across the state by 2080, with the greatest decreases in South Florida.	1, 2
	Panhandle	Average annual precipitation projected to increase by: +1.4% by 2050 +1.6% by 2080.	2
	North Peninsula	Average annual precipitation projected to increase by: +1.9% by 2050 +1.6% by 2080	2
	Central	Average annual precipitation projected to decrease by: -0.2% by 2050 -1.3% (-5.5% to +1.3%) by 2080.	2
	South	Average annual precipitation projected to decrease by: -3.3% by 2050 -5% by 2080.	2
Soil moisture	Average	The USGCRP models show mixed results for the summer soil moisture content. The Canadian model projects that drought will be more frequent, while the Hadley model suggests that northern Florida will have more soil moisture.	3, 4
Sea level rise (SLR)	Statewide	Modeling of past trends project a SLR of 0.25-0.34 m by 2080 with no deceleration indicated over the time period of forecast.	6
	Gulf Coast	Modeling of past trends project a SLR by 2080 of: 0.31 m at Key West 0.35 m rise at St. Petersburg	6, 21, 22

Sea level rise (SLR)		0.27 m rise at Cedar Key 0.34 m rise at Pensacola Projected best estimates of SLR are 0.13 m by 2030, and 0.3 m for Naples, St. Petersburg, Clearwater and Pensacola by 2050.	
Sea level rise (SLR)	Atlantic Coast	Modeling of past trends project a SLR of 0.25 m at Fernandina by 2080. Projected best estimates of SLR of 0.14 m by 2030 and 0.33 m by 2050 for Fernandina Beach.	6, 21, 22
Ocean acidification	Gulf and Atlantic coasts	Decline in oceanic pH by 0.3-0.7 by 2100 (global, not FL specific). Will cause associated > in CO_2 partial pressures and bicarbonate ion concentrations, < bicarbonate ions, shifts in trace metal and nutrient chemistry. OA could < nitrification rates by 3–44%, affecting oceanic nitrous oxide production, < supplies of oxidized nitrogen in the upper layers of the ocean, and fundamentally alter nitrogen cycling in the sea.	14, 15, 16, 17
Sea surface temperature (SST)	Statewide	Florida SST trends from 1848-2002 are +0.1-0.9°C/century. Local trends available for various coastal cities on the Gulf and Atlantic coasts of FL. High variability with increased spatial scale.	18
Sea surface temperature (SST)	Global	IPCC 2007 made global SST projections to 2100 of increases of 1.5-2.6°C. Using IPCC SRES A1B scenario one model predicts Northern Hemisphere SST to increase by 1.1-1.3°C by 2050.	19, 20
Changes in storm patterns (intensity & frequency)	Statewide	There is uncertainty due to past storm variability. Projections based on high-resolution models also show variation, indicating a 6-34% global decrease in the frequency of tropical cyclones but with more frequent stronger storms (category 4 and 5) with intensity increases of 2-11% and a 20% increase in precipitation rate within 100 km of the storm center by 2100. Changes in the Atlantic may be detectable after 2050. Some models predict the greatest change to occur in the Western Atlantic, north of 20°N. Sea level rise may exacerbate storm damage.	7-13
Altered Groundwater	Statewide	Increased evapotranspiration due to higher temperature and decrease in precipitation leads to less groundwater recharge.	24, 29
Altered Groundwater	Coastal Areas	SLR will cause intrusion into coastal aquifers.	4, 23, 24
Altered Hydrology	Statewide	In spring, it is projected to be much drier. During fall, all regions are subject to slightly wet conditions. As an average, the downscaled models project an 11% decrease in rainfall March-May, an 8% decrease in Jun-Aug, a 3% increase in Sept-Nov and a 5% decrease during Dec-Feb.	1
Altered Hydrology	Statewide	Human demand on freshwater reserves will increase leading to less water availability for natural systems.	4, 25

Altered Hydrology	Statewide	Lower base flows, higher peak flows, and longer droughts due to overall lower precipitation, but with an increase in stochastic heavy rain events.	26, 27
		Wet and dry periods will be more extreme.	29
		The proportion of total annual rainfall from heavy rainfall events is likely to increase.	30
	Peninsula	This area is expected to have a severe drying condition that is projected to be most severe Jun-Aug.	1
	Panhandle	During the winter this area will be dryer.	1
		Apalachicola River predicted to have lower high and low flows. Average year mid-century may have 18% less floodplain inundation than current flow regime.	31
Inland water temperature	Statewide	Increase mean water temperature by an average of 2-3°C due to direct correlation with air temperature increase when not mediated by groundwater springs.	28

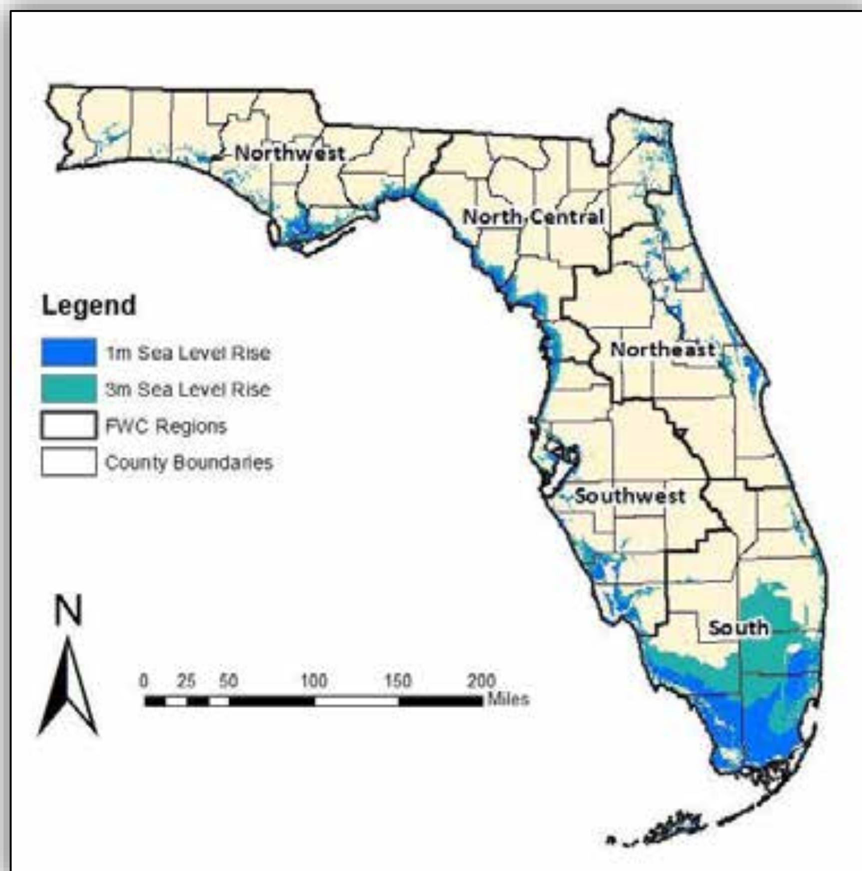
**Averages in projections are based on emission scenarios B1, A1B, A2 across different regional locations.. Locations for regional predictions are: Panhandle (Pensacola, Panama City, Tallahassee); North Peninsula (Jacksonville, Lake City, Gainesville); Central Florida (Orlando, Tampa, Lake Wales); South Florida (Miami, Naples, Flamingo).*

One of the most direct and pronounced changes due to global climatic change is SLR. While SLR is not technically climatic change itself (rather a result of major climatic change), it is associated with specific measurable shifts that results in ecological impacts and consequences in much the same way as the other climatic changes described. Therefore, for the purpose of this adaptation guide, SLR will be referred to and treated as a major climatic change with subsequent measurable climatic shifts.

Easily modeled and quantified at multiple scales, SLR will be commonly used as a landscape level example of climate change in this guide. Sea level rise is often modeled simply in defined increments such as feet or meters. The following maps illustrate the importance of SLR on coastal Florida, as well as the need for climate change adaptation development and to predict future impacts on species, habitats, and communities. While useful, the models do not provide consistent predictions as to impacts at different temporal and spatial scales. Sea level rise will not impact the coastal areas of Florida to the same degree, Table 4.3 shows the effect of SLR on land area the five FWC operational regions as a reference to where impacts maybe the greatest. Figure 4.4 depicts the impacts of one and three meters of SLR on Florida, including the various FWC regions. Figures 4.5-4.9 show the modeled inundation impacts of one and three meters of SLR on various regions of Florida, with overlays of Wildlife Management Areas.

Table 4.3. Percent reduction of land area for the five FWC regions due to inundation from SLR of 1 and three meters (based on a bathtub inundation model, which does not account for SLR variability throughout the state, calculated by FWC).

FWC region	% flooded 1m	% flooded 3m
South	22.0	50.4
Southwest	5.6	10.2
Northeast	5.4	9.7
North Central	4.6	9.6
Northwest	3.6	8.4



F*igure 4.4. This map is a simple SLR projection based depicting the extent of one and three meters of sea level rise on Florida's landscape.*

The Sea Level Scenarios Sketch Planning Tool (SLSSPT) is a viewer developed to look at modeled SLR projections on decadal scales, focused on the impact on transportation infrastructure (Thomas *et al*. 2013). While the focus is impacts to transportation infrastructure, it provides an approach to SLR modeling and could conceivably be useful for a variety of applications (http://sls.geoplan.ufl.edu/),

4 Climate Projections

additional viewers are included in Section 10.2.2. The tool utilizes US Army Corps of Engineers (USACE) projection curves (Low = Historic rate of increase, Medium = Intermediate curve, and High = High curve) and incorporates multiple tidal datums (MHHW = Mean Higher High Water, MHW = Mean High Water, MSL = Mean Sea Level, MLW = Mean Low Water, MLLW = Mean Lower Low Water).

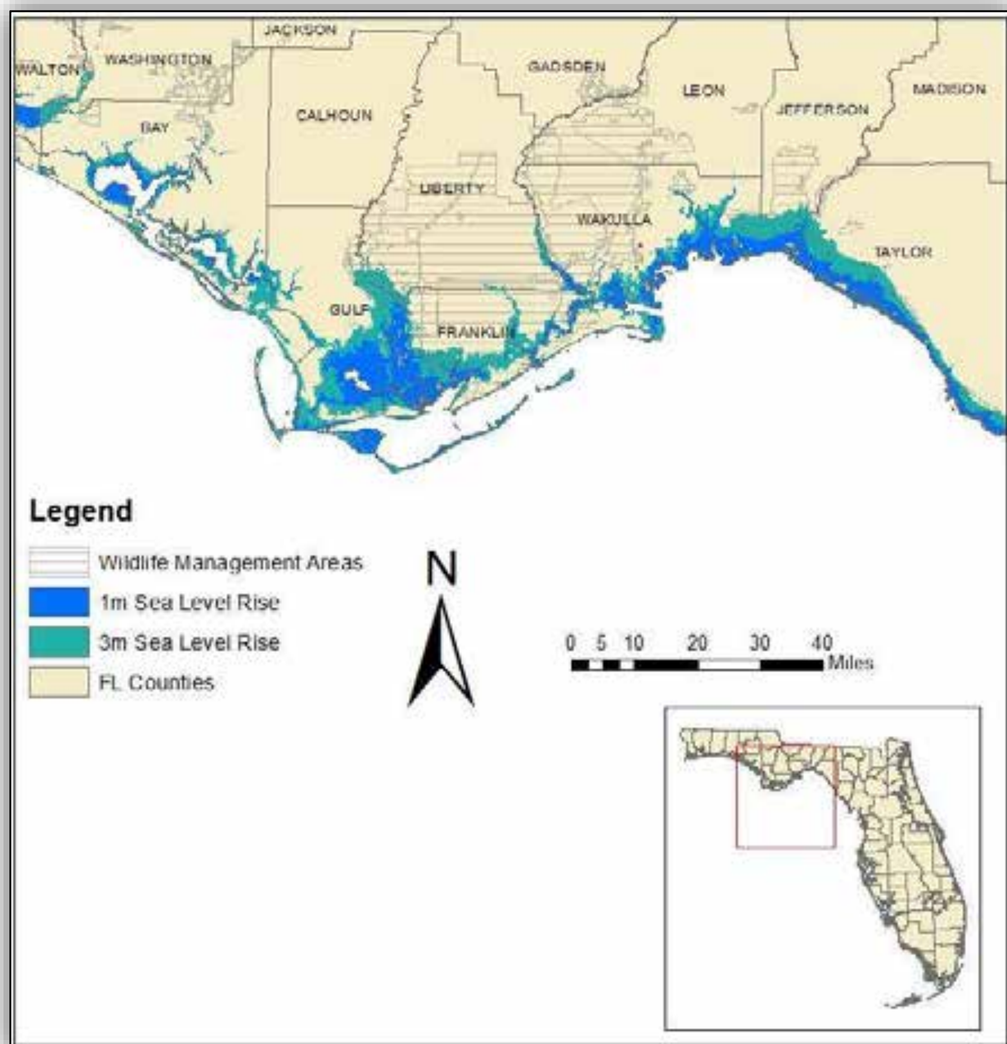


Figure 4.5. SLR projections for one and three meters on a portion of northwest Florida with overlays of FWC's Wildlife Management Areas.

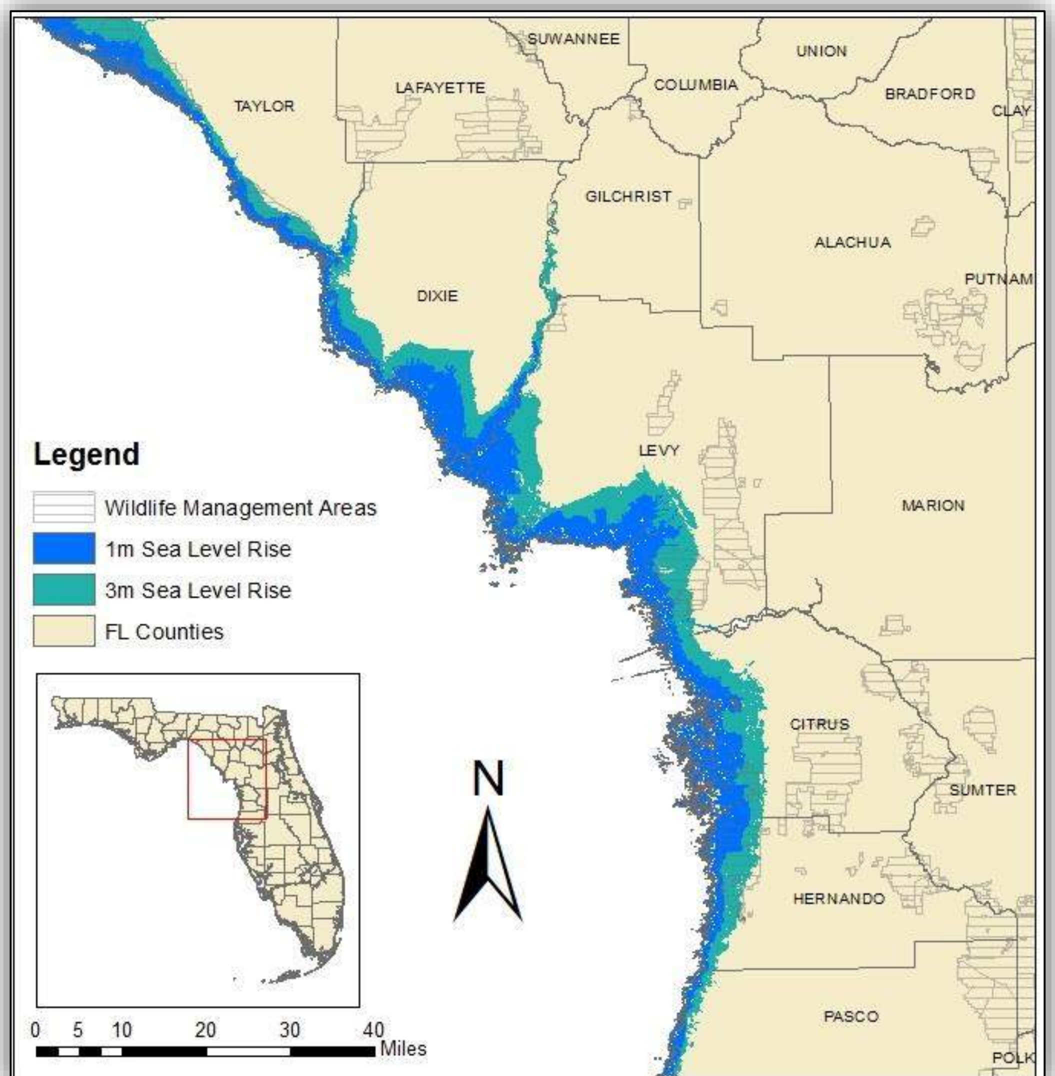


Figure 4.6. SLR projections for one and three meters on a portion of the big bend regions of Florida with overlays of FWC's Wildlife Management Areas.

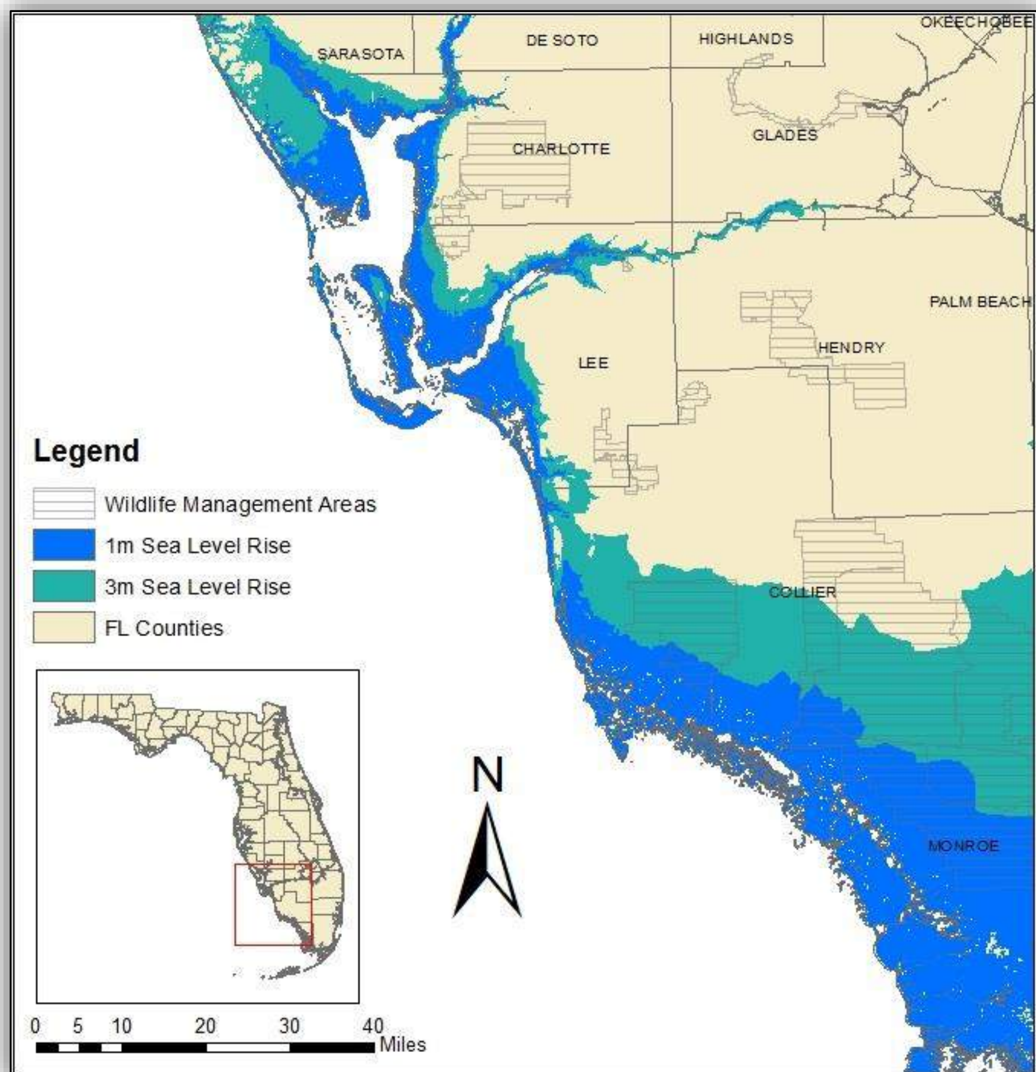


Figure 4.7. SLR projections for one and three meters on a portion of southwest Florida with overlays of FWC's Wildlife Management Areas.

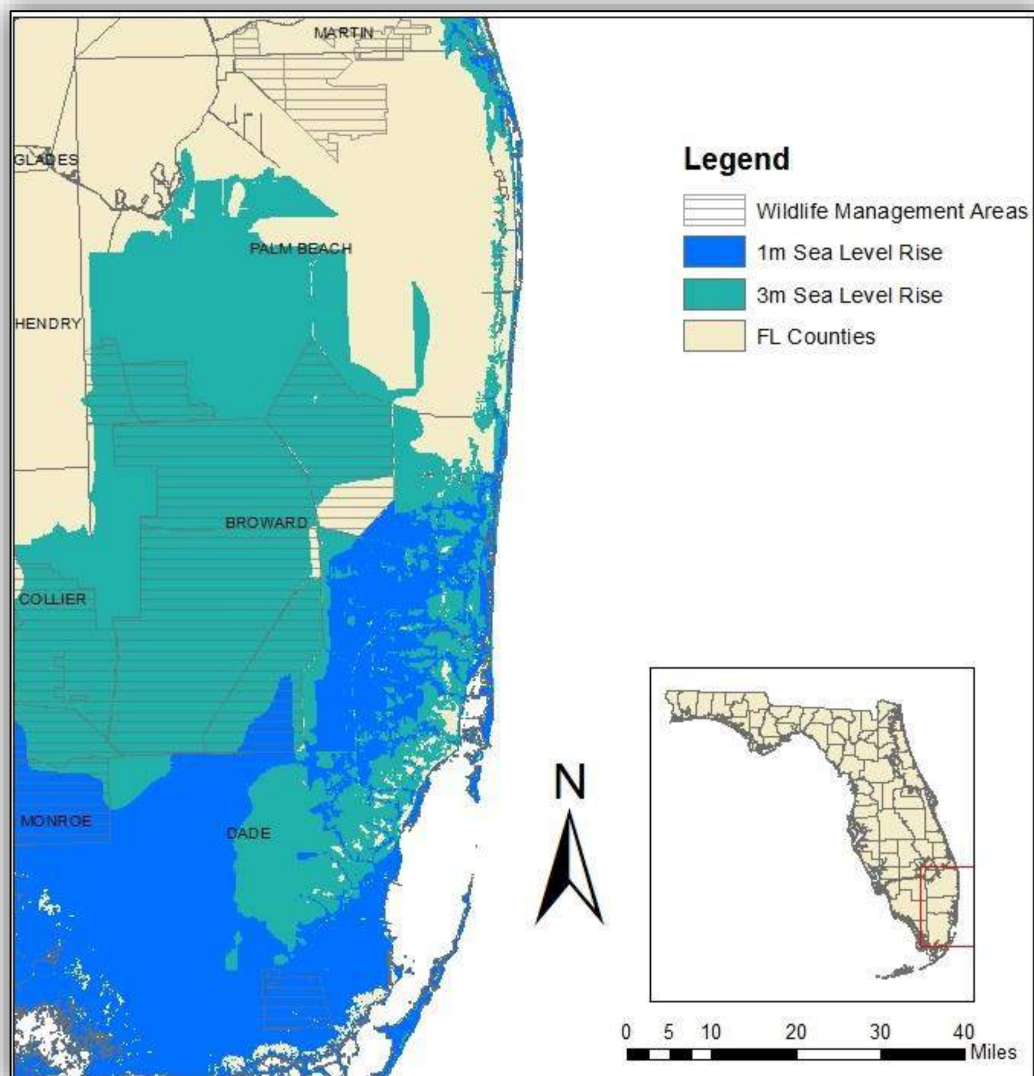


Figure 4.8. SLR projections for one and three meters on a portion of southeastern Florida with overlays of FWC's Wildlife Management Areas.

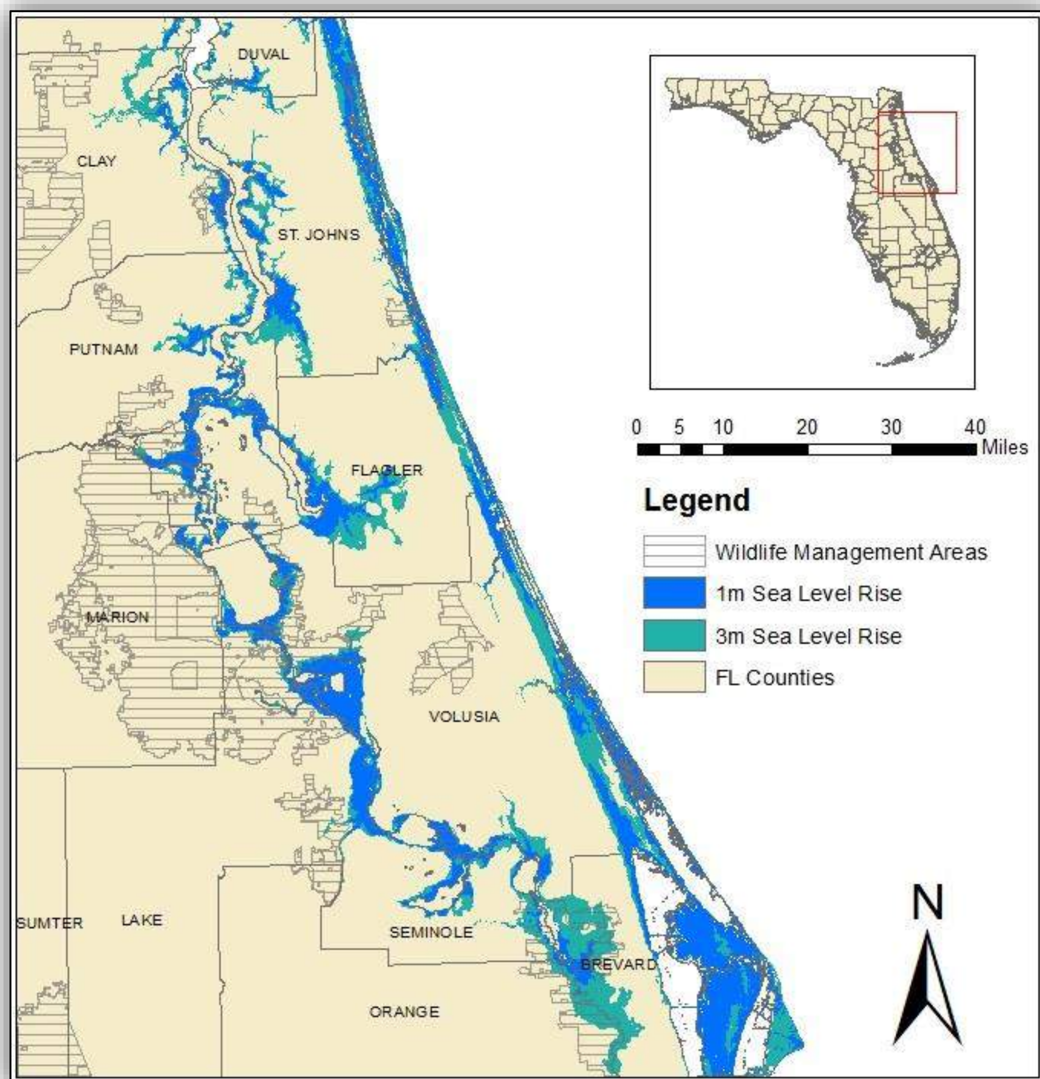
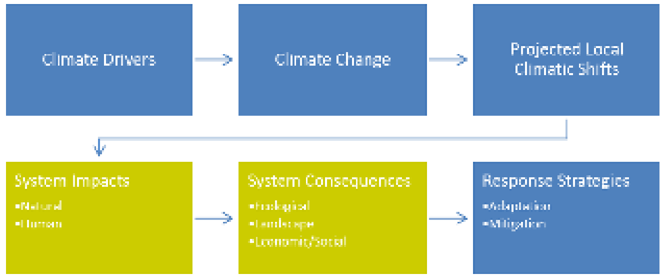


Figure 4.9. SLR projections for one and three meters on a portion of northeastern Florida with overlays of FWC's Wildlife Management Areas.

4.1 FROM CLIMATIC SHIFTS TO IMPACTS AND CONSEQUENCES

Projected shifts in Florida's climate will impact both natural and anthropogenic systems across the state, causing potentially negative (and some positive) consequences for terrestrial, freshwater, and marine/coastal systems. This next section outlines the connections between climate change impacts and their consequences both broadly and for each of these three systems. The following section outlines the connections between climate change impacts and their consequences both broadly and for each of these systems, and identifies which ecological consequences are likely to affect various habitats, communities, and species.

5 IMPACTS AND CONSEQUENCES OF CLIMATE CHANGE ON FLORIDA



In previous sections, climate change projections were presented derived from downscaled regional climate models and other regional or national climate change assessments or modeling exercises. The next step of this process is to assess Florida's vulnerability to these climatic changes and the associated impacts. National and regional level resources do not provide the necessary detail to adequately assess the vulnerability of communities, habitats and species in Florida nor derive adaptation strategies. To accomplish these tasks effectively, FWC saw the need to assess the impacts and consequences of climate change using a more robust impact assessment that could be linked to the regional and national level models and resources. While this is not a fully realized vulnerability assessment, it does provide a detailed starting point and more specific guidance on adaptation strategy development than previous, less thorough approaches. Only by referencing community or habitat specific impacts (and their consequences), can sufficiently precise climate adaptation be developed.

In response to these needs, FWC initiated the development of detailed review and assessment of potential climate change impacts and their ecological consequences through various partnerships, case study projects, literature review, and working groups. This impact assessment employed brainstorming exercises aimed at soliciting expert opinion, input and consensus on broad systems, communities, and habitats, the results of which precede grouped habitat sections in Section 6. The result was a linking of each measurable climatic shift to a set of impacts, which were then linked to a specific set of ecological consequences. The working groups also developed adaptation strategies based on their review and analysis of the systems and habitats.

5.1 ECOLOGICAL IMPACTS OF CLIMATE CHANGE

Many species of fish and wildlife in Florida have limited ranges that are determined in part by climatic conditions and their survival could be threatened by climatic shifts. This threat is greater for those with narrower tolerance ranges, or those occupying habitats in areas where migration or relocation is challenging due to physical barriers (e.g., rivers) or unsuitable habitat (e.g., caused by clearing of vegetation, soil differences, topography). Species with a limited ability to disperse or having specialized habitat requirements, small populations or low genetic diversity are expected to be most at risk. Physical environmental parameters (e.g., temperature and rainfall) play a major direct or indirect role in determining species distribution, survival and ecosystem sustainability. The appropriate site conditions for a habitat or species may shift locations within the landscape as climate factors change. The following list is representative of potential ecological impacts of climate change that can act synergistically or cumulatively with other stressors that in turn lead to further cascades of consequences and effects. It is challenging to predict the full extent of ecological changes that may result from climate change and the list should not be considered all inclusive.

Climate change has the potential to cause positive and negative impacts on species and ecosystems:

Species

- *Reductions or expansions in the geographic range*: Many Florida species have distributions that are limited by temperature, precipitation, or other physical habitat parameters and they may be vulnerable to even modest changes in climate.
- *Changes to lifecycles (shifts in phenology):* The timing of life stages may shift with changing climate conditions. Species with closely intertwined life cycles may experience mismatched shifts of event timing if species shift do not coincide (e.g. bird migration/nesting cycles and insect emergence). There is growing evidence that some species are breeding earlier as a result of recent warming.
- *Changes in species dynamics and survival*: It is projected that temperature and moisture availability may be impacted, which can directly affect the physiology of species. Declines are possible if there are spatial and temporal barriers to successful habitat migration.
- *Changes in habitat location:* The location of suitable habitat may shift, as vegetative composition and other key environmental variables respond to climate change. Some species may be able to move as a means of adapting to shifts in habitat conditions, while others may not as the shifts in suitable habitat outpace their ability to move. It is also likely that some different climatic boundaries may move at different rates, thus further affecting the size of species ranges over time.
- *Increased risk of extinction, especially for vulnerable species*: Species with limited ranges or dispersal ability, have specialized habitat requirements, have small populations and/or have low genetic diversity are typically the most vulnerable to extinction. Species with extensive ranges, long-range dispersal mechanisms, large populations and high genetic diversity are less likely to be at risk of extinction.
- *Increased expansion of invasive species:* Many exotic and invasive plants and pest species already possess characteristics that will allow them to take advantage of climatic changes (e. g., highly mobile, opportunistic breeding, wide climatic tolerance). Native communities under stress from climatic changes may be more susceptible to invasion and other disturbances.

Ecosystems and Communities

- *Changes in the structure and composition:* The factors affecting species previously described (e.g., temperature and precipitation) will in turn alter interspecific interactions, such as competition and predication, leading to changes in the structure and composition of communities and ecosystems. Variations in climate will affect the distribution, phenology, physiology, habitat use and extinction rates of individual species. Growing seasons of plants may shift along with first blooms.

- *Changes in coastal and estuarine habitat due to rising sea levels*: Mangroves, coastal wetlands, and seagrass communities will be affected in various ways, depending on erosion, depositional processes and coastline relief.
- *Projected increases of carbon dioxide (CO_2) concentration in the atmosphere:* These increases could lead to changes in rate of plant growth, which can alter plant–animal interactions, change dominant plant species within habitats, and modify ecosystem-level processes. Further, it is expected that there would be interaction effects from variation in CO_2, temperature and rainfall.
- *Indirect effects:* Climate change could cause indirect effects by influencing the intensity and magnitude of existing processes (e.g., fire regimes), stresses (e.g., invasive species), habitat quality, and ecosystem functions.

5.2 GENERAL ECOLOGICAL CONSEQUENCES OF CLIMATE CHANGE

These broad ecological impacts are associated with more precise changes in the ecology of the system that is influenced, called ecological consequences throughout this adaptation guide. Ecological consequences can be either positive or negative depending on the system and organisms effected. Some of the most common of these ecological consequences are listed below in Table 5.1, however there are many others and these consequences can be categorized in multiple different ways.

Table 5.1. Common ecological consequences of climate change organized by type of system impacted.

Category of consequence		Examples of negative (-) and positive (+) consequences
Community Dynamics	-	Decreased prey availability
	-	Decreased predation pressure (also +)
	-	Declines in native species diversity
	-	Imbalance of predator prey relationships
	-	Reductions (or expansions) in species ranges and occurrences
	-	Increased success of invasive and introduced species
	-	Reduced recruitment success
	+	Decreased invasive and introduced species

Physiology/Phenology	-	Increased disease outbreaks
	-	Increased mortality
	-	Decreased longevity
	-	Reduced reproductive success
	-	Reduced metabolic processes
	-	Impeded physiological processes
	-	Altered sex ratios and behaviors
	-	Changes in reproductive phenology
	-	Changes in migration and movement phenology
	-	Changes in disease vector phenology
	+	Increased growth rates
Land cover and Habitats	-	Habitat degradation
	-	Habitat loss
	-	Habitat migration
	-	Habitat fragmentation
	-	Loss/movement of nesting sites/locations
	-	Changes in nutrient/sediment flows (also +)
	-	Changes in water chemistry and quality
	+	Habitat expansion
Disturbance Regimes	-	Altered fire regimes
	-	Decreased frost frequency (also +)
	-	Increased frequency, duration, and severity of droughts
	-	Increased frequency, duration, and severity of floods
	-	Increased severity and duration of storm events

5.2.1 ECOLOGICAL CONSEQUENCES FROM SEA LEVEL RISE

An extreme ecological consequence for a species is the loss of its habitat. Sea level rise is projected to impact a wide array of habitats and species. For some, the consequences could be devastating. Some species are projected to lose all of their existing habitat with even one meter of SLR. Figure 5.1 shows the projected statewide spatial extent of SLR inundation for one and three meters. Tables 5.2 and 5.3 show the percentage of various land cover classes and habitats or species affected and do not include any possible range expansions due to climate change.

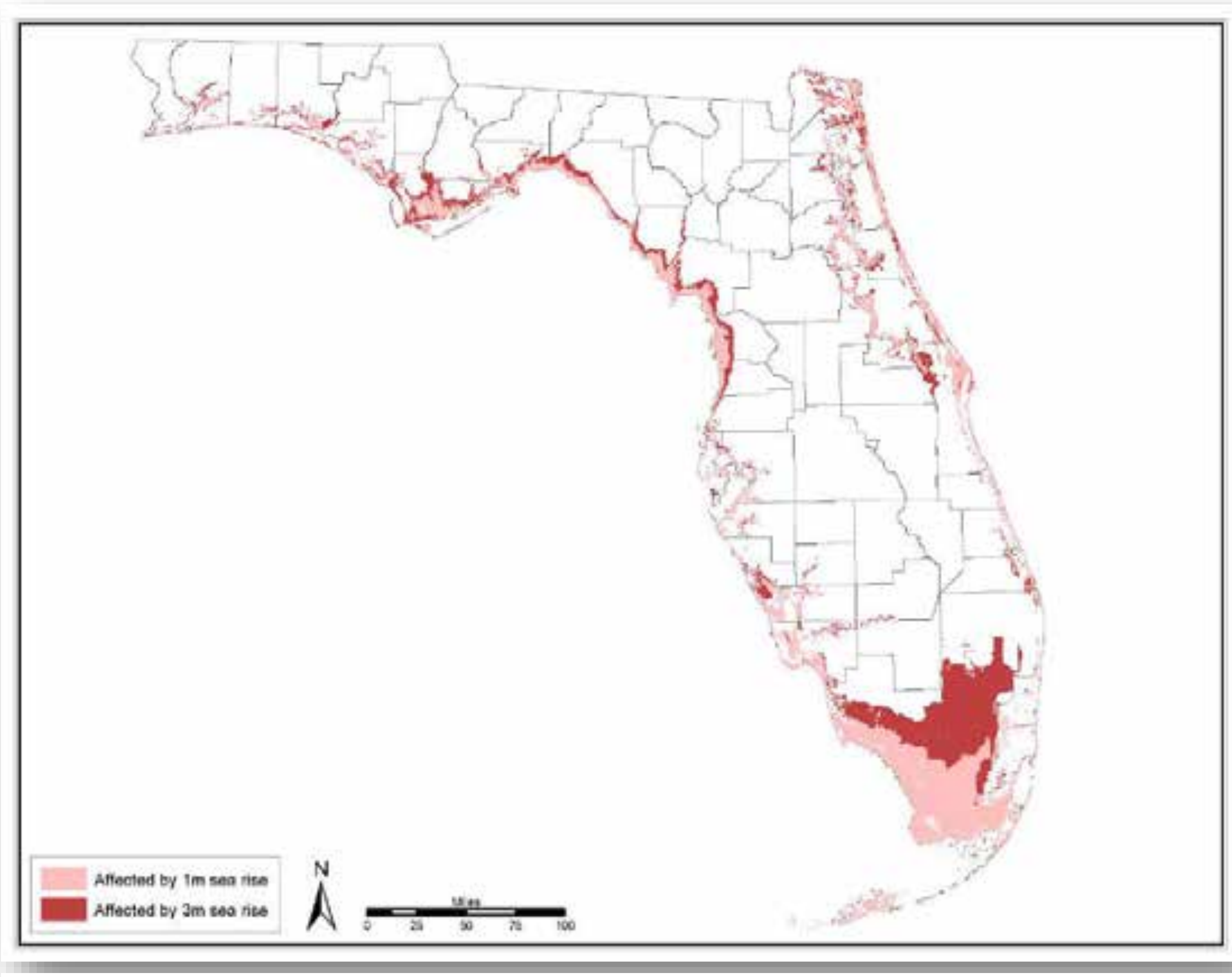


Figure 5.1. Spatial extent of inundation due to SLR (one and three meters) as it relates to the undeveloped areas along the coast of Florida, impacts to developed areas (urban and suburban) not shown.

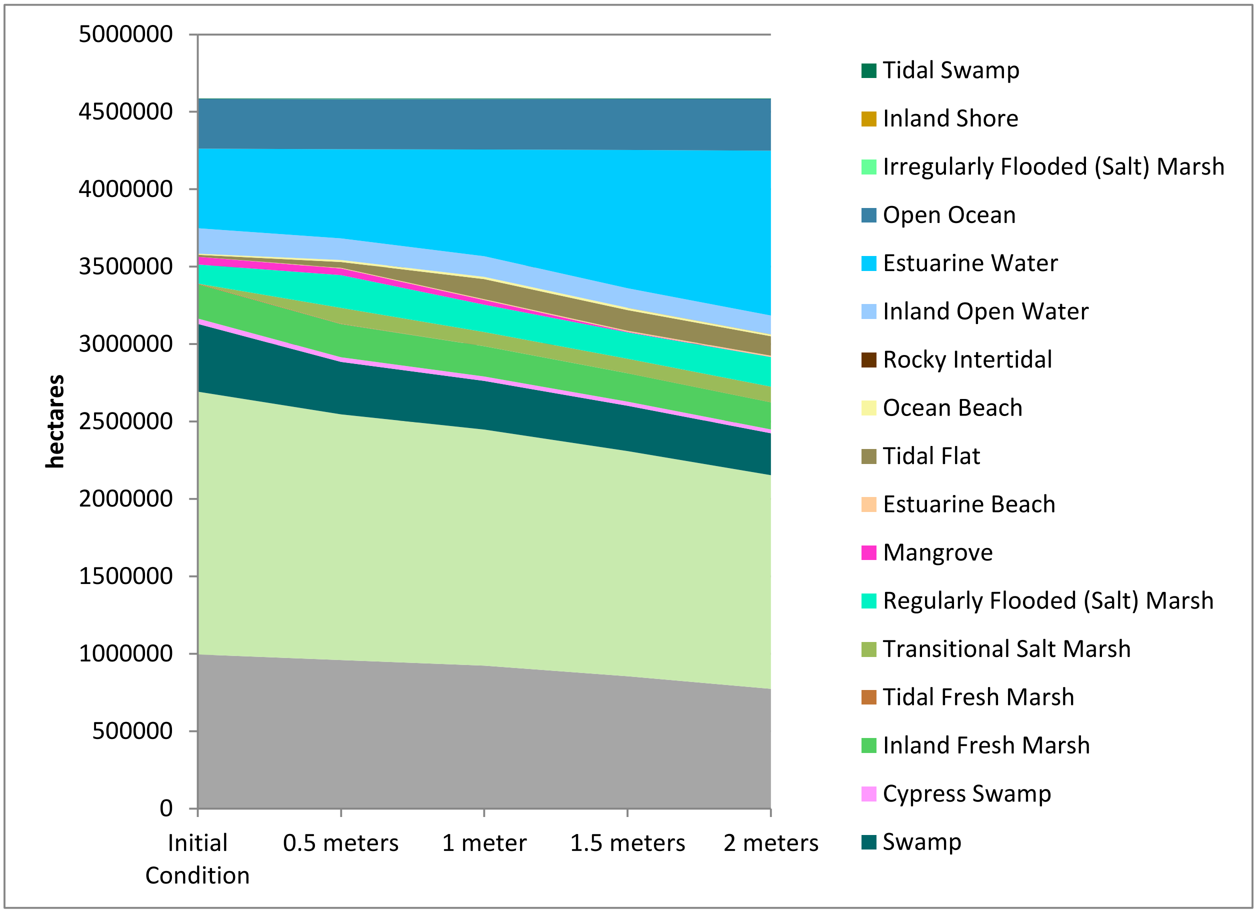


Figure 5.2. Projected land cover changes due to SLR (0-2 meters), as it relates to some of Florida's ecological communities. This graphic is a reproduced outcome of the SIVVA Report, created with SLAMM run results (Center for Landscape Conservation Planning and Florida Natural Areas Inventory 2014).

Figure 5.2 demonstrates that different land cover types may expand or contract with SLR, therefore habitat loss and gain may be variable over time (Center for Landscape Conservation Planning and Florida Natural Areas Inventory 2014) and Table 5.2. It is too simplistic to treat SLR as purely a habitat loss or inundation, as some land cover types may expand or shift up in elevation in the face of SLR. Some habitat and community shifts are likely to occur, especially with a more modest rise in sea levels. However, as the rate of SLR becomes increases, open water land cover types become more prominent as other habitats diminish. When considering the impact of SLR, there will likely be a shift in the natural community structure before being completely lost. With loss of habitat, the impact to species will vary, but in some cases will be extreme. Table 5.3 displays the percent reduction of habitat due to sea level rise of more than 50 of Florida's species.

Table 5.2. Percent reductions in various habitats and communities using current Cooperative Land Cover Map (Version 3.0) (FNAI and FWC 2015), due to inundation from SLR of one and three meters (based on simple bath tub inundation model).

Class	% flooded 1 m	% flooded 3 m
Beach/Surf	20.4	42.0
Coastal Strand	31.9	74.9
Cypress	8.6	26.1
Dry Prairie	0.0	0.0
Floodplain Swamp	27.8	39.6
Hardwood Swamp	8.8	20.5
Hydric Hammock	29.3	52.5
Mangrove	88.1	88.2
Marsh/Wet Prairie	19.4	50.8
Pineland	2.4	7.7
Pine Rockland	80.9	98.6
Salt Marsh	83.5	87.8
Sandhill	0.1	1.0
Scrub	4.1	9.5
Tidal Flat	10.4	10.6
Transitional	0.7	4.5
Tropical Hammock	55.1	88.3

Table 5.3. Percent reductions of species' habitat of at least 10% reduction, due to SLR inundation of one and three meters (based on simple bath tub inundation model and FWC models). Species selected were those that had existing potential habitat models and have some of their potential habitat in close proximity to the coast.

Species	% of habitat flooded - 1 m	% of habitat flooded - 3m
Lower Keys marsh rabbit	100.0	100.0
Silver Rice rat	100.0	100.0
Florida ribbon snake	100.0	100.0
Cuban yellow warbler	100.0	100.0
Crocodile	99.9	100.0
Key deer	99.9	100.0
Keys mud turtle	99.9	100.0
Key ringneck snake	99.9	100.0
Mangrove terrapin	99.9	100.0
Sanibel Island rice rat	99.8	100.0

Mangrove cuckoo	99.7	100.0
Black-whiskered vireo	99.7	100.0
Mangrove snake	99.6	99.9
Brown pelican	99.6	99.9
Prairie warbler	99.5	100.0
Salt marsh vole	99.4	100.0
White-crowned pigeon	99.2	99.9
Ornate diamondback terrapin	98.9	99.7
Gulf salt marsh snake	98.6	99.8
Marians marsh wren	98.5	99.9
Roseate tern	98.2	100.0
Scotts seaside sparrow	98.2	99.9
Florida east coast terrapin	96.1	98.9
Atlantic salt marsh snake	95.8	99.4
Florida keys mole skink	94.4	99.9
Florida mink	93.6	99.5
Worthington's marsh wren	86.0	99.8
Carolina Diamondback terrapin	84.7	97.9
McGillivray seaside sparrow	84.2	99.8
Rim rock crowned snake	82.7	98.3
Mississippi diamondback terrapin	80.2	93.1
Louisiana seaside sparrow	79.0	96.8
Key largo woodrat	65.7	99.2
Key largo cotton mouse	65.7	99.2
Southeastern beach mouse	60.9	89.0
Black Skimmer	54.3	87.0
Cuban snowy plover	53.6	87.2
Cedar key mole skink	52.8	90.0
Least tern	50.7	83.5
Everglades mink	39.8	94.2
Gulf hammock dwarf siren	35.6	73.0
Choctawhatchee beach mouse	35.1	67.8
Wading birds	32.5	52.6
Black-crowned night heron	29.7	57.4
Yellow-crowned night heron	29.0	51.5
Black rail	27.0	38.2
Barbour's map turtle	26.9	30.0

Least bittern	26.2	65.1
Snail kite	22.5	66.7
Limpkin	20.8	53.4
St. Andrews beach mouse	19.8	72.3
Coastal dunes crowned snake	19.3	38.2
Glossy ibis	16.3	36.9
Big cypress fox squirrel	10.0	43.1
Spotted turtle	9.7	15.8
Panther	7.3	27.6
Sherman's short-tailed shrew	6.4	14.5

Additional maps of SLR effects for several land cover classes are included in Appendix 2 and discussed in the ecological consequences section of the respective land cover class. In addition, this section will describe the potential positive and negative consequences climate change may have on some of these habitats and species.

5.3 SOCIAL/CULTURAL/ECONOMIC IMPACTS

Climate change will have additional impacts on Florida's natural resources that will affect the ability of residents and tourist to safely enjoy and use them. The availability of healthy and safe resources such as clean ground and surface water, and a disease-free environment may be limited. Non-consumptive uses could also be altered by climate change including the diversity and abundance of species and natural habitats to view and access to outdoor recreational activities. The abundance of commercially and recreationally harvested species may also be altered. It is important for FWC staff and other conservationists to acknowledge these types of impacts as they may prove more relevant or important to some landowners, partners and stakeholders. A broader knowledge base will be vital to effectively engage a more diverse group of stakeholders. Managing the lands to maximize ecological processes, even with shifting natural communities, will impact the greater landscape level by being more resilient to the impacts of climate change.

Outdoor activities by residents and tourists contribute significantly to Florida's economy. Changes in precipitation patterns, SLR, and an increased intensity of storms may cause a reduction in activities such as birdwatching, wildlife viewing, hunting, fishing, and other recreational opportunities. Such opportunities may be affected due to changes in the species presence, abundance, diversity and health, alterations to the species habitats, compromised habitat due to storm damages and flooding, and restricted access to waterways. Florida may lose key elements of its floral and faunal diversity, including endemic species, many of which are the focus of wildlife viewing activities. However, there may be some positive consequences to climate related changes. Precipitation changes may provide increased opportunities for waterfowl hunting, improved sportfish populations, and improved angler harvest.

Additional indirect consequences of climate change impacts could include increases in numbers of insects due to population declines of predators (e.g., frogs), leading to an increased need to manage nuisance insects (e.g., mosquitos). Altered fire regimes could lead to increased costs for management activities such as fire suppression, and smoke management. Control of invasive plant species that are able to better adapt to changing climate conditions could have significant budgetary impacts for agencies and private landowners. Natural hazards could pose larger threats to property damage as coastal buffers lose ground, leading to economic impacts to private property. Emergence and virility could become a larger concern in regards to animal and human diseases as abundance and diversity of parasites and vectors increases.

Commercially important areas and activities may experience decreased stocks of harvested fish, crabs, shrimp, clams and oysters due to effects on species growth, reproduction or survival or important nursery grounds and reef habitats. The number, size, and health of harvestable species will directly affect individuals who depend on a healthy fishery for their livelihood. Warmer winter temperatures could better enable pests to overwinter, disease vectors and prevalence could lead to impacts on forest health and harvesting.

In the future, there may be increased competition for limited freshwater resources between humans and wildlife. This limitation could be caused by and/or contribute to a reduction in healthy ground surface water supplies. Changes in precipitation and storm events (e.g., floods) could increase the number and severity of contaminated wellfields.

5.4 SOCIAL/CULTURAL/ECONOMIC CONSEQUENCES

The broad impacts on human systems can be either positive or negative consequences depending on the system and components effected (Table 5.4).

Table 5.4. Types and examples of some indirect\secondary consequences to human systems caused by impacts of climate change (alterations to fish, wildlife and habitats).

Category of consequence	Examples of negative (-) and positive (+) consequences
Recreational activities	- Reduced birdwatching opportunities
	- Reduced wildlife viewing opportunities
	- Loss of outdoor recreational opportunities
	- Decreased access to outdoor recreational opportunities
	- Reduced hunting opportunities (e.g., quail)
	- Decreased recreational and subsistence fishing opportunities
	- Decreased sportfish populations

	-	Reduced bass fishery
	-	Increased obstructions to angling
	-	Reduced boating access to waterways/waterbodies
	-	Decreased nature-based tourism
	+	Increased fishing opportunities
	+	Increased waterfowl hunting opportunities
	+	Improved angler harvest
	+	Improved sportfish populations
Management activities	-	Increased cost of fire suppression
	-	Increased cost of smoke management
	-	Increased cost of invasive plant control
	-	Increased mosquito control costs
Human health and safety	-	Loss of buffers to storm damage
	-	Increased wave induced breaches
	-	Increased competition for limited freshwater resources
	-	Reduction in healthy groundwater supplies
	-	Increased contamination of wellfields
	-	Increased human disease issues (parasites, pathogens, insects)
Commercial harvest	-	Reduction in fishery value
	-	Shortened peak fishing season
	-	Unhealthy fish
	-	Reduction/shifts in diversity of fish
	-	Decreased stocks of fish, crabs, shrimp, clams, oysters
	-	Loss of important nursery habitat for fish and shellfish
	-	Decreased health of reef habitat

5.4.1 CULTURAL/ECONOMIC CONSEQUENCES OF SEA LEVEL RISE

Beyond natural communities, human systems will be particularly affected by rising seas and tides. This brief section shows how SLR will impact human defined areas.

Depending upon the level of SLR, south Florida counties are projected to be severely impacted while other areas will likely experience little direct impact (Figure 5.3). The left-most map (5.3a) displays the county inundation that occurs with one meter of SLR and the map on the right (5.3b) displays what occurs with three meters of SLR. These scenarios are all bathtub inundation (or simple elevation based SLR models and do not reflect hydrologic connectivity). Most of the bathtub models are limited in their accuracy for certain regions or areas or at a finer scale. Sea level rise is likely to fluctuate greatly by location due to various factors, such as accretion or subsidence rates. The use of more precise (and environmentally inclusive) SLR modeling methods, such as SLAMM, is likely to yield more accurate local and regional results.

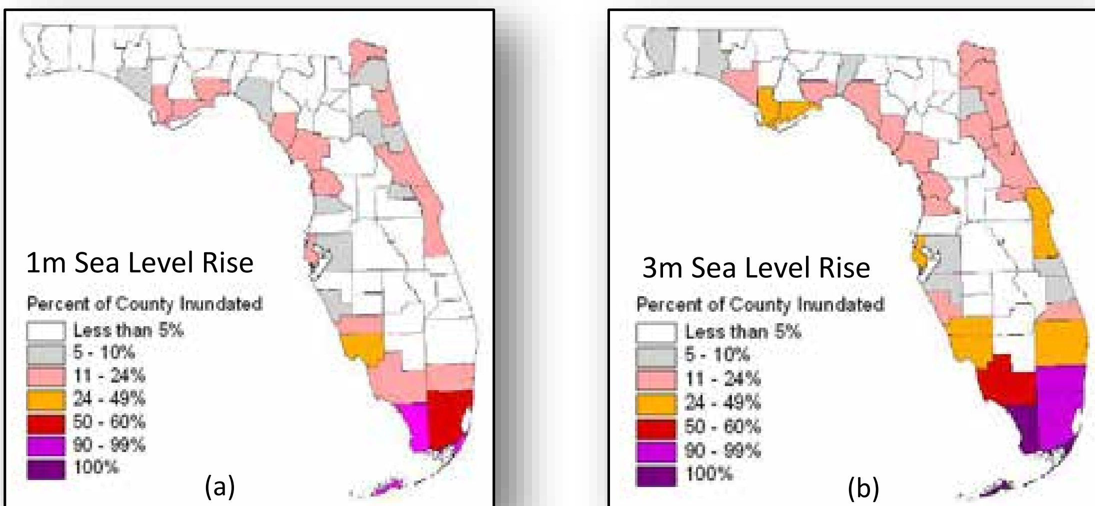


Figure 5.3. Percent of Florida counties inundated by one (a) and three (b) meters of SLR (based on simple bathtub inundation model).

Florida Fish and Wildlife Conservation Commission management areas are going to experience SLR impacts, with the severity of extent varying throughout the state. Projections for one and three meters SLR are shown with corresponding management areas likely to be affected (Figures 5.4 and 5.5).

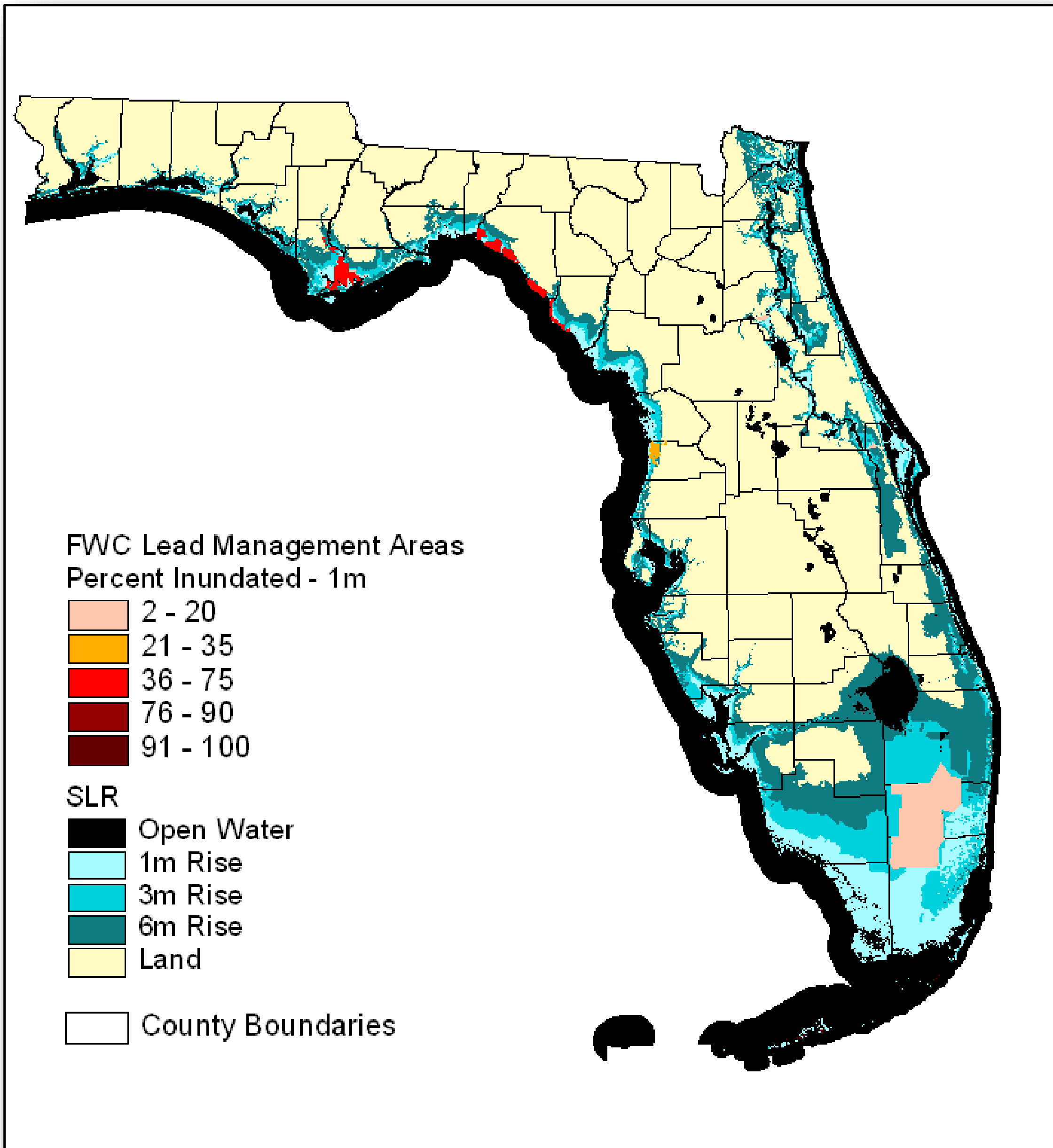


Figure 5.4. Percent inundation of FWC lead management areas due to inundation from one meter of SLR and areas of Florida expected to be inundated at three levels of SLR (based on simple bathtub inundation model).

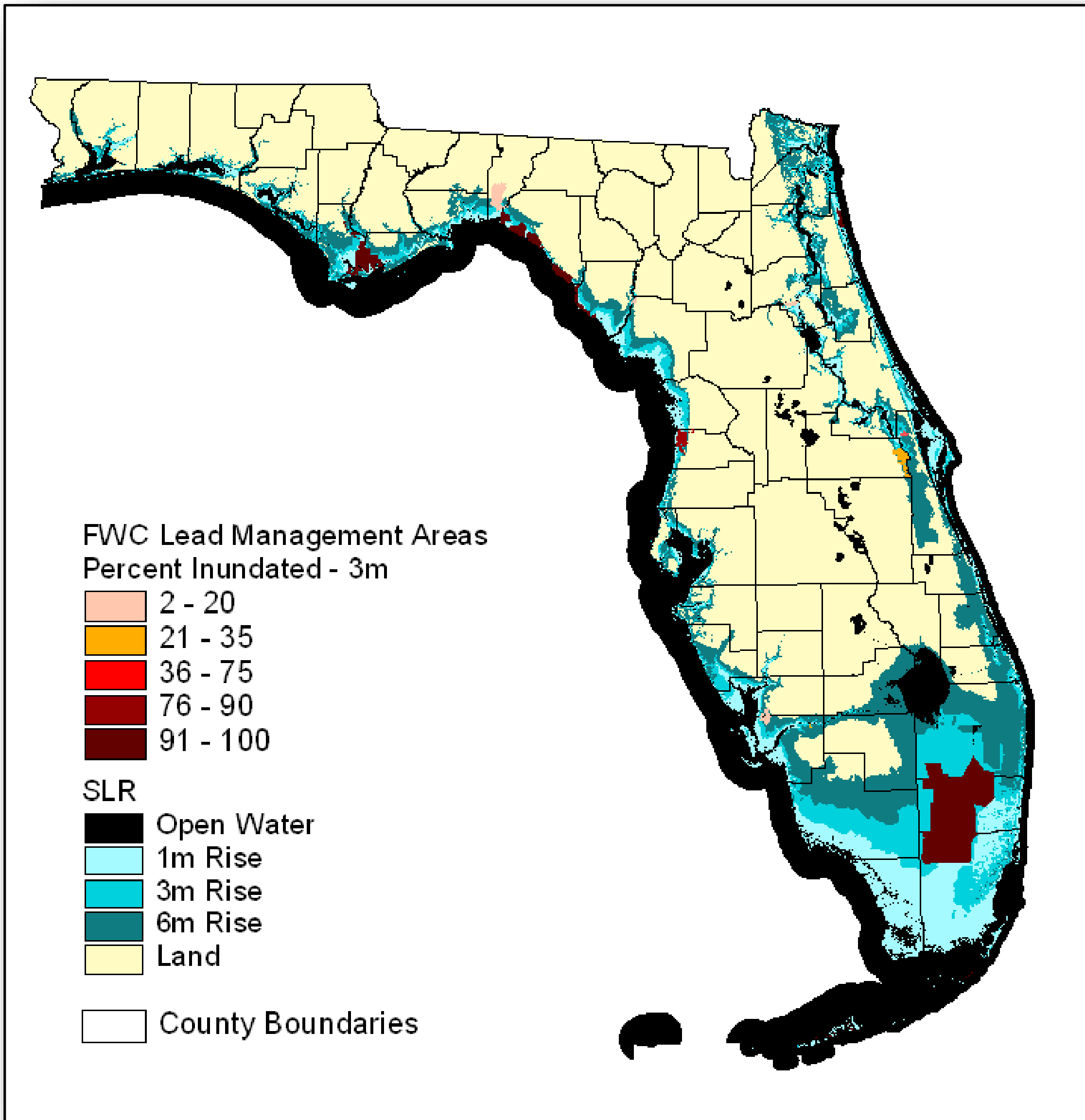
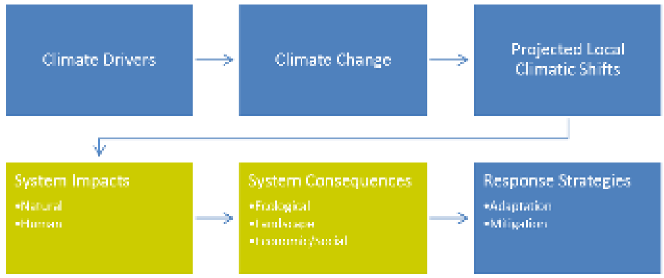


Figure 5.5. Percent inundation of FWC lead management areas due to inundation from three meters of SLR and areas of Florida expected to be inundated at 3 levels of SLR (based on simple bathtub inundation model).

6 IMPACTS AND CONSEQUENCES ON FLORIDA'S HABITATS AND COMMUNITIES



Impacts to Florida's habitats and species due to changing environmental factors have been documented, some are included under specific habitats below, including sea turtles nesting earlier (Weishampel *et al*. 2004) and mangroves migrating northward (Cavanaugh *et al*. 2014). Vegetative communities may shift, species may move to new nesting, breeding or feeding grounds under changing environmental conditions. The working groups that were tasked with assessing climate change vulnerability started with the habitat categories outlined in the State Wildlife Action Plan (FWC 2012). The habitats have been broadly grouped in this section into Terrestrial, Freshwater and Coastal, Marine and Estuarine habitats, while it is possible that a habitat could fit into more than one grouping the following organizational structure is used (Table 6.1). The SWAP categories were largely taken with some subsequent modification and combined to match land cover classification changes to ease analysis. The impacts are then expanded by the measurable climatic shifts expected to take place in Florida outlined previously and linked to the potential ecological consequences affecting Florida's three broad ecological systems (terrestrial, freshwater, and marine/coastal). These classifications do not perfectly "cross-walk" with one another, but this organization proved more useful for conducting impact assessments and developing adaptation strategies.

The information included for each specific habitat or habitat grouping described below is derived from various sources. However, the three predominant sources of information were the State Wildlife Action Plan (FWC 2012), a recent report entitled "Predicting And Mitigating The Effects Of Sea Level Rise And Land Use Changes On Imperiled Species And Natural Communities In Florida", referred to as the SIVVA report for its use of a "Standardized Index of Vulnerability and Value Assessments" (see the resources section of this guide for more information)(Center for Landscape Conservation Planning and Florida Natural Areas Inventory 2014), and the tabulated results from a series of meetings of FWC's climate adaptation working groups. Specifically, the habitat descriptions, listings of additional threats, conservation status classification and description, as well as the photographs are all reproduced from the SWAP. Most of the remaining information comes from the information produced by working group meetings and supplementary analysis of up to date land cover and habitat data. Additionally, there is further climate change status and vulnerability information included from the SIVVA report.

Table 6.1. Habitat groupings used in this section.

Terrestrial	Freshwater	Coastal, Marine and Estuarine
Forested Wetlands	Ephemeral Ponds/Wetlands	Bays/Inlets/Open Ocean
Floodplain Forest	Freshwater Marsh and Wet Prairie	Beach/Surf Zone
Cypress Swamp	Large Alluvial Stream	Coastal Strand
Hydric Hardwood Hammock	Springs and Spring Runs	Salt Marsh
Scrub	Natural Lake	Mangrove
Sandhill	Ponds	Bivalve Reef
Pine Rocklands	Reservoir/Impoundments	Coral Reef
Dry Prairie	Calcareous Stream	Submerged Aquatic Vegetation
Disturbed: Transitional, Industrial Pineland, Grassland/Pastureland	Softwater Streams	Tidal Flat
	Coastal Tidal River or Stream	Hardbottom

The maps and climate change status identifications and descriptions (largely based on SLR calculations and vulnerability evaluations) included in the subsections below are based on the SIVVA Report and supplementary spatial analysis using the new Cooperative Land Cover Map that was recently completed through a partnership with the Florida Natural Areas Inventory (FNAI) and FWC (i.e. Version 3.0) (Center for Landscape Conservation Planning and Florida Natural Areas Inventory 2014). It is important to note that the SIVVA Report is discussed in more detail in the resources section of this guide. Unfortunately, these analyses were not performed for all of the habitat categories below (e.g. those that do not have maps included or a climate change status identified) both due to the nature of SLR modeling, as it is easier to map how it impacts widespread terrestrial land covers, and because the new Cooperative Land Cover Map (and adaptation working groups) breaks land cover classes and habitats very differently than the previous versions of the land cover map, like those used in the SWAP. Therefore, the habitat and community calculations used in the SWAP and the SIVVA Report (or other previous works) cannot be directly related to the habitat and SLR calculations made for this adaptation guide. For instance, the acreage calculations used in the SWAP's determination of conservation status are not the same as the acreage calculations made for this guide to determine a community's status in the face of climate change, particularly SLR. Any other resources that are utilized will be documented as such.

6.1 CLIMATE CHANGE IMPACTS AND ECOLOGICAL CONSEQUENCES BY HABITATS AND COMMUNITIES

Habitats are broadly grouped as Terrestrial, Freshwater or Coastal/Marine/Estuarine habitat categories. At the beginning of each broad habitat group section, there is a set of climatic shifts and ecological consequences and impacts in an outline format. Each habitat subsection includes a description, assessment of the current conservation status (textually and spatially), current climate change vulnerability status (particularly in relation to SLR), outlines which climate change impacts are most likely, summarizes potential ecological consequences of those impacts, and enumerates other threats to the habitat (threats that are synergistic with climate change are outlined in bold). These sections are meant to be used as a reference for moving forward with adaptation strategy development. The climate change (SLR) vulnerability descriptions included for each habitat below draw from results from the SIVVA report. However, a graphical representation of some of those results is also included in Figure 6.1 and will be referred to throughout this section.

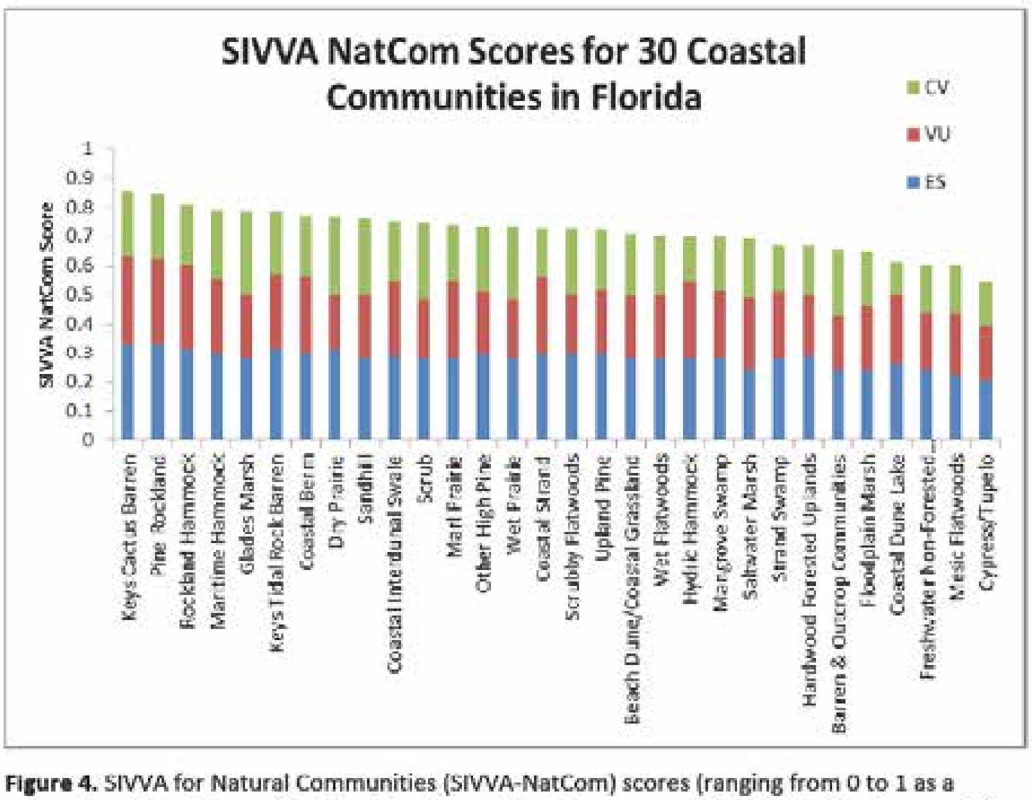


Figure 6.1. SIVVA Score results (for SLR vulnerability) for 30 coastal communities reproduced from the SIVVA report. Please note that the reproduced caption above contains an error (original to the document). Vulnerability is denoted in red in the figure while Ecosystem status is denoted in blue (Noss et al. 2014).

6.2 TERRESTRIAL HABITATS

Useful Resources: http://adaptationworkbook.org/ , Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers (General Technical Report NRS-87), the Forest Service Climate Change Atlas http://www.fs.fed.us/nrs/atlas/ , The ForeCASTS Project (Forecasts of climate-associated shifts in tree species)

Climatic Shift- Changes in Temperature Extremes

Ecological Consequences:

- Loss or gain of species due to changes in or uncoupling of competitive/predator-prey/parasite-host relationships
- Decreases survival of species, particularly ectotherms due to temperature shifts within their habitat that are outside of their thermal operational range
- Altered plant and animal species composition due to loss or gain of species as temperature extremes affect some species more than others
- Increased summer temperatures
    - More frequent and/or more intense wildfire
    - Species range reductions or shifts due to reduced habitats
    - Reduction of rare communities and threatened species due to temperature increases exacerbating existing stressors
    - Reduction or loss of suitable wetland habitats due to increased water temperatures and evaporation rates as air temperature increases
- Minimum winter temperatures increase
    - Reduced fitness, competitive ability, and survival due to increased exposure to new pathogens or parasites as these diseases/disease vectors respond to warmer temperatures
    - Increased mortality of plants and animals due to increased pathogen and vector survival and disease transmission rates
    - Pine forests shifting to pine-oak forests
    - Northward shift of subtropical and temperature communities that may be restricted by frost /freeze line (longleaf pine dominated pinelands)
- Minimum winter temperatures decrease
    - Reduced reproductive success due to delayed timing of reproduction and/or altered timing of resources
    - Delayed plant flowering leading to weakening/breaking of linkages between species (reproductive success, predator release, community level processes within habitats)
    - Shift in species distribution due to temperature extremes and interactions of temperature, precipitation and possibly CO_2
    - Limit northern extent of exotic species range (+)

Climatic Shift- Increased Storm Intensity

Ecological Consequences:

- Decreased survival and reduced fitness of species due to increased exposure to invasive species and parasites
- Increased accretion/sedimentation and erosion due to stronger storms
- Increased die-offs of plan and animal species due to extreme cold events
- Increased structural damage to coastal systems due to increased storm intensity
- Loss of coastal habitats due to degradation of low lying marshes and barrier islands due to coastal erosion and inundation by salt water
- Increased salinity of coastal wetlands and surficial groundwater due to increased storms
- Alteration of habitats and/or disruption of life cycle events due to increased instances of flash flooding as surface runoff increases.
- Increased accumulation of heavy metals and other pollution as surface runoff increases
- Loss of foraging, nesting, or shelter sites due to damages to vegetation caused by more intense storms

Climatic Shift- Intensification of Hydrologic Cycle

Ecological Consequences:

- Floods
  - Increased mortality due to higher water levels
  - Shift in dominant species due to species-specific flood induced mortality (advantages of previously dominant species are eliminated)
- Longer wet periods
  - Prescribed fire difficulties due to increased soil moisture and increased plant growth
- Droughts
  - Loss of species due to alteration of habitat
  - Changes in species composition of a community due to increased favorable conditions for invasive species
  - Increase in wildfires
  - Reduced opportunities for safe application of prescribed fire due to low humidity, drought stressed vegetation and drier fuels
  - Increased pest outbreaks due to drought stress and warmer temperatures
  - Increased mortality due to loss of vegetation and water sources and water level changes
  - Reduced forage due to drier conditions
  - Loss of wetland habitat types essential for terrestrial species such as ephemeral ponds and coastal wetlands
  - Increased drought related diseases in forest trees
  - Loss of critical sources of freshwater

- Longer dry periods
    - Increased competitive pressure on native vegetation as density and distribution increases for other native, more heat-tolerant species
    - Range expansion of sub-tropical vegetation and range contraction of temperate woody species
    - Southern pine forests replaced by pine savannas and grassland due to increased fires and moisture stress
    - Decreased efficiency of prescribed fire as opportunities to burn are reduced
    - Increased pine mortality due to pine beetle infestations as trees become stressed
    - Increased avian mortality due to water loss
    - Reduced amphibian reproductive success
    - Decreased avian reproductive success due to decreased food (arthropod) availability
- Increased Rainfall
    - Increased above ground biomass (scrub ecosystems)
    - Reduced reproduction/survival for amphibians – increased flooding/flash flooding events may transport fish into isolated (fishless wetlands)
    - Reduced efficiency of prescribed fire due to increased soil moisture
    - Reproductive failure for ground-nesting birds due to flooding
- Decreased Rainfall
    - Shifts in range of temperate trees and shrubs as rainfall decreases and temperature increases
    - Increased wildfires due to drier conditions
    - Reduced reproductive success in birds due to decreased availability of arthropods
- Timing of precipitation
    - Altered grassland plant species composition due to increased rainfall variability
    - Altered thermoregulatory responses/tactics of reptiles due to change in amount of sunlight penetrating to the ground as plant growth changes

Climatic Shift- Salinity Shifts

Ecological Consequences:

- Reduction/loss of critical freshwater sources in the Keys
- Decreased fire frequency/intensity due to loss of fuel (pines, other vegetation) as salinity stress from salinization of groundwater and increased tidal overwash causes reduction in fuel species
- Loss of coastal upland forest habitat as they transition into other more salt tolerant systems due to increased groundwater and soil salinity

- Alteration in type, abundance and configuration of coastal upland communities as increased groundwater and soil salinity increases cause changes in plant communities (shifts to more salt tolerant species) leading to habitat loss and fragmentation
- Shifts in species presence and abundance due to changes in plant community structure as vegetation responds to changes in groundwater and soil salinity
- Reduction in extent of occurrence of unique Key species/subspecies due to loss of critical upland forest habitat
- Decreased range for species in coastal areas and south Florida dependent on large areas of salt-intolerant terrestrial habitats that are likely to be impacted by salinity stress
- Changes in competition and predator/prey relationships due to de-coupling of mutualistic relationships as salt-intolerant plants and animals are reduced and/or replaced by salt tolerant species
- New suites of species interacting in different ways due to changes in species composition as a result of salinity stress related shifts

6.2.1 FORESTED WETLANDS

Includes: Bay Swamp, Shrub Swamp, Hardwood Swamp/Mixed Wetland Forest

Bay Swamp

FNAI types: Baygall, Bog

Habitat Description:

These hardwood swamps contain broadleaf evergreen trees that occur in shallow, stagnant drainages or depressions often found within pine flatwoods, or at the base of sandy ridges where seepage maintains constantly wet soils. Where Bay Swamp occurs in seepage areas it is often associated with or grades into Seepage/Steephead Stream habitat. The soils, which are usually covered by an abundant layer of leaf litter, are mostly acidic peat or muck that remains saturated for long periods but over which little water level fluctuation occurs.

The overstory within bayheads primarily is composed of evergreen hardwood trees, but bay trees, especially sweetbay, red bay, and loblolly bay, dominate the canopy and characterize the community. Depending on the location within the state, other species including pond pine, slash pine, blackgum, cypress, and Atlantic white cedar can occur as scattered individuals. Understory and ground cover species may include dahoon holly, wax myrtle, fetterbush, greenbriar, royal fern, cinnamon fern, and sphagnum moss. For mapping/calculation purposes, this habitat was combined with the other habitats in this subsection, subsequently referred to as Forested Wetland.

Conservation Status:

Current condition: Unknown. According to the SWAP, 201,765 acres (81,651 ha) of Bay Swamp habitat exist, of which 32% (65,570 ac; 26,535 ha) are in existing conservation or managed areas. Another 14% (27,471 ac; 11,117 ha) are Florida Forever projects and 7% (13,486 ac; 5,458 ha) are SHCA-identified lands. The remaining 47% (95,238 ac; 38,541 ha) are other private lands.

Climate Change Status:

A SIVVA score not created. This habitat type (and the others in this subsection, all grouped) is projected to experience sizeable declines due to SLR, with as much as 536,785 acres (~20.5% of the total for this habitat group) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in the Table 6.2.

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, changes in water chemistry, increased storm intensity, SLR

Ecological Consequences:

Altered community composition and structure, decreased diversity, decreased reproductive success and recruitment, habitat loss and degradation, water quality degradation

Other Threats:

- Conversion to agriculture
- Conversion to housing and urban development
- **Groundwater withdrawal**
- Incompatible fire
- Invasive animals
- Invasive plants
- **Surface water withdrawal and diversion**
- Roads

Shrub Swamp

FNAI types: None

Habitat Description:

Shrub Swamps are wetland communities dominated by dense, low-growing, woody shrubs or small trees. Shrub Swamps are usually characteristic of wetland areas that are experiencing environmental change, and are early to mid-successional in species complement and structure. These changes are a result of natural or man-induced perturbations due to increased or decreased hydroperiod, fire, clear cutting or land clearing, and siltation.

Shrub Swamps statewide may be dominated by one species, such as willow, or an array of opportunistic plants may form a dense, low canopy. Common species include willow, wax myrtle, primrose willow, buttonbush, and saplings of red maple, sweetbay, black gum, and other hydric tree species indicative of wooded wetlands. In northern Florida, some Shrub Swamps are a fire-maintained subclimax of Bay Swamps. These dense shrubby areas are dominated by black titi, swamp cyrilla, fetterbush, sweet pepperbush, doghobble, large gallberry, and myrtle-leaf holly. For mapping/calculation purposes, this habitat was combined with the other habitats in this subsection, subsequently referred to as Forested Wetlands.

Conservation Status:

Current condition: Unknown. According to the SWAP, 1,069,770 acres (432,921 ha) of Shrub Swamp habitat exist, of which 49% (521,957 ac; 211,229 ha) are in existing conservation or managed areas. Another 7% (74,135 ac; 30,001 ha) are Florida Forever projects and 8% (88,325 ac; 35,744 ha) are SHCA-identified lands. The remaining 36% (385,353 ac; 155,947 ha) are other private lands.

Climate Change Status (SLR):

A SIVVA score not created. This habitat type (and the others in this subsection, all grouped) is projected to experience sizeable declines due to SLR, with as much as 536,785 acres (~20.5% of the total for this habitat group) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.2.

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, changes in water chemistry, increased storm intensity, SLR

Ecological Consequences:

Altered community composition and structure, decreased diversity, decreased reproductive success and recruitment, habitat loss and degradation, water quality degradation

Other Threats:

- **Groundwater withdrawal**
- Incompatible fire
- Invasive animals
- Invasive plants
- **Surface water withdrawal**

Hardwood Swamp/Mixed Wetland Forest

FNAI types: Bottomland Forest, Basin Swamp

Habitat Description:

These wooded wetland communities are composed of either pure stands of hardwoods, or occur as a mixture of hardwoods and cypress where hardwoods achieve dominance. This association of wetland-adapted trees occurs throughout the state on organic soils and forms the forested floodplains of non-alluvial rivers, creeks, and broad lake basins. Tree species include a mixed overstory containing black gum, water tupelo, bald cypress, dahoon holly, red maple, swamp ash, cabbage palm, and sweetbay. Also included in this category are mixed wetland forest communities in which neither hardwoods nor conifers achieve dominance. The mix can include hardwoods with pine or cypress and can represent a mixed hydric site or a transition between hardwoods and conifers on hydric/mesic sites. Hardwood Swamp/Mixed Wetland Forests occur on low-lying flatlands or scattered low spots in basins and depressions that will only flood in extreme conditions. The canopy is usually dense and closed, keeping air movement and light penetration relatively low and, thus, keeping the humidity high. Due to these damp conditions, this habitat infrequently burns. For mapping/calculation purposes, this habitat was combined with the other habitats in this subsection, subsequently referred to as Forested Wetlands (Figure 6.2).

Conservation Status:

Current condition: Good and declining. According to the SWAP, 3,250,491 acres (1,315,427 ha) of Hardwood Swamp/Mixed Wetland Forest habitat exist, of which 36% (1,175,787 ac; 475,824 ha) are in conservation or managed areas. Another 8% (274,280 ac; 110,997 ha) are in Florida Forever projects and 11% (346,382 ac; 140,176 ha) are in SHCA-designated lands. The remaining 45% (1,454,042 ac; 588,430 ha) are other private lands.

Climate Change Status:

A SIVVA score not created. This grouped habitat type is projected to experience sizeable declines due to SLR, with as much as 536,785 acres (~20.5% of the total for this habitat group) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.2.

Table 6.2. Acreage calculations for Forested Wetlands and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	2,621,224	1,166,897	1,454,328
1 Meter SLR	231,889 (8.85%)	176,950 (15.16%)	54,938 (3.78%)
3 Meter SLR	304,896 (11.63%)	226,863 (19.44%)	78,032 (5.37%)

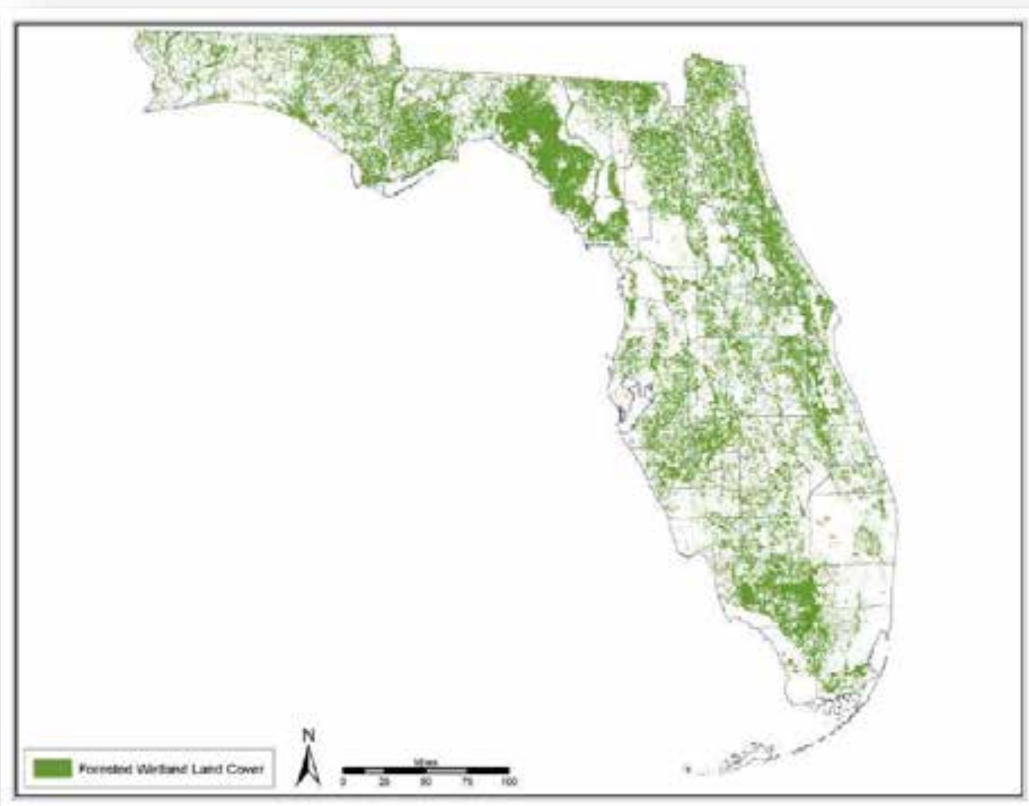


Figure 6.2. This map shows the locations and extent of Forested Wetlands land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, increased storm intensity, SLR

Ecological Consequences:

Altered community composition and structure, decreased diversity, decreased reproductive success and recruitment, habitat loss and degradation

Other Threats:

- Conversion to agriculture
- Conversion to housing and urban development
- **Groundwater withdrawal**
- Incompatible fire
- Incompatible forestry practices
- Incompatible recreational activities
- Invasive animals
- Invasive plants
- Roads
- **Surface water withdrawal and diversion**

Forested wetlands:
Bay swamp/Shrub swamp/Hardwood swamp

Shift	Consequence	Example Species
Sea level rise – Inundation	•Altered distribution of habitat •Decreased reproduction and recruitment •Habitat loss	Wading birds, Swallow-tailed kite Alligator, Gulf hammock dwarf siren, amphibians River otter
Sea level rise – Salinity shifts	•Altered soil chemistry •Altered surface and groundwater hydrology	
Drought	•Habitat degradation •Increased disease in trees	Wading birds Alligator, amphibians
Change in water chemistry (e.g., pH, DO)	•Decreased diversity •Habitat degradation •Altered species composition	Amphibians
Increased intensity of storms	•Altered community structure •Habitat loss •Altered distribution of habitat •Habitat degradation	Wading birds Trees (wind damage from storms)

6.2.2 FLOODPLAIN FOREST

Bottomland Hardwood Forest (i.e. Floodplain Forest)

FNAI types: Floodplain Forest, Floodplain Swamp, Freshwater Tidal Swamp

Habitat Description:

These seasonally flooded wetland forests are composed of a diverse assortment of hydric hardwoods which occur on the rich alluvial soils of silt and clay deposited along the floodplain of several Panhandle rivers including the Apalachicola, Choctawhatchee, and Escambia. These communities are characterized by an overstory that includes water hickory, overcup oak, swamp chestnut oak, river birch, American sycamore, red maple, Florida elm, bald cypress, blue beech, and swamp ash. The understory can range from open and park-like to dense and nearly impenetrable. Understory plants can include bluestem palmetto, hackberry, swamp azalea, pink azalea, lanceleaf greenbrier, poison ivy, peppervine, rattanvine, indigo bush, white grass, plume grass, redtop panicum, caric sedges, silverbells, crossvine, American wisteria, and wood grass. In Bottomland Hardwood Forests, soils and hydroperiods primarily determine the diverse temporary and permanent species composition along with community structure. Additionally, the rich organic material that accumulates on the forest floor is carried off by flooding waters during the wet season, and therefore provides an essential source of minerals and nutrients for downstream ecosystems such as estuarine systems. This habitat type is referred to as Floodplain Swamp or Floodplain Forest in the maps (Figure 6.3) and tables below.

Conservation Status:

Current condition: Good and unknown trend. According to the SWAP, 84,141 acres (34,051 ha) of Bottomland Hardwood Forest habitat exist, of which 58% (48,778 ac; 19,740 ha) are in conservation or managed areas. Another 5% (4,721 ac; 1,911 ha) are in Florida Forever projects and 25% (20,647 ac; 8,356 ha) are in SHCA-designated lands. The remaining 12% (9,995 ac; 4,045 ha) are other private lands.

Climate Change Status:

A SIVVA score not created. This habitat type is projected to experience significant declines due to SLR, with as much as 151,693 acres (~40% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in the Table 6.3.

Table 6.3. Acreage calculations for Floodplain Swamp and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	382,417	341,428	40,989
1 Meter SLR	106,385 (27.82%)	99,565 (29.16%)	6,820 (16.64%)
3 Meter SLR	45,308 (11.85%)	43,213 (12.66%)	2,096 (5.11%)

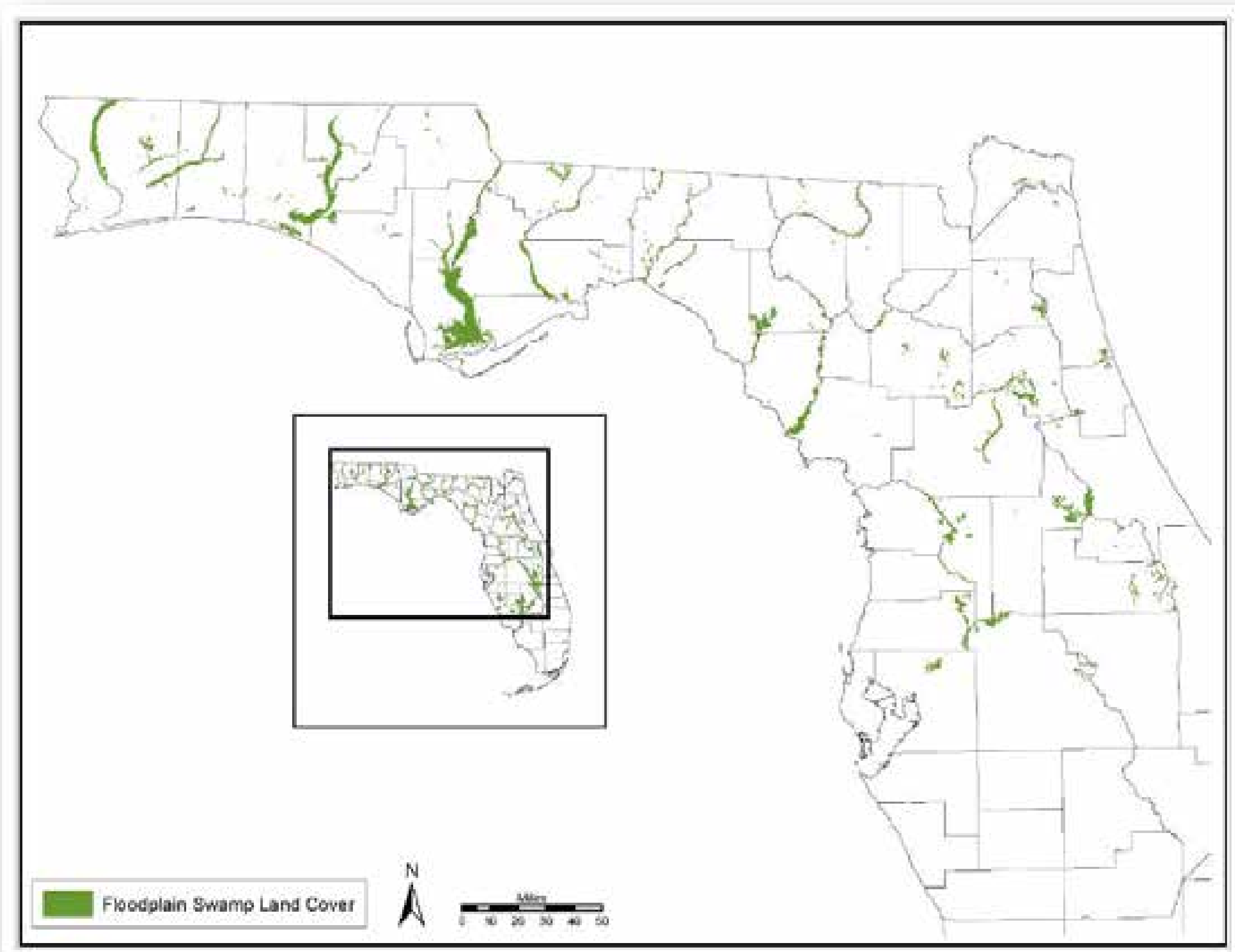


Figure 6.3. This map shows the locations and extent of Floodplain Swamp land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

<u>Measurable Climatic Shifts:</u>

Changes in precipitation frequency and intensity, increased storm intensity, SLR

Ecological Consequences:

Altered community composition, dynamics and structure, altered habitat distribution and quality, habitat loss

Other Threats:

- Invasive animals
- Invasive plants
- Roads

Floodplain Forests

Shift	Consequence	Example Species
Flood	•Species mortality •Altered community structure •Shift in population trends	
Sea level rise – Inundation	•Habitat loss	
Sea level rise – Salinity shift	•Altered distribution of habitat •Altered community structure/composition	
Increased intensity of storms	•Altered community structure •Habitat loss •Altered distribution of habitat	Wading birds Trees (wind damage from storms)
Drought	•Habitat degradation •Habitat loss	

6.2.3 CYPRESS SWAMP

Cypress Swamp

FNAI types: Strand Swamp, Dome Swamp

Habitat Description:

These regularly inundated wetlands form a forested border along large rivers, creeks, and lakes, or occur in depressions as circular domes or linear strands. These communities are strongly dominated by either bald cypress or pond cypress, with very low numbers of scattered black gum, red maple, and sweetbay. Understory and ground cover are usually sparse due to frequent flooding but sometimes include such species as buttonbush, lizard's-tail, and various ferns.

Conservation Status:

Current Condition: Poor and declining. According to the SWAP, 1,586,941 acres (642,212 ha) of Cypress Swamp habitat exist (Figure 6.4), of which 44% (689,955 ac; 279,215 ha) are in existing conservation or managed areas. Another 11% (173,971 ac; 70,404 ha) are in Florida Forever projects and 10% (163,702 ac; 66,248 ha) are in SHCA-designated lands. The remaining 35% (559,313 ac; 226,346 ha) are other private lands.

Climate Change Status:

Ranked in final third of evaluated communities (SIVVA Score: 0.5 – 0.6). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value and calculated an overall score between 0.5 and 0.6, placing it 30th in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience declines due SLR, with as much as 167,856 acres (~26% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.4.

Table 6.4. Acreage calculations for Cypress Swamp and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	642,783	360,993	281,791
1 Meter SLR	55,269 (8.60%)	49,885 (13.82%)	5,384 (1.91%)
3 Meter SLR	112,587 (17.52%)	103,178 (28.58%)	9,409 (3.34%)

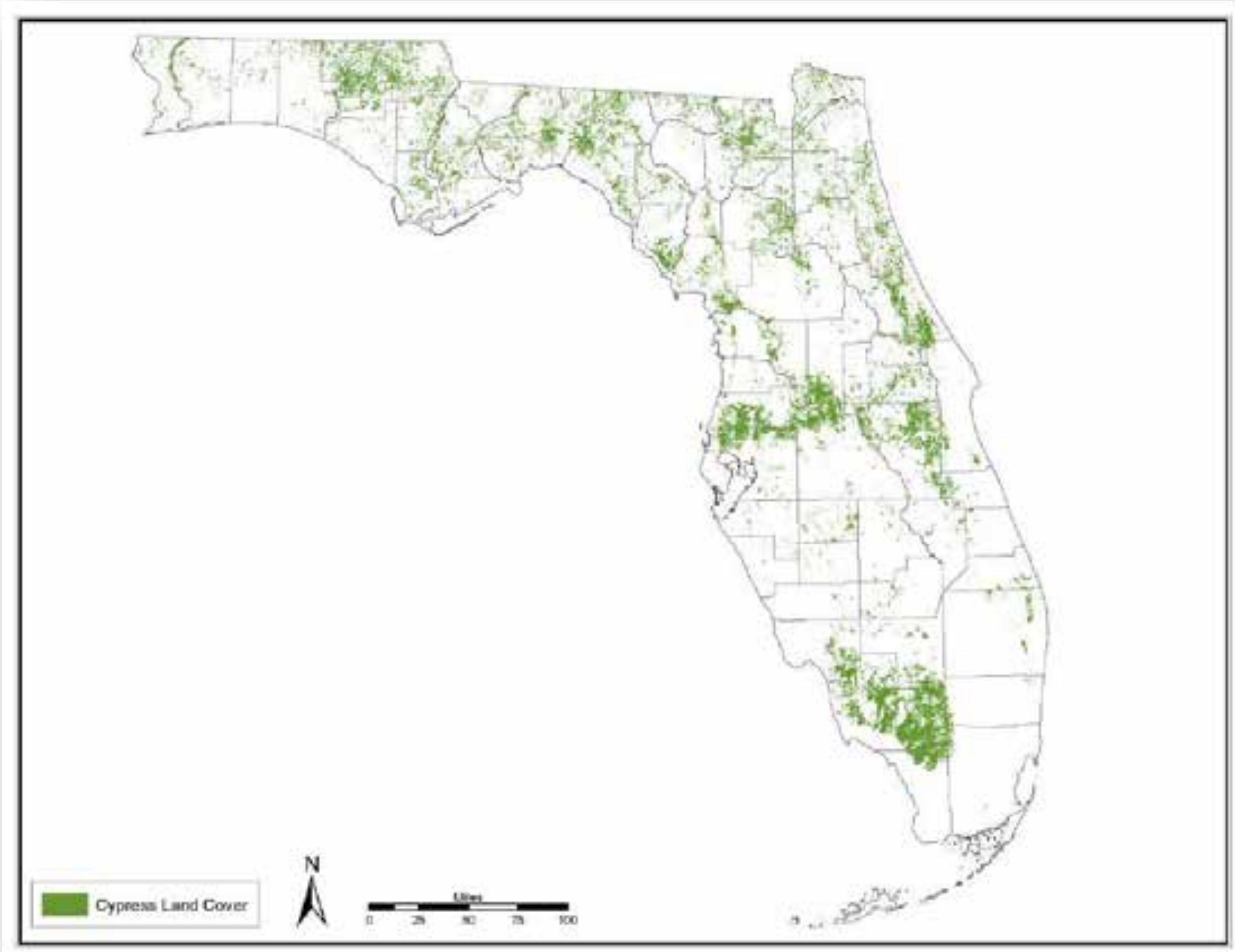


Figure 6.4. This map shows the locations and extent of Cypress Swamp land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in water chemistry, changes in precipitation frequency and intensity, SLR

Ecological Consequences:

Altered community structure, habitat loss, degradation, and migration due to rising sea levels, increased disease and stress for various plant and animal species

Other Threats:

- Conversion to agriculture
- Conversion to housing and urban development
- **Groundwater withdrawal**
- Incompatible fire
- Incompatible forestry practices

- Incompatible resource extraction–mining/drilling
- Invasive animals
- Invasive plants
- Nutrient loads–agriculture
- Nutrient loads–urban
- Roads
- **Surface water withdrawal and diversion**

Cypress Swamp

Shift	Consequence	Example Species
Drought	•Habitat degradation •Increased disease in trees	Wading birds Alligator, amphibians
Sea level rise - Inundation	•Altered distribution of habitat •Habitat loss	Wading birds Florida panther, Everglades mink
Sea level rise – Salinity shift	•Altered distribution of habitat •Altered community structure/composition	Wading birds Florida panther, Everglades mink
Increased intensity of storms	•Altered community structure •Habitat loss •Altered distribution of habitat	Wading birds Trees (wind damage from storms)

6.2.4 HYDRIC HAMMOCK

Hydric Hammock

FNAI types: Hydric Hammock

Habitat Description:

Hydric Hammock occurs on soils that are poorly drained or have high water tables. This association is a still-water wetland, flooded less frequently and for shorter periods of time than mixed hardwood and cypress swamps. Outcrops of limestone are common in the Gulf coastal area.

> STUDIES IN WACCASASSA BAY STATE PRESERVE HAVE SHOWN THAT CABBAGE PALMS LOSE THE ABILITY TO REGENERATE SEEDLINGS SUCCESSFULLY DUE TO SEA LEVEL RISE STRESSES, EVEN DECADES BEFORE TREE DEATH.
>
> Williams *et al*. 1999

Typical plant species include laurel oak, live oak, cabbage palm, southern red cedar, and sweetgum. Canopy closure is typically 75%-90%. The sub-canopy layer and ground layer vegetation is highly variable between sites. Wax myrtle is the most frequent shrub in Hydric Hammock. Other shrubs include yaupon, dahoon, and swamp dogwood. Ground cover may be absent or consist of a dense growth of ferns, sedges, grasses, and greenbriars. Sites are usually between mesic hammocks or pine flatwoods and river swamp, wet prairie, or marsh. Hydric Hammock is found in a narrow band along parts of the Gulf coast and along the St. Johns River where it often extends to the edge of coastal salt marshes.

Conservation Status:

Current condition: Good and declining. According to the SWAP, 35,341 acres (14,302 ha) of Hydric Hammock habitat exist (Figure 6.5), of which 75% (26,409 ac; 10,687 ha) are in existing conservation or managed areas. Another 9% (3,271 ac; 1,324 ha) are in Florida Forever projects, and 2% (691 ac; 280 ha) are in SHCA-designated lands. The remaining 14% (4,970 ac; 2,011 ha) are other private lands.

Climate Change Status:

Ranked in middle third of evaluated communities (SIVVA Score: 0.7 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value and calculated an overall score between 0.7 and 0.8, placing it 20th in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience significant declines due to SLR, with as much as 117,964 acres (~52% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in

Table 6.5 below. Hydric Hammock in coastal areas has been documented as being lost due to SLR (Figures 6.6-6.7).

Table 6.5. Acreage calculations for Hydric Hammock and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	224,910	211,425	13,485
1 Meter SLR	65,973 (29.33%)	64,782 (30.64%)	1,191 (8.83%)
3 Meter SLR	51,991 (23.12%)	50,908 (24.08%)	1,083 (8.03%)

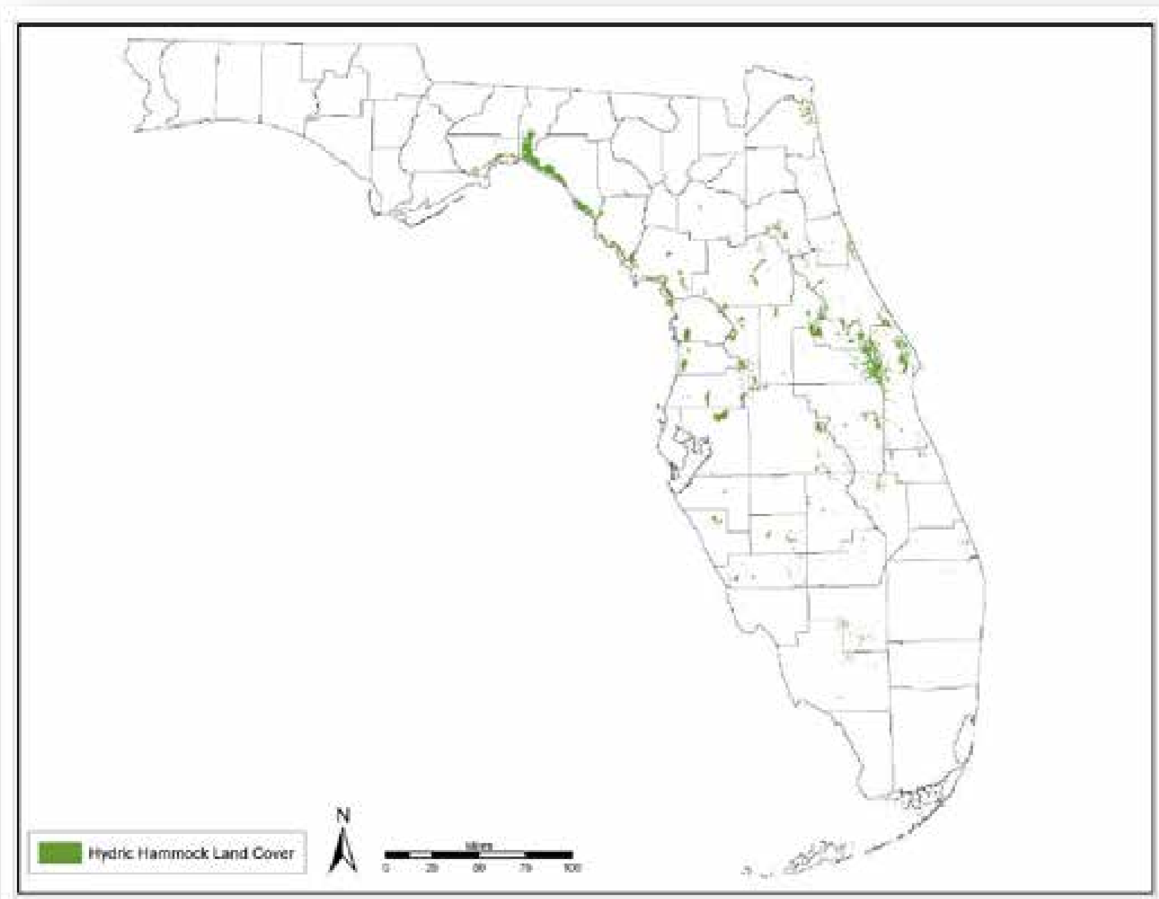


Figure 6.5. This map shows the locations and extent of Hydric Hammock land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Decline in water availability, SLR

Ecological Consequences:

Altered community composition and extent, increased disease, decreased reproductive success, habitat loss and degradation

Other Threats:

- Invasive plants

Hydric Hammock

Shift	Consequence	Example Species
Sea level rise - Inundation	•Habitat loss •Habitat degradation •Reduced reproduction and recruitment •Altered range/extent of occurrence of species	Swallow-tailed kite, Gulf hammock dwarf siren, Gulf Coast box turtle, amphibians
Sea level rise – Salinity shifts	•Altered community structure •Altered range/extent of occurrence of species •Habitat loss	Amphibians Black bear
Drought	•Habitat degradation •Increased disease in trees	Wading birds Alligator, amphibians

NOTED HYDRIC HAMMOCK IMPACTS IN THE BIG BEND REGION OF FLORIDA

RETROSPECTIVE SLAMM MODELING IN WACCASASSA BAY, FROM A 1986 BASELINE PREDICTED CONDITIONS SIMILAR TO THOSE FOUND IN FIELD SURVEYS PERFORMED IN THE 2000'S WITH HYDRIC HAMMOCK LOSSES AND SALT MARSH MIGRATION.

Greselbracht *et al*. 2011

ANALYSIS OF T-SHEETS FROM THE 19TH CENTURY AND CONTEMPORARY IMAGERY IN THE SAME REGION HAS SHOWN LANDWARD MIGRATION OF SALT MARSH INTO COASTAL FOREST AREA.

Raabe and Stumpf 2016

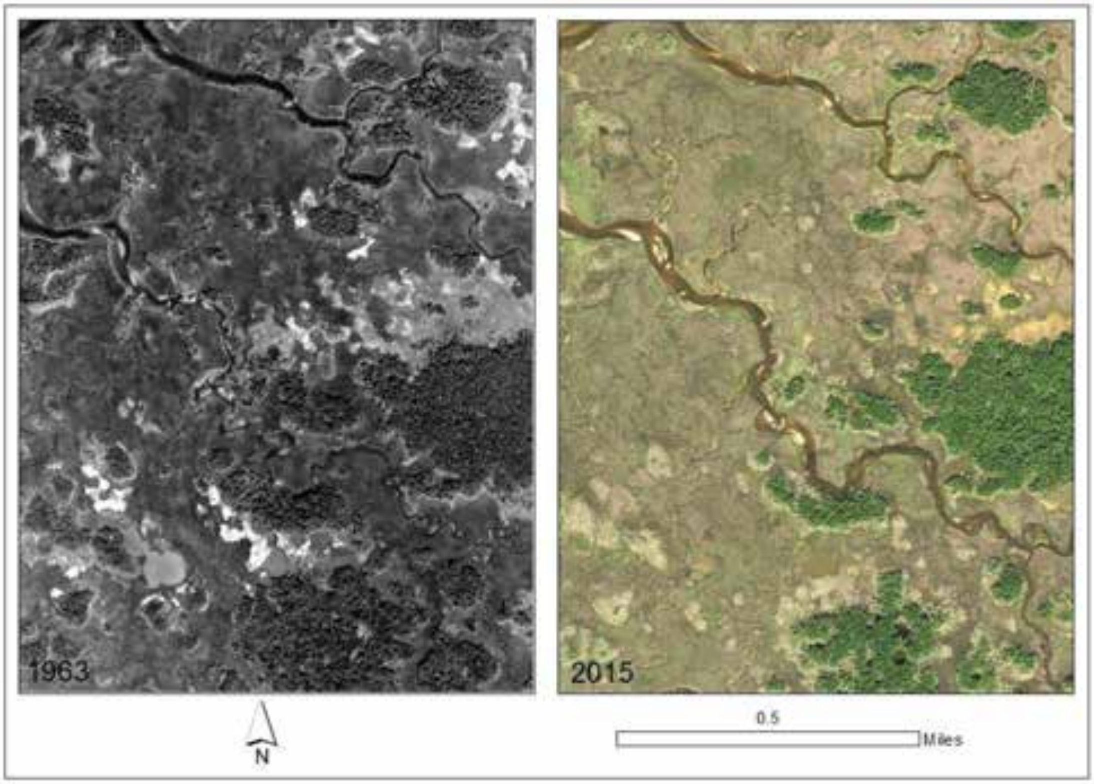


Figure 6.6. Aerial imagery near Waccasassa Bay State Preserve from 1963 and 2015. Hydric hammock habitat has been transitioning to salt marsh, see lower left corner of each aerial for example.

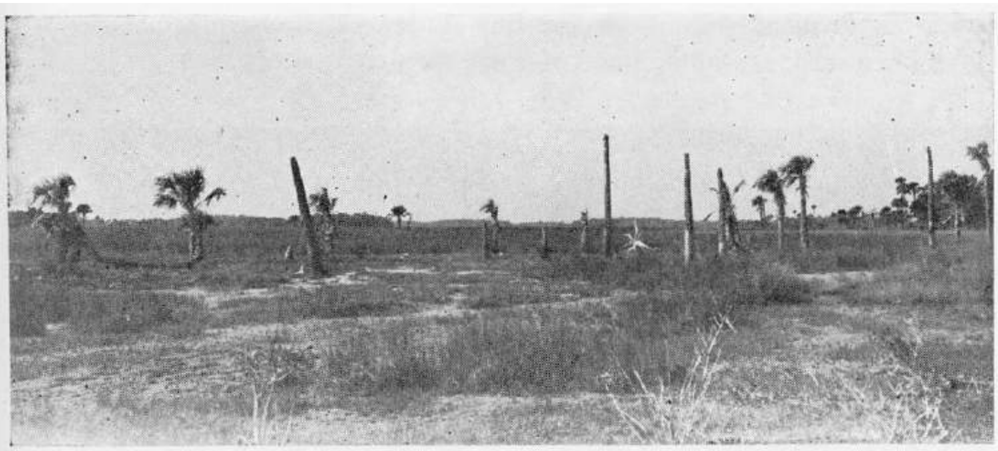


Figure 4. Drowning of coastal margins by salt-water marsh. Photograph taken facing due west at old Stevens Homestead, three miles northwest of Yankeetown, Levy County. Islands in the marsh in the background are composed of limestone of the Inglis member of the Moodys Branch formation.

Figure 6.7. Cabbage palm die-off and transition to salt marsh noted in mid-1950's, original caption depicted (Vernon 1951).

6.2.5 TROPICAL HARDWOOD HAMMOCK

Tropical Hardwood Hammock

FNAI types: Rockland Hammock

Habitat Description:

These upland hardwood forests occur only in south Florida and are characterized by tree and shrub species on the northern edge of a range that extends southward into the Caribbean. These communities are sparsely distributed along coastal uplands south of a line from about Vero Beach on the Atlantic coast to Sarasota on the Gulf coast. They occur on many tree islands in the Everglades and on uplands throughout the Florida Keys. This cold-intolerant tropical community has very high plant species diversity, sometimes containing over 35 species of trees and about 65 species of shrubs. Characteristic tropical plants include strangler fig, gumbo-limbo, mastic, bustic, lancewood, ironwoods, poisonwood, pigeon plum, Jamaica dogwood, and Bahama lysiloma. Live oak and cabbage palm are also sometimes found within this community. Tropical Hardwood Hammocks in the Florida Keys may also contain several plants, including lignum vitae, mahogany, thatch palms, and manchineel, which are extremely rare within the United States.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 15,232 acres (6,164 ha) of Tropical Hardwood Hammock habitat exist (Figure 6.8), of which 71% (10,867 ac; 4,398 ha) are in existing conservation or managed areas. Another 10% (1,470 ac; 595 ha) are Florida Forever projects and 5% (783 ac; 317 ha) are SHCA-identified lands. The remaining 14% (2,112 ac; 855 ha) are other private lands.

Climate Change Status:

Ranked in first third of evaluated communities (SIVVA Score: 0.8 - 0.9). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value. Placing it 3rd in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience severe declines due to SLR, with as much as 16,559 acres (~68% of the total for this habitat) projected to be lost with three meters of SLR, however, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR . The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.6.

Table 6.6. Acreage calculations for Tropical Hardwood Hammock and projected inundations of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	18,745	17,576	1,168
1 Meter SLR	10,335 (55.13%)	9,359 (53.25%)	976 (83.56%)
3 Meter SLR	6,224 (33.20%)	6,076 (34.57%)	148 (12.67%)

Figure 6.6. This map shows the locations and extent of Tropical Hardwood Hammock land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Increased storm intensity, SLR

Ecological Consequences:

Altered fire regimes, altered community composition and structure, habitat loss and degradation, increased disease outbreaks and invasive species

Other Threats:

- Chemicals and toxins
- Conversion to housing and urban development
- Groundwater withdrawal
- Incompatible fire
- Invasive animals and plants
- Roads
- Surface water withdrawal

Tropical Hardwood Hammock

Shift	Consequence	Example Species
Sea level rise – Inundation	•Habitat loss •Habitat fragmentation •Changes in species range/extent of occurrence	Migratory birds, White crowned pigeon, Black-whiskered vireo, Mangrove cuckoo Rim rock crowned snake Florida panther, Florida Key deer, Key Largo cotton mouse, Key Largo woodrat, Florida mastiff bat Stock Island tree snail, Schaus swallowtail butterfly
Sea level rise – Salinity shifts	•Habitat loss - Increased soil salinity •Habitat degradation •Habitat fragmentation •Altered fire regimes – loss fuel as plant composition changes •Altered species composition – as salinity intolerant species are eliminated (plants and animals) •Altered community dynamics •Changes in species range/extent of occurrence	Migratory birds, White crowned pigeon, Black-whiskered vireo, Mangrove cuckoo Rim rock crowned snake Florida panther, Florida Key deer, Key Largo cotton mouse, Key Largo woodrat, Florida mastiff bat Stock Island tree snail, Schaus swallowtail butterfly
Increased intensity of storms	•Habitat loss •Habitat degradation •Increased disease outbreaks (Ips beetles, weevils) •Increased invasive species	

In addition to the habitats included above, the working groups also developed universal ecological consequences that were likely to impact most if not all of forested systems. These general forested consequences are listed in the outlined below.

Forested - general

Shift	Consequence	Example Species
Decreased rainfall / Longer dry periods / Drought	•Altered pest and disease outbreaks •Altered community structure or composition •Habitat degradation	Vegetative shift from tree species to scrub or dry grassland species, Increased density and distribution of more drought tolerant species
Increased average summer temperatures	•Increased frequency and intensity of wildfires	Increased density and distribution of more heat tolerant species
Increased rainfall / Longer wet periods	•Increased soil moisture and increased plant growth – impacts ability to use prescribed fire	
Increased intensity of storms	•Altered community structure •Habitat loss •Altered distribution of habitat	Trees (wind damage from storms) and species dependent upon them for forage, nest or shelter sites

6 Impact on Communities

6.2.6 SCRUB

Scrub

FNAI types: Scrub

Habitat Description:

This habitat occurs on areas of deep, well-drained, infertile sandy soils that are typically white or near white. Scrub has a patchy distribution and occurs in both inland and coastal areas, from the panhandle through subtropical regions of the peninsula. The largest and most important patches of Scrub occur along the central ridge of the peninsula near Ocala and in Polk and Highlands counties. This habitat is fire-dependent; it is maintained by fires that are usually very hot or intense, but occur infrequently at intervals of 10-20 years, or more. Generally, Scrub is dominated by evergreen, or nearly evergreen, oaks and/or Florida rosemary, with or without a pine overstory. A relatively large suite of plant species is endemic to Scrub (e.g., scrub holly and inopina oak); the rarest endemic plant species are restricted to the Lake Wales area of the central ridge (e.g., pygmy fringe tree and scrub plum). Some species of wildlife also are endemic or largely restricted to Scrub habitat (e.g., Florida scrub-jay and sand skink). Several types of Scrub are recognized. Oak Scrub is a hardwood community typically consisting of clumped patches of low growing oaks interspersed with patches of bare, white sand. Pines are uncommon or absent. Oak Scrub is dominated by myrtle oak, Chapman's oak, sand-live oak, inopina oak, scrub holly, scrub plum, scrub hickory, rosemary, scrub palmetto, and saw palmetto. Sand Pine Scrub occurs on former shorelines and islands of ancient seas. This plant community is dominated by an overstory of sand pine and has an understory of myrtle oak, Chapman's oak, sand-live oak, rusty lyonia, wild olive, scrub bay, and scrub holly. Ground cover is usually sparse to absent, especially in mature stands, and rosemary and lichens occur in some open areas. Rosemary Scrub has few or no sand pines or scrub oaks but is dominated by rosemary with scattered lichen cover, scrub hypericum, and paper nailwort. Scrubby Flatwoods, differing from Scrub by having a sparse canopy of slash pine, is addressed in the Natural Pineland habitat section. Additionally, many temporary wetlands are found throughout the Scrub landscape and are an integral part of this habitat type, providing breeding and foraging habitat for many wildlife species.

<u>Conservation Status</u>:

Current condition: Poor and declining. According to the SWAP, 337,458 acres (136,564 ha) of Scrub habitat exist (Figure 6.9), of which 76% (257,015 ac; 104,010 ha) are in existing protected or managed areas. Another 3% (11,311 ac; 4,577 ha) are in Florida Forever projects, while 4% (14,031 ac; 5,678 ha) are in SHCA-designated lands. The remaining 16% (55,101 ac; 22,299 ha) are other private lands.

<u>Climate Change Status:</u>

Ranked in middle third of evaluated communities (SIVVA Score: 0.7 - 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value. Placing it 11th in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience significant declines due to SLR, with as much as 38,161 acres (~10% of the total for this habitat) projected to be lost with three meters of SLR, however, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.7.

Table 6.7. Acreage calculations for the Scrub and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	398,370	324,247	74,123
1 Meter SLR	16,222 (4.07%)	14,436 (4.45%)	1,786 (2.41%)
3 Meter SLR	21,939 (5.51%)	17,700 (5.46%)	4,239 (5.72%)

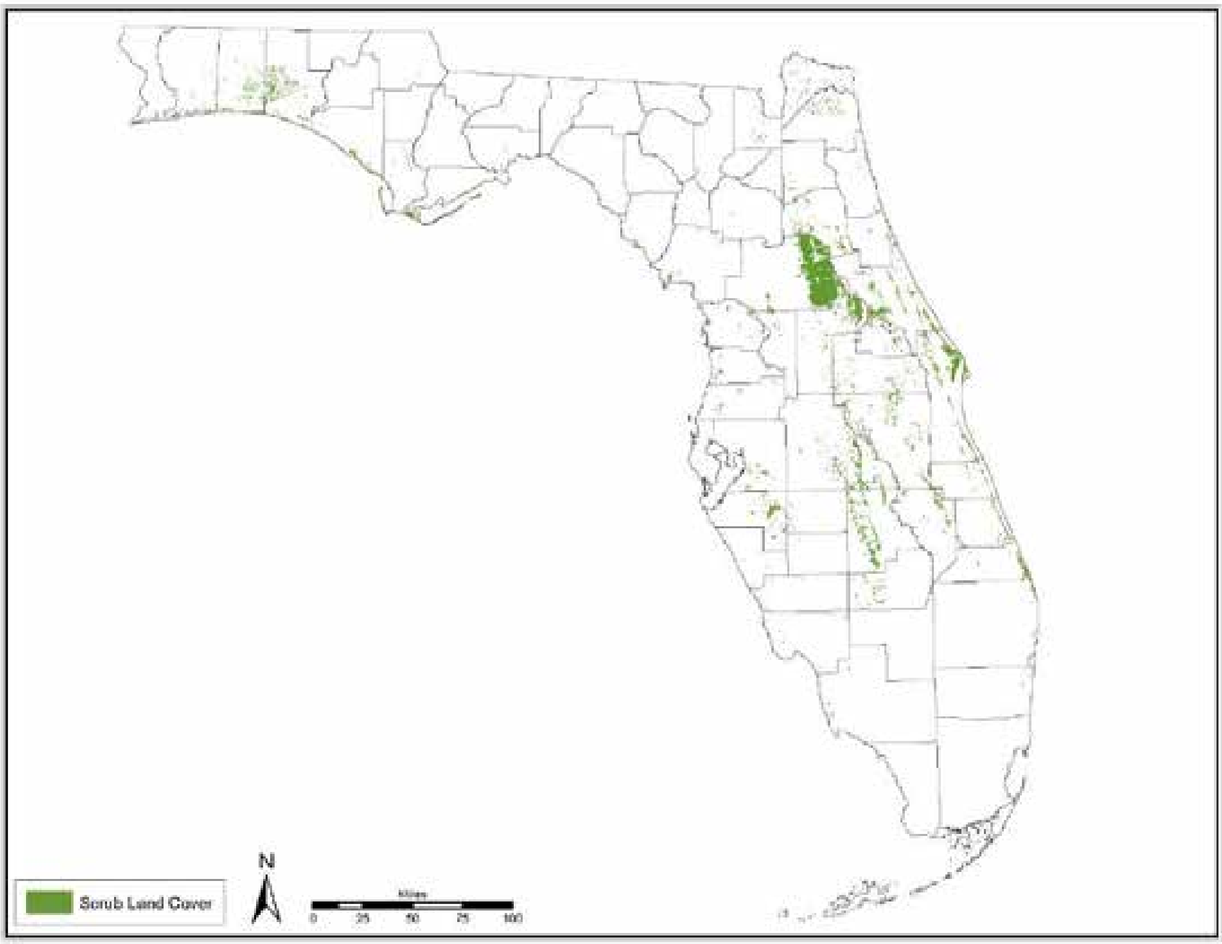


Figure 6.7. This map shows the locations and extent of Scrub land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in frequency, intensity and timing of precipitation, increased average temperature, SLR

Ecological Consequences:

Altered fire regimes, altered community structure and composition, decreased reproductive success, habitat fragmentation, loss and degradation

Other Threats:

- Conversion to agriculture
- Conversion to commercial and industrial development
- Conversion to housing and urban development
- Conversion to recreation areas

- Incompatible fire
- Incompatible forestry practices
- Incompatible recreational activities
- Incompatible resource extraction: mining/drilling
- Invasive animals
- Invasive plants
- Roads

Scrub

Shift	Consequence	Example Species
Decreased rainfall / Longer dry periods / Drought	•Increased wild fires •Reduced opportunities for prescribed fire •Altered species range/extent of occurrence •Reduced opportunities for breeding	Florida scrub jay Gopher tortoise, amphibians
Increased rainfall	•Increased above ground biomass •Altered community structure or composition •Increased flooding/flash flooding	Myrtle Oak
Increased average summer temperatures	•Increased risk of wildfires •Increased frequency and intensity of wildfires •Reduced opportunities for prescribed fire	Florida scrub jay Gopher tortoise
Sea level rise – Inundation *coastal scrub	•Habitat fragmentation •Altered distribution of habitat •Altered range/extent of occurrence of species •Habitat loss	
Sea level rise – Salinity shifts	•Altered distribution of habitat •Altered fire regime	

6.2.7 SANDHILL

Sandhill

FNAI types: Sandhill

Habitat Description:

Sandhill communities occur only in north and central Florida in areas of gently rolling terrain on deep, well-drained, mostly yellow, sterile sands. This xeric community is dominated by an overstory of widely spaced, scattered longleaf pine, along with an understory of turkey oak, sand post oak, and bluejack oak. The park-like ground cover consists of various grasses and herbs, including wiregrass, lopsided Indian grass, bluestems, blazing star, partridge pea, beggars tick, milk pea, queen's delight, and others. Due to the poor water retention properties of the soils and open canopy, temperature and humidity fluctuate rapidly and frequently in this habitat compared to high-moisture closed-canopy forests. However, many temporary wetlands are found throughout Sandhill landscapes and are an integral part of this habitat type, providing breeding and foraging habitat for many wildlife species. Sandhill is a community that is sustained by ground fires with short return intervals to reduce hardwood intrusion and to promote flowering of many grasses and herbs. In the absence of fire, Sandhill will eventually succeed into a xeric hammock. Sand pine can quickly invade Sandhills where seed sources are available and fires are suppressed.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 753,547 acres (304,950 ha) of Sandhill habitat exist (Figure 6.10), of which 46% (348,512 ac; 141,038 ha) are in conservation or managed areas. Another 5% (35,052 ac; 14,185 ha) are in Florida Forever projects and 5% (34,517; 13,969 ha) are in SHCA-designated lands. The remaining 45% (335,466; 135,758 ha) are other private lands.

Climate Change Status:

Ranked in first third of evaluated communities (SIVVA Score: 0.7 - 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value and calculated an overall score between 0.7 and 0.8, placing it 9th in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience declines due to SLR, with as much as 7,608 acres (~1% of the total for this habitat) projected to be lost with three meters of SLR, however, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.8.

Table 6.8. Acreage calculations for Sandhill and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	773,163	520,728	252,436
1 Meter SLR	495 (0.06%)	461 (0.09%)	34 (0.01%)
3 Meter SLR	7,113 (0.92%)	4,753 (0.91%)	2,360 (0.93%)

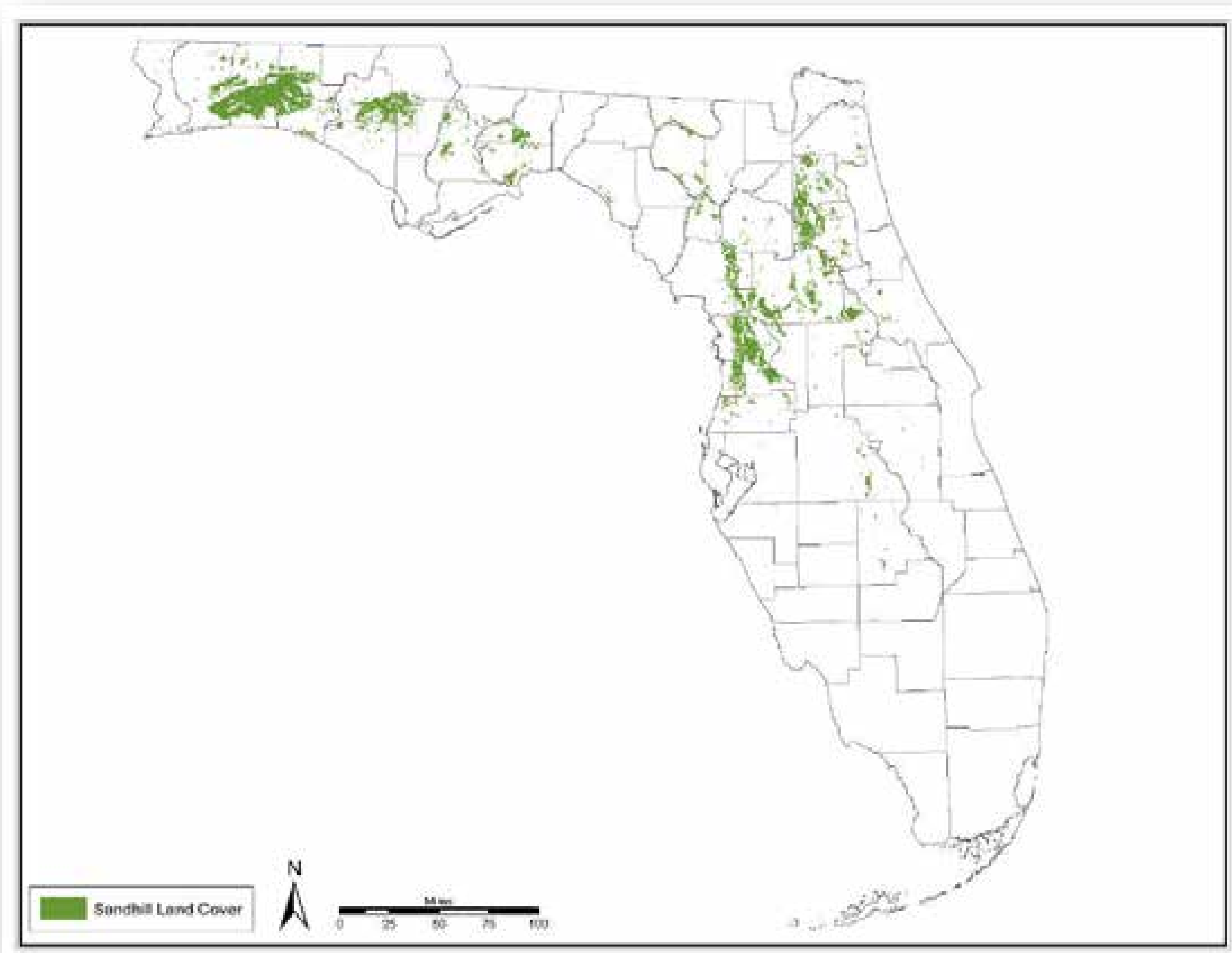


Figure 6.8. This map shows the locations and extent of Sandhill land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in frequency, intensity and timing of precipitation, increased average temperature, SLR

Ecological Consequences:

Altered fire regimes, altered community structure and composition, reduced species diversity, increased mortality, decreased reproductive success, habitat loss and degradation

Other Threats:

- Conversion to commercial and industrial development
- Conversion to housing and urban development
- Conversion to recreation areas
- **Incompatible fire**
- Incompatible recreational activities
- Incompatible resource extraction: mining/drilling
- Invasive animals
- Invasive plants
- Roads

Sandhill

Shift	Consequence	Example Species
Sea level rise – Inundation	Relocation of coastal human populations leading to: •Habitat loss •Habitat fragmentation •Habitat degradation	Florida burrowing owl, Northern bobwhite Gopher tortoise, Eastern indigo snake, Gopher frog Sherman's fox squirrel
Decreased rainfall / Longer dry periods / Drought	•Increased wild fires •Shift in community structure - to more open scrub or dry grasslands •Reduced opportunities for prescribed fire •Altered nutrient uptake in plants •Reduced reproductive success	Gopher tortoise, frogs
Increased rainfall / Longer wet periods	•Altered natural fire regimes – higher humidity, higher soil moisture	
Change in timing of rainfall	•Reduced physiological/metabolic processes – thermoregulatory responses/tactics •Changes in plant species diversity	Snakes (Florida pine snake, Indigo snake, Short-tailed snake)
Increased average summer temperature	•Increased wild fires •Reduced opportunities for prescribed fire	

6.2.8 PINE ROCKLANDS

Pine Rocklands

FNAI types: Pine Rocklands

Habitat Description:

Pine Rockland is a unique type of pine flatwoods that is found exclusively on limestone substrate in the Florida Keys, the Big Cypress Swamp, and the Miami Rock Ridge (the limestone outcropping that rises from the Everglades to heights of 23 feet (7 m) above sea level). The overstory of Pine Rockland habitat contains a single canopy species, South Florida slash pine. The dominant pines tower over a savanna-like understory of saw palmettos, locust berry, willow bustic, beautyberry, broom grasses, silver palms, and a rich herbaceous layer. This community is often associated with rockland hammock and other short-hydroperiod freshwater wetland communities. These sub-tropical pine trees and understory plants have adapted to seasonal wildfires and the lack of soil on the exposed limestone rock. Pine Rockland communities are globally imperiled and support federal and state listed plant species, such as deltoid spurge and Small's milkwort which only occur in this habitat.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 2,959 acres (1,197 ha) of Pine Rockland habitat exist (Figure 6.11), of which 77% (2,275 ac; 921 ha) are in existing conservation or managed areas. Another 13% (382 ac; 155 ha) are Florida Forever projects and 1% (25 ac; 10 ha) are SHCA-identified lands. The remaining 9% (277 ac; 112 ha) are other private lands.

Climate Change Status:

Ranked in first third of evaluated communities (SIVVA Score: 0.8 – 0.9). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value and calculated an overall score between 0.8 and 0.9, placing it 2nd in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience severe declines due to SLR, with as much as 16,608 acres (~99% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.9. However, it is likely that at least some of the projected loses of this habitat could migrate with SLR.

> Dead pine trees found within mangrove swamps in Key Largo were thought to be evidence of sea level rise (Alexander, 1974). This was confirmed decades later by through studying remaining pine rockland habitat, historic aerials and groundwater measurements. Pine mortality was found to proceed from the forest edge towards the interior, succeeding to vegetation better suited to new salinity regimes found in groundwater and soil salinity conditions
>
> Ross *et al*. 1994

Table 6.9. Acreage calculations for Pine Rocklands and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	16,850	16,447	403
1 Meter SLR	13,631 (80.90%)	13,593 (82.65%)	38 (9.43%)
3 Meter SLR	2,977 (17.67%)	2,644 (16.08%)	333 (82.63%)

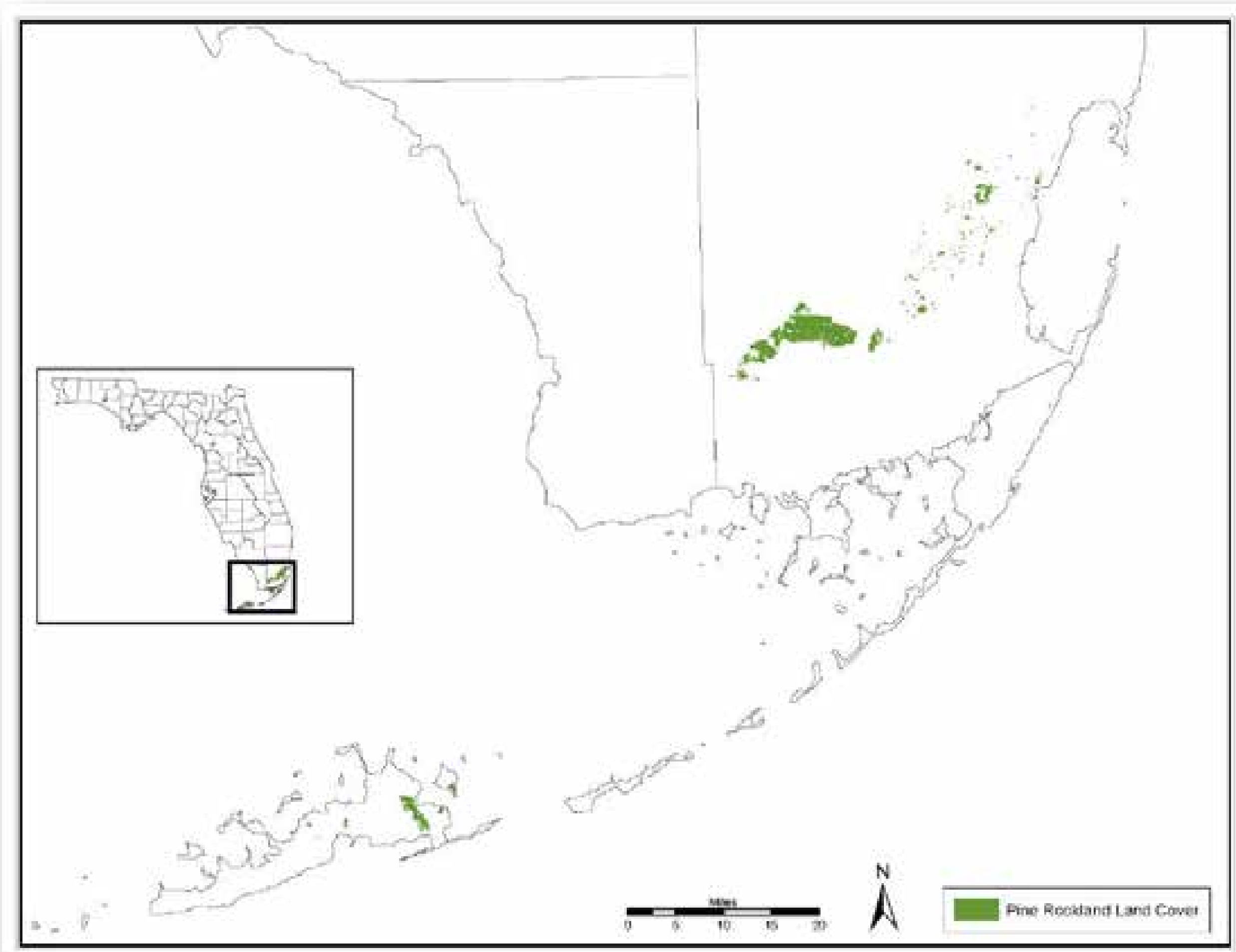


Figure 6.9. This map shows the locations and extent of Pine Rocklands land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Increased storm intensity, SLR

Ecological Consequences:

Altered community structure, composition and phenology, altered fire regimes increased invasive species, pest outbreaks and disease, habitat loss and degradation

Other Threats:

- Chemicals and toxins
- Conversion to commercial and industrial development
- Conversion to housing and urban development
- **Incompatible fire**
- **Invasive animals**
- **Invasive plants**
- Roads

Pine Rocklands

Shift	Consequence	Example Species
Sea level rise – Inundation	•Habitat loss •Habitat fragmentation •Changes in species range/extent of occurrence	Indigo snake, Key ring-necked snake, Rim rock crowned snake Key deer, Florida panther Bartram's hairstreak (butterfly) Endemic/listed plant species
Sea level rise – Salinity shifts	•Habitat loss - Increased soil salinity •Habitat degradation •Habitat fragmentation •Altered fire regimes – loss of fuel as plant composition changes •Altered species composition – as salinity intolerant species are eliminated (plants and animals) •Altered community dynamics •Changes in species range/extent of occurrence	Indigo snake, Key ring-necked snake, Rim rock crowned snake Key deer, Florida panther Bartram's hairstreak Endemic/listed plant species
Increased intensity of storms	•Habitat loss •Habitat degradation •Increased disease outbreaks •Increased invasive species	

6.2.9 PINELAND

Natural Pineland

FNAI types: Mesic Flatwoods, Scrubby Flatwoods, Wet Flatwoods, Upland Pine Forest

Habitat Description:

This category includes natural pine forests, excluding pine rocklands, sandhills, and sand pine scrub, which are listed as separate categories. Natural Pineland habitats include mesic, hydric and scrubby flatwoods, and upland pine forests. Before human settlement, much of north and central Florida was covered by Natural Pineland. Much of this habitat type has been altered by humans as a result of conversion to agriculture and pine plantations, alteration of fire regimes, and introduced species. Pine flatwoods occur on flat sandy terrain where the overstory is characterized by longleaf pine, slash pine, or pond pine. The type of pineland habitat present is usually related to soil differences and small variations in topography. Hydroperiod is an important factor determining what kind of pineland is represented. Generally, flatwoods dominated by longleaf pine occur on well-drained sites while pond pine-dominated sites occur in poorly drained areas, and slash pine-dominated sites occupy intermediate or moderately moist areas. The understory and ground cover within these three communities are somewhat similar and include several common species such as saw palmetto, gallberry, wax myrtle, and a wide variety of grasses and herbs. Generally, wiregrass and runner oak dominate longleaf pine sites; fetterbush and bay trees are found in pond pine areas, while saw palmetto, gallberry, and rusty lyonia occupy slash pine flatwoods sites. Scrubby flatwoods habitat typically occurs on drier ridges, many of which formed originally on or near old coastal dunes. Longleaf pine or slash pine dominates the overstory, whereas the ground cover is similar to that present in xeric oak scrub habitat. Cypress domes, bay heads, titi swamps, and freshwater marshes are commonly interspersed in isolated depressions throughout natural pineland habitats. A wide variety of animals utilize this habitat including the white-tailed deer, eastern diamondback rattlesnake, red-cockaded woodpecker, and pine woods tree frog. Fire is an important factor that helps to maintain and shape Natural Pineland communities; almost all of the plants and animals found here are adapted to having fires occur at least every one to eight years.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 3,095,165 acres (1,252,569 ha) of Natural Pinelands are present in Florida (Figure 6.12). Of that total, 30% (917,949 acres; 371,481 ha) are in existing conservation or managed areas, 7% (206,899 acres; 83,729 ha) are on private lands encompassed by Florida Forever projects, 8% (235,176 acres; 95,172 ha) are SCHA-identified lands, and the remaining 56% (1,735,141 acres; 702,187 ha) are within other private lands.

Climate Change Status:

This habitat was divided among several habitats in the SIVVA report. They were spread throughout the middle and final thirds of evaluated communities (SIVVA Score: 0.6 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value and calculated an overall score between .6 and .8, placing it either 13th (Other High Pine), 16th (Scrubby Flatwoods), 17th (Upland Pine), 19th (Wet Flatwoods), or 29th (Mesic Flatwoods) in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience significant declines due to SLR, with as much as 149,299 acres (~8% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.10. However, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR.

Table 6.10. Acreage calculations for Pineland and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	1,932,695	1,204,291	728,404
1 Meter SLR	45,442 (2.35%)	33,056 (25.74%)	12,386 (1.70%)
3 Meter SLR	103,857 (5.37%)	67,601 (5.61%)	36,256 (4.98%)

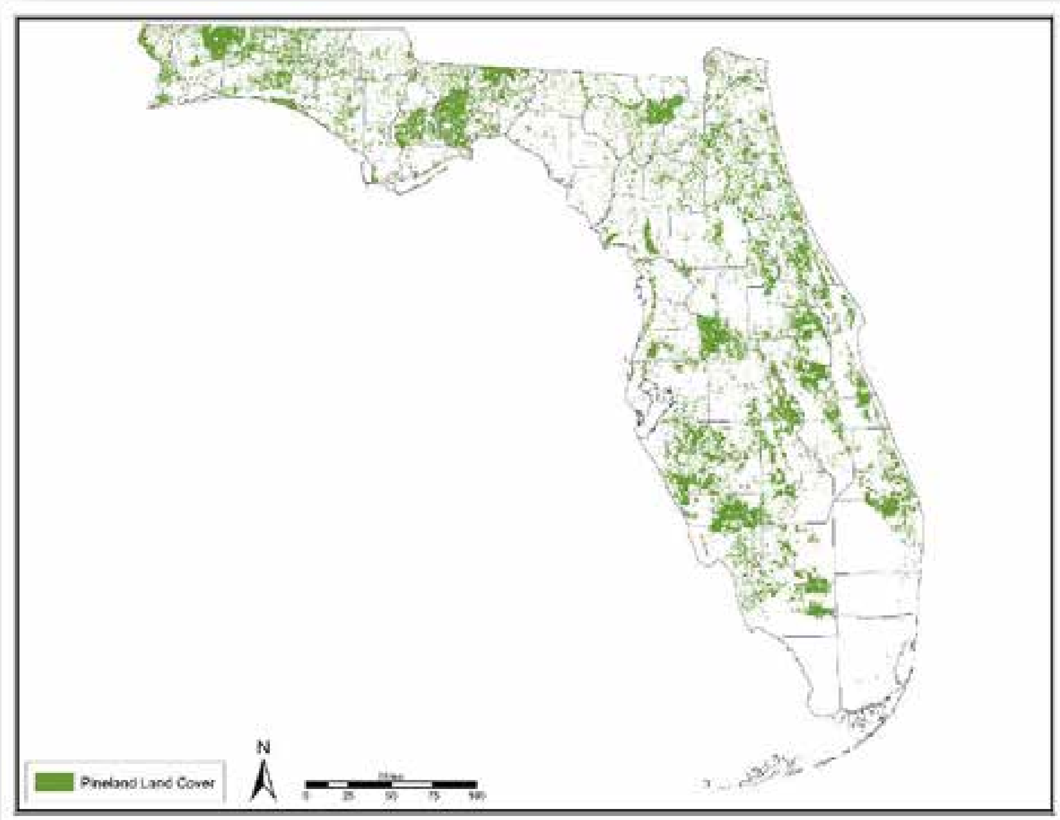


Figure 6.10. This map shows the locations and extent of Pineland land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in frequency, intensity and timing of precipitation, increased temperatures, increased storm intensity, SLR

Ecological Consequences

Altered community structure, composition and phenology, altered fire regimes, increased invasive species, pest outbreaks and disease, increased mortality, decreased reproductive success, habitat loss and degradation

Other Threats:

- Conversion to agriculture
- Conversion to commercial and industrial development
- Conversion to housing and urban development
- Conversion to recreation areas
- **Groundwater withdrawal**
- **Incompatible fire**
- Incompatible forestry practices
- Incompatible recreational activities

- Incompatible resource extraction: mining/drilling
- **Invasive animals**
- **Invasive plants**
- Roads
- **Surface water withdrawal**

Pineland

Shift	Consequence	Example Species
Decreased rainfall / Longer Dry periods / Drought	•Decreased prey availability (arthropods, seeds) •Reduced reproductive success •Altered breeding chronology •Increased wildfire risk •Reduced opportunities for prescribed fire •Increased pest outbreaks	Breeding birds, over-wintering birds, Amphibians Pine trees
Increased rainfall / Flood	•Increased mortality •Altered community structure •Increased frequency of flooding events – transportation of fish to previously fishless ponds: •Changes in predator prey relationships •Reduced reproductive success	Ground nesting birds Frogs, Salamanders
Sea level rise – Inundation	•Habitat loss •Habitat fragmentation •Impacts from relocation of coastal human populations	Gopher tortoise, Eastern indigo snake, Gopher frog Sherman's fox squirrel
Sea level rise- Salinity shifts	•Altered community structure – shifts to more salinity tolerant species •Altered fire regime •Altered species range/extent of occurrence •Altered community dynamics	Gopher tortoise, Eastern indigo snake, Gopher frog Sherman's fox squirrel, Black bear

Pinelands Continued

Shift	Consequence	Example Species
Increased average summer temperatures	•Altered fire regime •Altered species composition •Altered species range/extent of occurrence •Increased disease outbreaks •Increased pest outbreaks	Pine species
Increased intensity of storms	•Habitat loss •Habitat degradation •Increased disease outbreaks (Ips beetles, weevils) •Increased invasive species	
Change in timing of rainfall	•Reduced physiological/metabolic processes – thermoregulatory responses/tactics •Changes in plant species diversity	Snakes (Florida pine snake, Indigo snake, Short-tailed snake)

6.2.10 DRY PRAIRIE

Dry Prairie

FNAI types: Dry Prairie

Habitat Description:

Dry Prairies are large native grass- and shrub-lands occurring on very flat terrain interspersed with scattered cypress domes and strands, bayheads, isolated freshwater marshes, and hardwood hammocks. This community is characterized by many species of grasses, sedges, herbs, and shrubs, including saw palmetto, fetterbush, staggerbush, tar flower, gallberry, blueberry, wiregrass, carpet grasses, and various bluestems. The largest areas of these treeless plains historically occurred just north of Lake Okeechobee. In central and south Florida, palmetto prairies, which consist of former pine flatwoods where the overstory trees have been thinned or removed, are also included in this category. These sites contain highly scattered pines that cover less than 10 to 15 % of an area.

Conservation Status:

Current Condition: Poor and declining. According to the SWAP, 1,215,099 acres (491,733 ha) of Dry Prairie habitat exist (Figure 6.13), of which 29% (353,768 ac; 143,165 ha) are in existing conservation or managed areas. Another 13% (163,613 ac; 66,212 ha) are in Florida Forever projects and 11% (131,803 ac; 53,339 ha) are in SHCA-designated lands. The remaining 47% (565,915 ac; 229,018 ha) are other private lands.

Climate Change Status:

Ranked in first third of evaluated communities (SIVVA Score: 0.7 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value and calculated an overall score between 0.7 and 0.8, placing it 8th in relation to 30 coastal communities examined in Florida. This habitat type are projected to experience declines due to SLR, with as much as 205,008 acres (~4.5% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.11.

Table 6.11. Acreage calculations for Dry Prairie and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	155,727	119,657	36,070
1 Meter SLR	0 (0.00%)	0 (0.00%)	0 (0.00%)
3 Meter SLR	0 (0.00%)	0 (0.00%)	0 (0.00%)

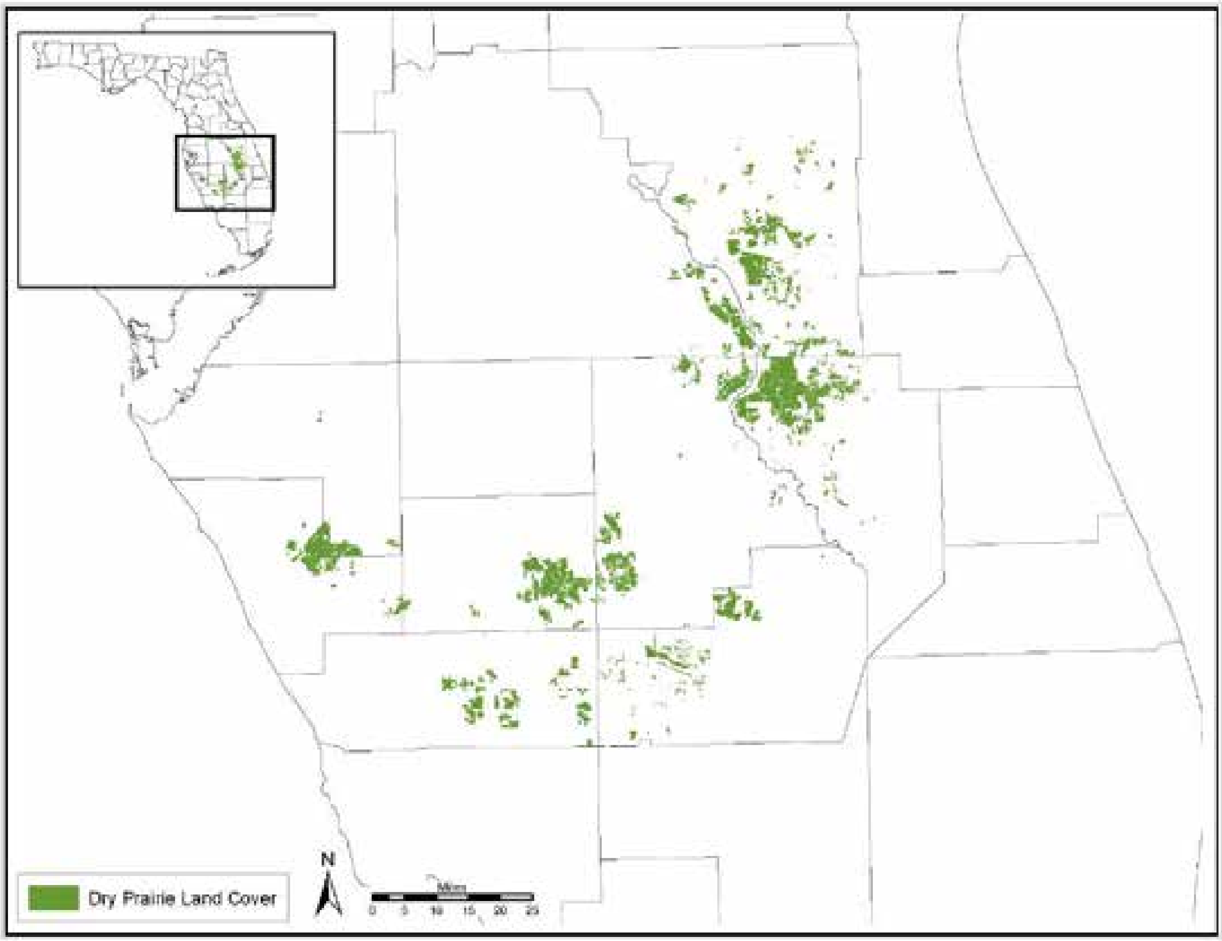


Figure 6.11. This map shows the locations and extent of Dry Prairie land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

<ins>Measurable Climatic Shifts:</ins>

Changes in precipitation frequency, intensity and timing

<ins>Ecological Consequences:</ins>

Altered fire regimes, increased mortality of plant and animal species, decreased reproductivity and altered breeding phenology

<ins>Other Threats</ins>:

- Conversion to agriculture
- Conversion to commercial and industrial development
- Conversion to housing and urban development
- **Incompatible fire**

- Incompatible forestry practices
- Incompatible resource extraction: mining/drilling
- Invasive plants
- Roads
- Surface water withdrawal

Dry Prairie

Shift	Consequence	Example Species
Increased rainfall / Longer wet periods	•Reduced reproductive success •Increased mortality •Reduced opportunities for prescribed fire	Ground nesting birds (Grasshopper sparrow, Eastern meadowlark, Northern bobwhite, Bachman's sparrow)
Decreased rainfall / Longer dry periods / Drought	•Increased wild fires •Reduced prey availability (arthropod) •Reduced food availability (seed) •Reduced reproductive success •Changes in breeding chronology	Ground nesting birds (Grasshopper sparrow, Eastern meadowlark, Northern bobwhite, Bachman's sparrow)
Change in timing of rainfall	•Changes in plant species diversity •Reduced reproductive success	

6.2.11 DISTURBED: TRANSITIONAL, INDUSTRIAL PINELAND, GRASSLAND/PASTURELAND

Transitional (i.e. Disturbed/Transitional)

FNAI types: None.

Habitat Description:

This habitat category includes two principal types of Disturbed/Transitional habitat. The first type is comprised of a variety of situations where a natural upland community type has recently experienced an extensive disturbance resulting in the loss of nearly all of the vegetative cover (e.g., clear-cutting, land clearing, or severe fire) and is recovering through natural successional processes. This includes areas that range from bare soil to recently denuded areas where vegetative growth has resulted in a dense, mixed cover of herbaceous vegetation, shrubs, and vines. Species composition may approximate that of the pre-existing stand. These areas could be characterized as early-successional habitats.

The second type of Disturbed/Transitional habitat is comprised of upland or wetland site dominated by non-native invasive plants, most commonly trees. These invasives may have been planted, or may have escaped cultivation and invaded native plant communities. These exotics include Melaleuca, Australian pine, Brazilian pepper, and Eucalyptus. For mapping/calculation purposes, this habitat was combined with the other habitats in this subsection, subsequently referred to as Transitional.

Conservation Status:

Current condition: Unknown. According to the SWAP, approximately 2,807,185 acres (1,136,027 ha) of Disturbed/Transitional habitat exist (Figure 6.14). However, this is a very dynamic cover class. Areas are rapidly added to and lost from this category, due to both natural processes (e.g., succession, wildfire) and human enterprise (e.g., agriculture).

Climate Change Status:

A SIVVA score not created. This habitat type (and the others in this subsection) are projected to experience declines due to SLR, with as much as 205,008 acres (~4.5% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.12.

Table 6.12. Acreage calculations for Transitional, Industrial Pineland, and Unimproved Pastureland (all referred to as disturbed here) and projected inundations or loses of existing land cover.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	4,549,970	1,130,459	3,419,511
1 Meter SLR	33,646 (0.74%)	18,778 (1.66%)	14,868 (0.43%)
3 Meter SLR	171,362 (3.77%)	74,154 (6.56%)	97,209 (2.84%)

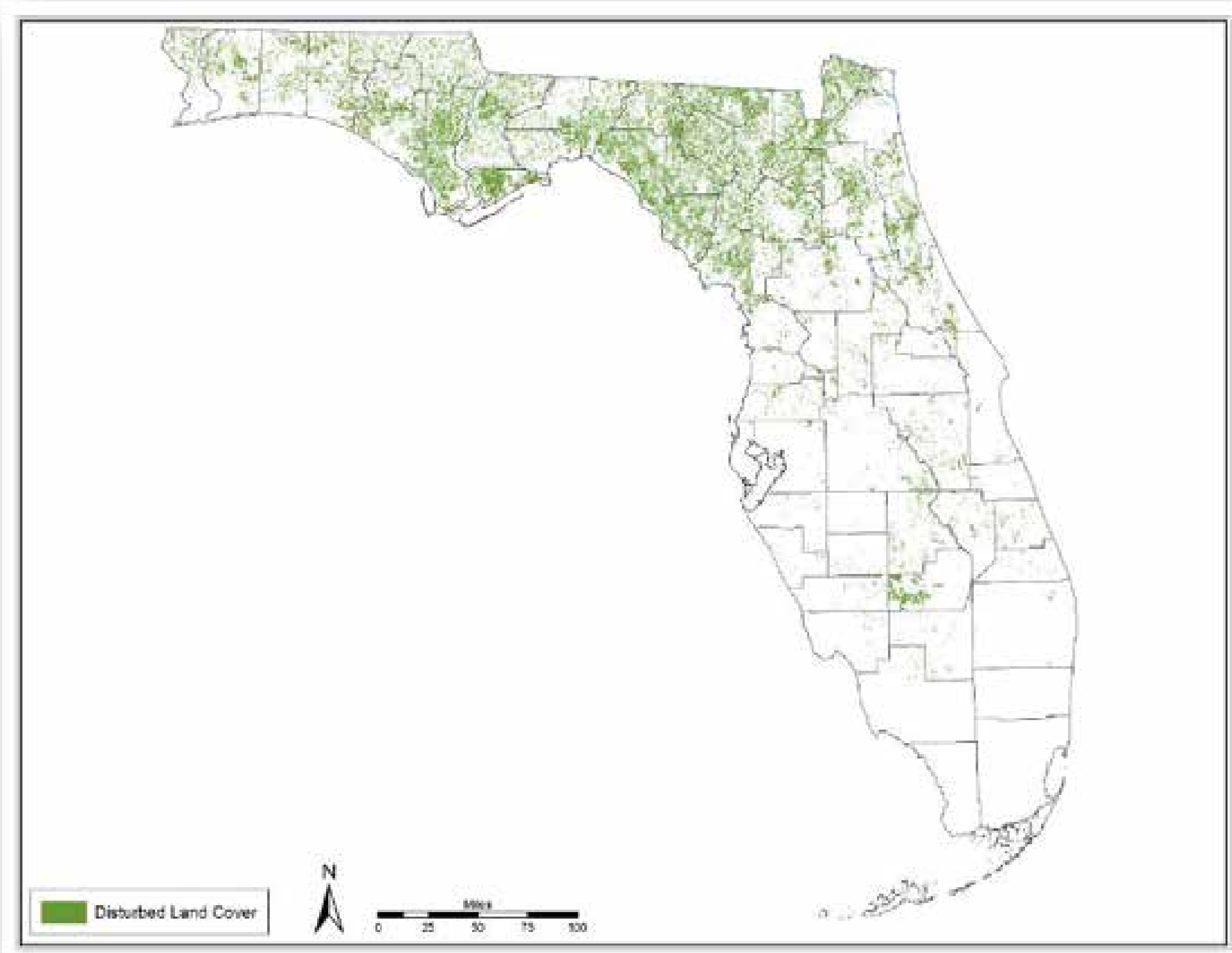


Figure 6.12. This map shows the locations and extent of Transitional, Industrial Pineland, and Unimproved Pastureland land cover across the state (all referred to as disturbed here). For a map examining the impact of SLR on this classification, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in precipitation frequency and intensity, SLR

Ecological Consequences:

Altered fire regimes, decreased colonization and reproductivity, increased mortality of plant and animal species

Other Threats:

- Chemicals and toxins
- Conversion to agriculture
- Conversion to commercial and industrial development

- Conversion to housing and urban development
- Conversion to recreation areas
- **Incompatible fire**
- Incompatible forestry practices
- Incompatible recreational activities
- Incompatible resource extraction–mining
- Incompatible wildlife and fisheries management strategies
- Invasive animals
- Invasive plants
- Lack of knowledge/ appreciation of early-successional habitat
- Nuisance animals
- Nutrient loads–agriculture
- Roads, bridges, and causeways

Industrial/Commercial Pineland

FNAI types: None

Habitat Description:

This category includes industrial and commercial pine plantations that are almost exclusively artificially produced through silviculture practices. Due to a climate conducive to rapid growth, Florida is part of one of the most productive timber-producing regions in the world; Florida's timberlands are a major contributor to the state's economy and provide critical water recharge areas within Florida. Industrial/Commercial Pineland habitat is characterized by high density, even-aged, single-species stands, planted in rows at regular intervals, across large areas. This habitat includes sites predominantly planted to slash pine, although longleaf pine and loblolly pine tracts also occur. Also included in this category are sand pine plantations, which often are planted on sites with poorer soils; many of these areas occur on intensively prepared sites. Ground cover and shrub vegetation on Industrial/Commercial Pineland sites vary with the growth stage of the pine trees and management techniques used at the site. On early or recently planted sites, ground cover and shrub vegetation may be excessively dense, and may include species such as palmetto, gallberry, and wax myrtle. As the trees become taller and canopy cover becomes complete, ground cover and shrub vegetation becomes sparse. As Industrial/Commercial Pineland sites approach maturity other vegetation may disappear and the ground cover may consist of a thick layer of pine needles and other litter. Industrial/Commercial Pineland may provide habitat for a variety of species depending upon the growth stage of the forest and the management practices employed on-site. Species such as the Florida panther and the black bear may use this habitat as a corridor between primary habitats. For mapping/calculation purposes, this habitat was combined with the other habitats in this subsection, subsequently referred to as Transitional.

Conservation Status:

Current condition: Good and declining. According to the SWAP, 3,363,024 acres (1,360,968 ha) of Industrial/Commercial Pineland are in Florida (Figure 32). Of that total, 19% (634,848 acres; 256,914 ha) are in existing conservation or managed areas, 11% (358,029 acres; 144,889 ha) are on private lands encompassed by Florida Forever projects, 6% (196,264 acres; 79,425 ha) are within SCHA-identified lands, and the remaining 65% (2,173,883 acres; 879,739 ha) are within other private lands.

Climate Change Status:

A SIVVA score not created. This habitat type (and the others in this subsection) are projected to experience declines due to SLR, with as much as 205,008 acres (~4.5% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included previously in Table 6.12.

Measurable Climatic Shifts:

Changes in precipitation frequency and intensity, SLR

Ecological Consequences:

Altered fire regimes, increased disease and pest outbreaks, increased mortality of plant and animal species, decreased reproductivity and altered breeding phenology

Other Threats:

- Conversion to commercial and industrial development
- Conversion to housing and urban development
- Incompatible forestry practices
- Roads

Grassland/Improved Pasture

FNAI types: None

Habitat Description:

This is an upland community where the predominant vegetative cover is very low-growing grasses and forbs, most commonly in monocultures of non-invasive, non-native species. Improved Pastures have typically been cleared, tilled, reseeded with specific grass types, and periodically improved with brush control and fertilizer application. For mapping/calculation purposes, this habitat was combined with the other habitats in this subsection, subsequently referred to as Transitional. However, improved pasture was not included in this calculation, only unimproved/woodland pasture and rural. This SWAP habitat category does not align with the land cover data analyzed for this adaptation guide, even though portions of it were included.

Conservation Status:

Current condition: Good and declining. According to the SWAP, 2,931,999 acres (1,186,538 ha) of Grassland/Improved Pasture habitat exist (Figure 32), of which 6% (186,662 ac; 75,539 ha) are in existing conservation or managed areas. Another 7% (193,063 ac; 78,130 ha) are in Florida Forever projects, and 9% (262,558 ac; 106,253 ha) are in SHCA-designated lands. The remaining 78% (2,289,716 ac; 926,615 ha) are other private lands.

Climate Change Status:

A SIVVA score not created. This habitat type (and the others in this subsection) are projected to experience declines due to SLR, with as much as 205,008 acres (~4.5% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included previously in Table 6.12.

Measurable Climatic Shifts:

Changes in precipitation frequency and intensity, SLR

Ecological Consequences:

Altered fire regimes, increased disease and pest outbreaks, increased mortality of plant and animal species, decreased reproductivity and altered breeding phenology

Other Threats:

- Conversion to more intensive agriculture
- Conversion to housing and urban development
- Conversion to recreation areas
- Roads

Disturbed/Transitional, Industrial Pineland, Grassland/Pastureland

Shift	Consequence	Example Species
Decreased rainfall / Longer dry periods / Drought	•Increased wildfires •Altered pest and disease outbreaks •Reduced availability of prey (arthopods) •Reduced seed availability •Reduced reproductive success •Altered breeding chronology	Grasshopper sparrow, Eastern meadowlark, Bachman's sparrow, Northern bobwhite quail, overwintering birds Ants
Increased rainfall	•Increased mortality •Reduced reproductive success •Altered fire regime	

6.3 FRESHWATER HABITATS

Climatic Shift- Changes in Temperature Extremes

Ecological Consequences:

- Increased mortality of exotic aquatic species due to extreme temperatures and duration of extreme temperatures (hotter summer and colder winter water temps) (+)
- Minimum winter temperatures increase
  - Local extirpations of species at the southern extent of their range as water temperatures increase (Centrarchidae)
  - Increased growth rates of fish due to warmer water temperatures (+)
  - Earlier onset of spawning by fish species whose spawning is initiated by a minimum temperature
  - Northward range shift of aquatic exotic species due to reductions/removal of climate barrier as water temperatures warm
  - Increased growth rate and expansion through the winter of invasive plant species
  - Increased duck hunting opportunities due to increased abundance of hydrilla as winter and spring water temperatures increase (+)
  - Loss of Alosine fishes due to mortality and reduced reproductive success as water temperature increases
  - Range expansion of euryhaline marine species further into inland waters
- Minimum winter temperatures decrease
  - Decoupling of predator/prey relationships of fish due to water temperature fluctuations
  - Impediments to sturgeon movement due to variation in temperature regimes
  - Increased mortality for cold temperature sensitive species
  - Increased occurrence and severity of cold kill events
  - Limit northern extent of exotic species range (+)
- Increased summer temperatures
  - Higher eutrophication rates, reduction of SAV, DO crashes due to increased algal blooms
  - Increased growth rates of aquatic vegetation
  - Shift in fish communities from sportfish to rough fish due to loss of submerged aquatic vegetation and forage shifts as water temperatures increase
  - Fish community structure changes as survival of fish species existing in thermally marginal habitats decreases and they are replaced by fish better able to tolerate increased water temperatures
  - Skewed sex ratio of species with temperature-dependent sex determination (alligator)
  - Altered length of spawning season for fish
  - Loss of habitat for least tolerant warm water fish species due to increased stream temperature
  - Increase in invasive species that can tolerate higher temperatures and low oxygen
  - Increased algal blooms due to increased water temperatures

- Altered food web as individual organisms shift distributions based on thermal tolerance and dispersal abilities (mayflies)
- Increased parasite loads for aquatic organisms
- Altered composition of parasite community
- Increased fish kills due to less dissolved oxygen

Climatic Shift- Increased Storm Intensity

Ecological Consequences:

- Altered habitat type/composition of forested riparian and wetland communities due wind damage caused by increased storm intensity
- Altered composition of aquatic species due to changes in biotic interactions
- Increased erosion, sediment transport and runoff into freshwater systems due to increased rainfall associated with increased storm intensity
- Increased spread of exotic or invasive species f into freshwater syste
- Increased levels of particulate and dissolved substances (nitrates, ammonia) in aquatic systems due to higher discharge rates
- Altered water chemistry due to increased runoff
- Increased mortality due to increased pollution entering the aquatic systems
- Increased extent of freshwater habitats due to increased precipitation from storms (+)
- Reduction/elimination of some aquatic species due to changes in biotic interactions
- Increased stream flow due to increased precipitation from storms
- Increased high water levels due to increased precipitation from storms
- Altered water quality due to changes in nutrient and sediment
- Disruption of reproductive cycles and migration in aquatic species due to changes in water flow
- Reduced species richness and abundance due to storm surge and saltwater intrusion into coastal freshwater wetlands

Climatic Shift- Intensification of Hydrological Cycle

Ecological Consequences:

- Floods
    - Decreased reproductive success and survival of amphibians in ephemeral ponds due to increase in predators as ponds become connected to adjacent wetlands and water bodies
    - Increased woody debris carried into stream channels by flood events, creating new high quality habitat
    - Decreased survival and fitness of sensitive aquatic species due to increased flow of pollutants from surrounding watersheds in to streams, rivers, ponds and lakes

    - Reduced food source for aquatic species due to displacement of stored organic carbon as floods cause scouring of the streambed
    - Increased turbidity and sedimentation from runoff
    - Increased nest failure of land-nesting aquatic species due to degradation or loss of nesting habitat
- longer wet periods
    - Decreased reproductive success of amphibians in ephemeral wetlands due to increased fluctuations to breeding season water levels
- Droughts
    - Shift in species composition to those species with short life cycle due to changes in habitat suitability as base flow decreases
    - Changes in stream temperature and debris loads due to alterations in riparian vegetation due as the duration and frequency of wildlife increases
    - Expansion of the ranges of temperature-sensitive exotic species
    - Reduced fitness of freshwater species in tidal creeks due to increased salinity as freshwater inflow decreases
    - Decreases in the oxygen-holding capacity of surface water
    - Increased anoxia and chemical transformation in surface waters
    - Alterations in the transport of organic matter or sediments into freshwater systems
    - Increased heavy metals and other toxic substance concentrations in water bodies and increased residence time of chemical constituents due to longer flushing times
    - Decreased bacterial, fungal and microbial activity due to reduced detritus decomposition
    - Increased mortality of fish and other aquatic species due to low water levels causing species to become trapped in isolated pools with decreased DO and increased temperature
    - Increased disease and wildlife health issues due to increased protozoa and bacteria levels in warm water
    - Increased habitat fragmentation due to changes in spatial distribution and extent of habitat
    - Increased invasive nonnative plant species in lakes and wetlands due to prolonged dry periods
    - Altered macro-invertebrate assemblages in streams
    - Altered species ranges due to habitat fragmentation
    - Decreased reproductive success and survival of amphibians in ephemeral ponds due to loss of water
    - Reduced spring flow due to decreased water level in the aquifer
    - Increased mortality of riparian trees and other vegetation due to prolonged absence of flooding
    - Loss of connectivity between freshwater systems due to drying up of systems
    - Decreased stream flow or drying up of streams in areas downstream of springs
    - Loss or reduction of some species as biotic interactions are altered

    - Increased predation on lower trophic level species due to increased densities of various species at freshwater sources as this resource becomes limited
- Longer dry periods
    - Lake bottom drying allow for burning of land bed stimulates desirable aquatic plants (+)
    - Increased abundance, prevalence and diversity of aquatic parasites
    - Increased cyanobacteria blooms and cyanotoxin concentrations in waterbodies
    - Decreased connectivity of 1st and 2nd order streams to main channel
    - Reduced river stage and flows in panhandle affecting freshwater mussel beds
    - Decreased reproductive success of amphibians in ephemeral wetlands
    - Loss of herbaceous aquatic vegetation as hardwood and pine encroaches into wetlands
- Increased Rainfall
    - Increased nutrient and sediment loading sue to increased runoff
    - Reduction in availability/connectivity of spawning areas if overall rainfall increases, but flooding events are less frequent
- Decreased Rainfall
    - Reduced spawning habitat as connectivity between rivers and floodplain is reduced (Apalachicola/Suwannee Rivers) (Increased water demand)
    - Increased growth of invasive aquatic plants and algae due to lower spring flow and increased nitrate concentrations
    - Reduced average freshwater discharge from Lake Okeechobee
    - Increased lake bed exposure and lake bottom consolidation
    - Reduced littoral zone flushing of tussock and other organic material as high water events are reduced
- Timing of Precipitation
    - Altered water chemistry
    - Altered low level trophic interactions – temporal mismatch between phytoplankton and zooplankton
    - Altered interactions between species due to decreased migratory connectivity of aquatic species accessing feeding/breeding grounds
    - Changes in timing of mosquito life cycles and nesting bird populations as related to mosquito borne diseases (St. Louis encephalitis virus and West Nile virus)
    - Decreased survival/reproductive success of amphibians and invertebrates in ephemeral wetlands
    - Decreased reproductive success of fish due to lack of connectivity to spawning grounds as timing of flood events change

Climatic Shift- Salinity Shifts

Ecological Consequences:

- Loss of suitable habitat for those species with limited osmoregulation
- Decrease in salt-intolerant vegetation due to increased salinity
- Decrease in coastal and tidal freshwater marshes due to changes in community structure as salinity increases
- Loss of critical freshwater sources in the Keys due to salt water intrusion
- Decreased productivity/growth of vegetation (wild celery)
- Reduction in groundwater due to changes in location/amount of withdrawals for drinking water as salinity increases at some locations

Climatic Shift- Changes in Water Chemistry

Ecological Consequences:

- Shifts in pH in lakes due to increased CO_2
- Decreased reproductive success (number of eggs produced, successful fertilization, egg and fry survival) due to lowering of pH (experimental study of flagfish)
- Decreased survival rates, increased larval period and decreased size at metamorphosis due to Lower pH (frogs)
- Increased invasive plant growth (hydrilla) for those species that have an affinity for CO_2
- Decreased amphibian diversity in the Florida panhandle due to increased acidic rain as atmospheric CO_2 increases
- Increased damage to host plants by epiphytes due to increased epiphytic growth

6.3.1 LARGE ALLUVIAL STREAM

Large Alluvial Stream

FNAI types: Alluvial Stream, River Floodplain Lake, Swamp Lake

Habitat Description:

Alluvial streams originate in high uplands that are composed of sand and silt based clays, thereby giving these streams a natural high turbidity. These streams only occur in the north region of Florida and are characterized as having meandering channels with a mix of sand bottom, sand and gravel, and areas of bedrock or shoals. Large Alluvial Streams have flow rates and sediment loads that range from low to high (flood) stages, consequently causing water depth and other water quality parameters to fluctuate substantially with seasonal rainfall patterns. Flood stages which overflow the banks and inundate the adjacent floodplain and Bottomland Hardwood Forest communities usually occur one or two times each year during winter or early spring. Due to the high natural turbidity of these streams there is minimal vegetation which is mostly confined to channel edges or backwaters. Typical plants include spatterdock, duckweed, American lotus, and water hyssop. Examples of this stream category include the Escambia, Choctawhatchee, and Apalachicola rivers.

Conservation Status:

Current condition: Good and declining. According to the SWAP, 1,019 miles (1,640 km) of Large Alluvial Stream habitat exist.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Altered water chemistry, changes in frequency, intensity and timing of precipitation, increased storm intensity, increased temperatures

Ecological Consequences:

Changes in water quality and biotic community due to increased runoff and pollution, reduced reproductive success and altered reproductive phenology, increased invasive and parasitic organisms, habitat loss and degradation

Other Threats:

- **Chemicals and toxins**
- Groundwater withdrawal
- Incompatible forestry practices
- Incompatible recreational activities
- Invasive animals
- **Surface water withdrawal and diversion**

Large Alluvial Stream

Shift	Consequence	Example Species
Increased rainfall / Flood	•Increased runoff/pollution •Increased sediment loading •Habitat degradation – reduced flood plain inundation •Reduced reproductive success •Increased habitat quality – importation of woody debris •Change in abiotic resource – loss of stored organic carbon due to streambed scouring •Altered community structure or composition – salt water intrusion from storm surge	Amphibians Centrarchidae Invertebrates
Decreased rainfall / Longer dry periods / Drought	•Habitat loss •Habitat degradation •Reduced reproductive success •Altered community composition - changes in species composition of macroinvertebrates •Change in abiotic resource - decreased bacterial, fungal and microbial activity •Increase in abundance, prevalence and diversity of aquatic parasites •Altered fire regime - riparian zone	American eel, Okaloosa darter, Blackmouth shiner, Bluenose shiner, Centrarchidae Macroinvertebrates, invertebrates
Change in timing of rainfall	•Altered community dynamics •Reduced reproductive success •Increased mortality •Altered functional processes – chemical process and nutrient concentrations	Migratory aquatic species Invertebrates
Increased intensity of storms	•Increased runoff and sediment transport •Altered water chemistry – higher levels of particulate and dissolved substances •Reduced reproductive success •Increased phenological mismatches – egg laying, migration	Shoal bass
Increased average summer temperature	•Altered sex ratio •Habitat degradation •Habitat loss •Increased parasite loads •Altered parasite composition	Alligator Striped bass
Altered water chemistry	•Reduced reproductive success	Flagfish

6.3.2 SPRINGS AND SPRING RUNS

Spring and Spring Run

FNAI types: Spring-run Stream

Habitat Description:

This habitat is present in the north and central regions of Florida, in most of the same areas occupied by Calcareous Stream habitat, where underlying limestone is close to the surface. Spring and Spring Run often represent headwaters or low-order tributaries of, and thus share many characteristics with Calcareous Streams. The Spring and Spring Run habitats originate from and have direct outflow through artesian openings in the underground, limestone, Floridian aquifer. Because of the calcareous nature of the limestone aquifer, the outflow from most springs carries dissolved mineral ions such as calcium, magnesium, bicarbonate, sulfate, and sodium. Springs typically have high water clarity, low sedimentation, stable channels, and openings that are less than 40 feet (12.2 m) wide. Individual springs are stable systems, with very little change in water temperature, water flow, or chemical composition, but those characteristics can vary from one spring to the next. The bottoms of spring runs are generally sand or exposed limestone along a central, stable channel. Vegetation in Spring and Spring Run habitats consist of submerged aquatic vegetation, aquatic algae covering limestone outcroppings, and species such as tape grass, wild rice, and giant cutgrass located in the spring runs. The constant temperatures of springs provide essential habitat for manatees and some species of fish. Examples of Spring and Spring Run include Silver Springs, Manatee Springs, Spring Creek, Blue Spring, and Rainbow Springs.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, there are approximately 570 springs arising from the Floridian Aquifer, constituting a total spring- run length of about 572 miles (921 km).

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

> Bases on SLR projections, some of commonly utilized power plant warm water refugia used by manatees may be inundated. Natural warm water refugia could be impacted by reduced spring flows, increased groundwater withdrawals or intrusion of cooler, salt water into the aquifer. However sea level rise or increased precipitation and the following water level increase may allow improved access to some shallow water springs systems depending on local conditions.
>
> Edwards 2013

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, changes in water chemistry, increased temperatures, increased storm intensity

Ecological Consequences:

Altered community structure and composition, changes in range and abundance of invasive and introduced species, biotic changes due to fluctuations in water quality, decreased reproductive success and changes in reproductive phenology, habitat change and shifts (expansion, fragmentation or loss)

Other Threats:

- Conversion to commercial/industrial development
- Conversion to recreation areas
- Groundwater withdrawal
- Incompatible forestry practices
- Incompatible recreational activities
- Invasive animals
- Invasive plants
- Nutrient loads–agriculture
- Nutrient loads–urban
- Surface water withdrawal/diversion

Springs

Shift	Consequence	Example Species
Drought	•Decreased flow – leading to decreased area of thermal refuge •Increase in nitrate concentrations •Increased abundance and density of invasive plants and algae	Manatees Largemouth bass, Centrarchidae, other bass species *Hydrilla* *Lyngbya*
Changes in temperature extremes	•Increased mortality •Reduction of exotic species (e.g., sailfin catfish, corbicula clams) •Altered community composition	
Increased minimum winter/spring temperatures (warmer)	•Increased range, abundance and diversity of exotic species (e.g., Blue tilapia, Brown hoplo, Mayan cichlid, Asian swamp eel) • Increased growth rates •Habitat degradation – increase in invasive plant range and density (e.g., *Hydrilla*, water hyacinth, water lettuce) •Habitat loss •Changes in reproductive cycle, earlier spawning (temp dependent species) •Changes in extent of habitat *(Hydrilla)* •Change in species composition	Waterfowl Centrarchidae, Cyprinidae

Springs Continued

Shift	Consequence	Example Species
Increased intensity of storms	•Increased runoff and sediment transport	
Changes in water chemistry	•Shifts in pH •Increased growth of invasive plant species (*Hydrilla*) •Increased epiphytic growth/decreased health of host plants	Submerged aqautic vegetation, *Vallisneria americana*, Illinois pondweed

Spring Run Stream

Shift	Consequence	Example Species
Decreased rainfall / Drought	•Decreased flow •Increase in nitrate concentrations •Increased abundance and density of invasive plants and algae (e.g., *Hydrilla*) •Habitat fragmentation •Lowering of groundwater tables	Largemouth bass, Centrarchidae, other bass species *Lyngbya*
Changes in temperature extremes	•Increased mortality •Reduction of exotic species (e.g., sailfin catfish, tilapia, corbicula clams) •Altered community composition	Striped bass
Increased average summer temperature	•Altered community composition •Increased vegetation growth rates •Changes in reproduction – protracted spawning season •Increased mortality (fishkills) •Increased algal blooms •Habitat degradation	Florida gar, Bowfin, Gizzard shad, Threadfin shad, Centrarchidae, Ictaluridae Bulrush, *Nuphar*, Pondweed, *Vallisneria*

Spring Run Stream Continued

Shift	Consequence	Example Species
Increased minimum winter/spring temperatures (warmer)	•Increased range, abundance and diversity of exotic species (e.g., Blue tilapia, Brown hoplo, Mayan chichlid, Asian swamp eel) • Increased growth rates •Habitat degradation – increase in invasive plant range and density (*Hydrilla*, Water hyacinth, Water lettuce) •Habitat loss •Changes in reproductive cycle, earlier spawning (temp dependent species) •Changes in extent of habitat (*Hydrilla*) •Change in species composition – euryhaline species moving upstream	Waterfowl Common snook, Red drum, Flounder, Gulf sturgeon, Centrarchidae, Cyprinidae
Changes in water chemistry	•Shifts in pH •Increased growth of invasive plant species (*Hydrilla*) •Increased epiphytic growth/decreased health of host plants	Submerged aquatic vegetation, *Vallisneria americana*, Illinois pondweed

6.3.3 FRESHWATER MARSH AND WET PRAIRIE

Freshwater Marsh and Wet Prairie

FNAI types: Basin Marsh, Coastal Interdunal Swale, Depression Marsh, Marl Prairie, Wet Prairie, Floodplain Marsh, Sough, Swale

Habitat Description:

These wetland communities are dominated by a wide assortment of herbaceous plant species growing on sand, clay, marl, and organic soils in areas of variable water depths and inundation regimes. Generally, Freshwater Marsh habitat occurs in deeper, more strongly inundated situations and is characterized by tall emergent and floating-leaved species. Freshwater Marshes occur within flatwoods depressions, along broad, shallow lake and river shorelines, and scattered in open areas within hardwood, Dry Prairie, and Cypress Swamps. Portions of freshwater lakes, rivers, and canals that are dominated by floating-leaved plants such as lotus, spatterdock, duckweed, and water hyacinths are included in this category. Freshwater Marshes are common features of many river deltas, such as the

Escambia, Apalachicola and Choctawhatchee, where these rivers discharge into estuaries. Wet Prairies commonly occur in shallow, periodically inundated areas and are usually dominated by aquatic grasses, sedges, and their associates. Wet Prairies occur as scattered, shallow depressions within Dry Prairie and flatwoods habitat and on marl prairie areas in south Florida. Areas in southwest Florida with scattered dwarf cypress having less than 20% canopy coverage and a dense ground cover of freshwater marsh plants are also included in this category. Various combinations of pickerel weed, sawgrass, maidencane, arrowhead, fire flag, cattail, spike rush, bulrush, white water lily, water shield, and various sedges dominate Freshwater Marshes and Wet Prairies. Many subcategories of this habitat, such as sawgrass marsh or maidencane prairie, have been described and named based on their dominant plant species.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 2,941,170 acres (1,190,249 ha) of Freshwater Marsh and Wet Prairie habitat exist (Figure 6.15), of which 67% (1,959,950 ac; 793,164 ha) are in existing conservation or managed areas. Another 5% (145,462 ac; 58,866 ha) are in Florida Forever projects and 7% (200,677 ac; 81,211 ha) are in SHCA-designated lands. The remaining 21% (635,081 ac; 257,008 ha) are other private lands.

Climate Change Status (SLR):

Ranked in middle third of evaluated communities (SIVVA Score: 0.7 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value. Placing it 14th in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience significant* declines due to SLR, with as much as 1,637,679 acres (~51% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.13. However, it is possible that at least some of the projected loses of this habitat could actually migrate with SLR.

Table 6.13. Acreage calculations for Marsh and Wet Prairie and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	3,223,812	2,405,444	818,368
1 Meter SLR	625,983 (19.42%)	607,264 (25.25%)	18,719 (2.29%)
3 Meter SLR	1,011,696 (31.38%)	976,033 (40.58%)	35,664 (4.36%)

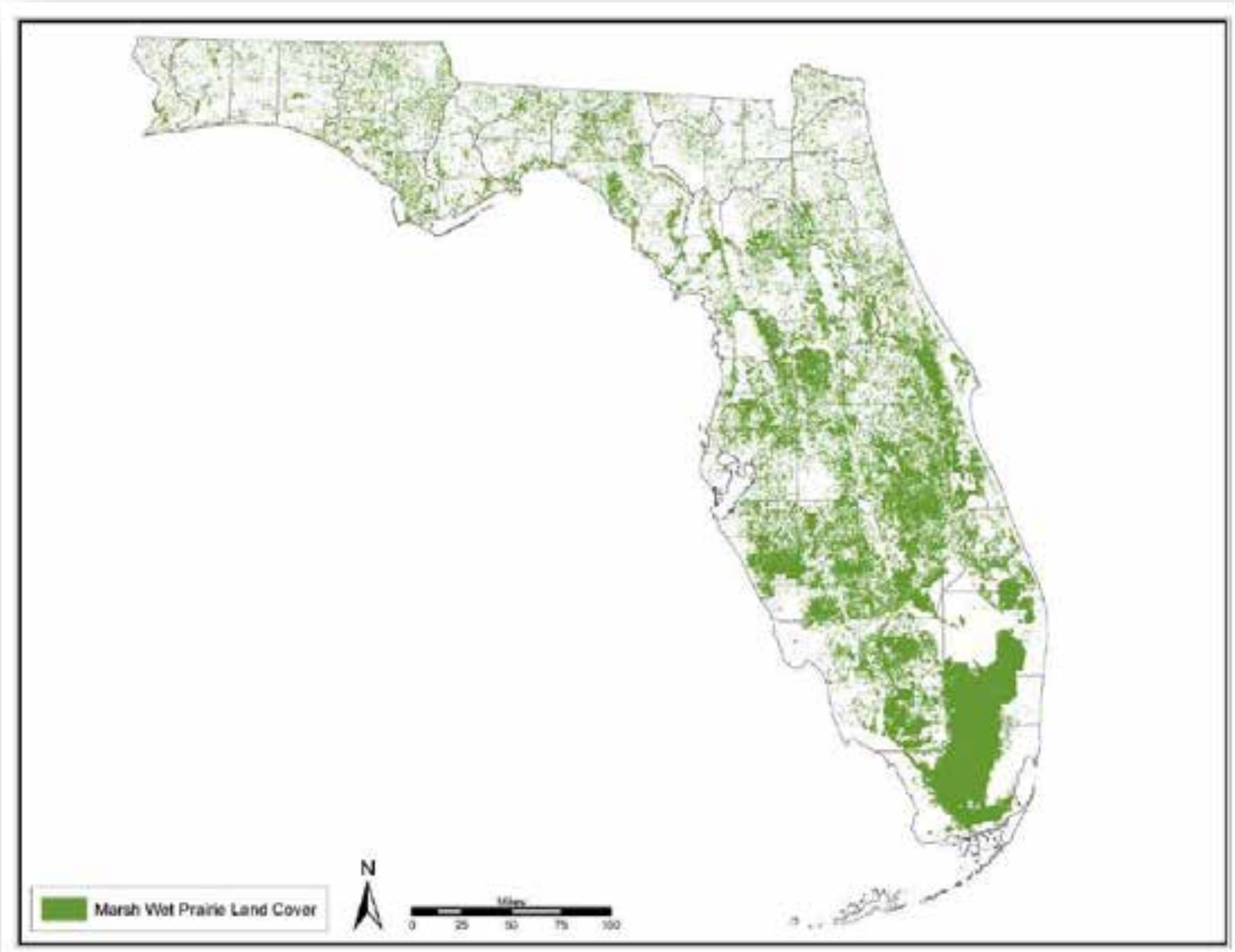


Figure 6.13. This map shows the locations and extent of Marsh and Wet Prairie land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

<u>Measurable Climatic Shifts:</u>

Changes in precipitation frequency, intensity and timing, increased temperatures, increased storm intensity, SLR

<u>Ecological Consequences:</u>

Altered community composition, dynamics and structure, changes in phenology and physiology of plant and animal species, habitat loss and degradation, increased mortality of plant and animal species, increased invasive species, decreased reproductive success

Other Threats:

- Conversion to agriculture
- Conversion to housing and urban development
- Groundwater withdrawal
- Incompatible fire
- Incompatible forestry practices
- Incompatible recreational activities
- Incompatible resource extraction–mining/drilling
- **Invasive animals**
- **Invasive plants**
- Nutrient loads–agriculture
- Nutrient loads–urban
- Roads
- Surface water withdrawal and diversion

Freshwater Marsh and Wet Prairie

Shift	Consequence	Example Species
Sea level rise - Inundation	•Altered distribution and extent of habitat •Habitat loss •Habitat degradation	Amphibians
Sea level rise – Salinity shifts	•Altered community structure or composition •Habitat degradation •Habitat loss	Halosensitive species
Flood	•Altered community structure or composition – introduction of fish into isolated wetlands •Altered community structure or composition – salinity increase due to flooding from storm surge •Increased mortality •Decreased reproductive success •Increased runoff/pollution •Habitat degradation	Sandhill crane, Wading birds Alligator, Amphibians Fish

Freshwater Marsh and Wet Prairie Continued

Shift	Consequence	Example Species
Longer dry periods / Drought	•Altered distribution and extent of habitat - hardwood and pine (woody species) encroachment •Altered community dynamics – trophic structure changes •Increased mortality •Increased in invasive nonnative plants •Reduced reproductive success •Habitat loss	Wading birds Flatwoods salamander, Bog frog, Striped newt, Gopher frog Fish Panama City crayfish, invertebrates s
Increased average summer temperature	•Reduced reproductive success •Habitat degradation (water temperature increase) •Habitat loss (evaporation)	Amphibians Fish
Increased intensity of storms	•Increased runoff/pollution •Increased mortality	Birds Amphibians Fish

6.3.4 NATURAL LAKE

Natural Lake

FNAI types: Clastic Upland Lake, Sandhill Lake, Sinkhole Lake

Habitat Description:

Florida has approximately 7,800 Natural Lakes with a surface area of one acre (0.4 ha) or more. Very few of these lakes were formed by riverine processes. However, the great majority were formed or enlarged by dissolution of the underlying limestone by acidic surface waters. Slumping of the overburden resulted in a surface depression. Most Natural Lakes in Florida retain an intimate connection with groundwater, and lack a natural surface outflow. They may be connected to aquatic caves by underground fissures or bedding planes, and thus provide additional habitat for animal species found in those subterranean habitats, or they may have bottom substrates of silt or sand. Most of these lakes have highly variable water levels.

Despite their origin, many Florida lakes are not alkaline, and are vulnerable to acidification. They also commonly are nutrient-deficient, thus are vulnerable to nutrient inputs.

Florida's lakes are usually less than 45 feet (14 m) deep, with sand, silt, or organic bottom substrates. Depending on the water chemistry, vegetation in the lakes can vary from nonexistent, to a fringe of emergent plants at the shoreline, to a complete covering of floating plants. Indeed, introduced aquatic weeds are a major threat to this habitat. Some Florida lakes have held water continuously for 8,000 years, and two exceed 30,000 years in age.

Conservation Status:

Current condition: Good and declining. According to the SWAP, 1,510,216 acres (611,163 ha) of Natural Lake habitat exist.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in frequency, intensity and timing of precipitation, increased temperatures

Ecological Consequences:

Altered community structure, composition and phenology, increased invasive species, increased mortality, decreased reproductive success, habitat loss and degradation

Other Threats:

- Chemicals and toxins
- Conversion to agriculture
- Conversion to commercial/industrial development
- Conversion to housing and urban development
- Groundwater withdrawal
- Incompatible recreational activities
- **Invasive animals**
- **Invasive plants**
- **Nutrient loads–agriculture**
- **Nutrient loads–urban**
- **Surface water withdrawal and diversion**

"Florida lakes, particularly those in the northern areas, are likely to undergo significant changes with climatic warming. Warming will shift the warm temperate lakes of north Florida to subtropical conditions, resulting in a reduction in length of mixing, an increase in productivity and nutrient cycling rates, simplification and reduction of the macrozooplankton community, and an increase in protozoa and bacteria. Management problems caused by blooms of the blue-green alga *Microcystis*, and by growths of the exotic macrophyte *Hydrilla verticillata*, primarily confined to the subtropical lakes, would expand northwards with a similar shift in subtropical conditions. Many of the native, temperate fish species will be lost and replaced with exotic, subtropical species, as has occurred in southern Florida."

Mulholland *et al*. 1997

Natural Lake

Shift	Consequence	Example Species
Decreased rainfall / Longer dry periods / Drought	•Increased abundance, prevalence and diversity of aquatic parasites •Increased periods of lake bed exposure •Reduced littoral zone flushing •Increased cyanobacteria blooms and cyanotoxin concentrations •Increased mortality (fishkills) •Increased invasive plants (e.g., *Hydrilla*, *Melaleuca*) •Decreased detritus decomposition •Altered community dynamics – trophic structure changes	Wading birds, Waterfowl American eel, sportfish Invertebrates
Increased rainfall / Flood	•Increased runoff •Increase in pollutants •Increased nutrient and sediment loading •Reduced reproductive success •Habitat degradation •Habitat loss	Alligator, Amphibians Fish

Natural Lake Cont'd

Change in timing of rainfall	•Phenological mismatches – Phytoplankton and zooplankton •Altered pest and disease outbreaks (including HAB) (e.g., *Aphanizomenon*, *Cylindrospermopsis*, *Microcystis*)	Forage fish *Daphnia* Diatoms
Increased average summer temperature	•Altered sex ratios •Altered community structure or composition •Altered extent/range of habitat •Increased parasite loads •Altered parasite composition •Increased aquatic plant growth rates •Protracted spawning season •Increased mortality (fishkills) •Increased range of HAB species (e.g., *Cylindrospermopsis raciborskii*) •Altered community dynamics (food web) •Increased prevalence of disease (Chytridiomycosis)	Alligator Common carp, Largemouth bass, Florida gar, Bowfin, Gizzard shad, Bluegill, Threadfin shad, Black crappie, Striped bass Mayflies *Hydrilla*, Bulrush, *Nuphar*

6.3.5 PONDS

Ponds

FNAI types: None.

Habitat Description:

Permanent depressions of freshwater that are isolated from the remainder of the hydrologic system.

Conservation Status:

Unknown.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in frequency, intensity and timing of precipitation, changes in water chemistry, increased temperatures, increased storm intensity

Ecological Consequences:

Altered community structure, composition and phenology, increased, pest outbreaks and disease, increased mortality, decreased reproductive success, habitat loss and degradation

Other Threats:

Not evaluated in the SWAP

Ponds

Shift	Consequence	Example Species
Longer dry periods / Drought	Altered pest and disease outbreaks (including HAB) (e.g., *Aphanizomenon, Cylindrospermopsis, Microcystis)*	
Change in timing of precipitation	•Altered phenological processes (mismatches)	*Culicoides*
Increased intensity of storms	•Habitat degradation •Increased runoff and pollution	
Increased average summer temperature	•Altered disease and pest outbreaks – host and vectors in close contact (West Nile Virus, St. Louis Encephalitis, *Culex nigripalpus*)	Birds
Changes in water chemistry – lowered pH	•Changes in growth and reproduction •Decreased survival	Barking treefrog, Pinewoods treefrog

6.3.6 RESERVOIR/IMPOUNDMENTS

Reservoir/Managed Lake

FNAI types: None

Habitat Description:

This habitat category consists exclusively of man-made standing water bodies, each created by the damming of a flowing stream or excavation within a terrestrial habitat. These landscape features range from farm ponds and borrow pits of less than one acre (0.4 ha) to municipal reservoirs of more than 30,000 acres (12,141 ha). Reservoir/Managed Lake habitats are essentially permanent, although some of them dry completely during droughts.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 601,902 acres (243,581 ha) of Reservoir/Managed Lake habitat exist.

Climate Change Status (SLR):

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in frequency, intensity and timing of precipitation, increasing temperatures and changes in temperature extremes

Ecological Consequences:

Altered community structure, composition and phenology, altered fire regime, changes in water quality, changes in invasive and introduced species, increased pest outbreaks and disease, habitat loss and degradation

Other Threats:

- Chemicals and toxins
- Incompatible forestry practices
- Incompatible recreational activities
- Invasive animals
- Invasive plants
- Nutrient loads–agriculture
- Nutrient loads–urban

Reservoir\Impoundment

Shift	Consequence	Example Species
Decreased rainfall / Longer dry periods / Drought	•Increased abundance, prevalence and diversity of aquatic parasites •Increased periods of lake bed exposure •Increased cyanobacteria blooms and cyanotoxin concentrations •Reduced littoral zone flushing •Increased mortality (fishkills) •Increased invasive plants (e.g., *Hydrilla*, *Melaleuca*) •Altered fire regime – lake bed •Reduced flow\discharge	Wading birds, Waterfowl American eel, sportfish,
Flood	•Reduced reproductive success •Habitat degradation •Habitat loss	Alligator, Amphibians Fish
Increased average summer temperature	•Altered community composition •Altered extent/range of habitat •Increased parasite loads •Altered parasite composition •Increased aquatic plant growth rates (e.g., *Hydrilla*) •Protracted spawning season •Increased mortality (fishkills) •Increased range of HAB species (e.g., *Cylindrospermopsis raciborskii*) •Increased abundance, prevalence and diversity of invasive species •Increased prevalence of disease (e.g., *Chytridiomycosis*)	Largemouth bass, Florida gar, Bowfin, Bluegill, Black crappie, Striped bass, Alosines Bulrush, *Nuphar*
Changes in temperature extremes	•Increased mortality •Reduction of exotic species (e.g., Sailfin catfish, Corbicula clams) •Altered community composition	
Change in timing of precipitation	•Altered pest and disease outbreaks (including HAB) (e.g., *Aphanizomenon, Cylindrospermopsis, Microcystis)* •Altered phenological processes (mismatches)	

6.3.7 CALCAREOUS STREAM

Calcareous Stream

FNAI type: Spring-run Stream

Habitat Description:

The Calcareous Stream habitat occurs only in the north and central regions of the state and is comprised of 26 streams originating in or flowing through the Ocala Uplift region of north central Florida and the eastern panhandle, and the Dougherty Plain (Dougherty Karst) region in the central panhandle. Springs and spring runs form low-order tributaries to most of the Calcareous Streams. As a result, Calcareous Streams share many characteristics with the Springs and Spring Run habitats.

This habitat typically has a high pH, high carbonate level, and sand bottom with some limestone exposed. Most Calcareous Streams are clear and cool, although in areas where they flow through pinelands or scrub the streams will become stained by the tannins in the vegetation. Some Calcareous Streams are associated with sinks, where all or sections of the stream flow underground before resurfacing to flow overland. Surface and groundwater recharge is bidirectional; water in the river recharges the aquifer during flood conditions and the water in the aquifer recharges the river during drought conditions. Submerged plants are frequently dense, and can include tape grass, wild rice, and giant cutgrass. Calcareous Streams provide habitat to a variety of species including many snails, water snakes, and fish, and is critical to certain species of anadromous fish, such as Gulf Sturgeon. Examples of streams in this category include the Suwannee River (downstream of the Big Shoals), Santa Fe River (downstream of the Big Rise), Ichetucknee, lower Withlacoochee (north) and Alapaha Rivers, Chipola River, Econfina Creek, Ocklawaha River, Hillsborough River and the lower, nontidal portions of most of the rivers draining into the Big Bend region on Florida's Gulf coast from the St. Marks River to the Waccasassa River.

Conservation Status:

Current condition: Good and declining. According to the SWAP, there are approximately 2,071 miles (3,332 km) of Calcareous Streams in Florida.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in intensity and frequency of precipitation, changes in water chemistry, increased storm intensity, increased temperatures

Ecological Consequences:

Altered community composition (reductions in native species, expansions of nonnatives), changes in phenology and physiology of aquatic life, various impacts on wildlife and habitat due to changes in water chemistry (e.g. sedimentation and nutrients)

Other Threats:

- Chemicals and toxins
- Conversion to housing and urban development
- Incompatible forestry practices
- Incompatible resource extraction: mining/drilling
- Invasive animals
- **Invasive plants**
- **Nutrient loads–agriculture**
- **Nutrient loads–urban**
- Road

Calcareous Stream

Shift	Consequence	Example Species
Longer dry periods / Drought	•Increase in abundance, prevalence and diversity of aquatic parasites •Altered community composition - changes in species composition of macroinvertebrates •Habitat fragmentation – loss of connectivity •Altered fire regime - riparian zone	American eel, Okaloosa darter, Blackmouth shiner, Bluenose shiner Macroinvertebrates
Flood	•Change in abiotic resource – loss of stored organic carbon - streambed scouring •Increased habitat quality – importation of woody debris	Invertebrates
Increased intensity of storms	•Increased runoff and sediment transport •Increase in extent of habitat due to increased precipitation during storm events	Shoal bass
Increased average summer temperature	•Altered community composition •Altered extent/range of habitat •Increased parasite loads •Altered parasite composition •Increased aquatic plant growth rates •Protracted spawning season •Increased mortality (fishkills) •Increased range of HAB species •Increased prevalence of disease (e.g., Chytridiomycosis)	Largemouth bass, Florida gar, Bowfin, Gizzard shad, Threadfin shad, Black crappie, American shad, Striped bass, Centrarchidae, *Hydrilla*, Bulrush, *Nuphar*, *Vallisneria*
Changes in temperature extremes	•Increased mortality •Reduction of exotic species (e.g., sailfin catfish) •Altered community composition	Striped bass

Calcareous Stream Cont'd

Changes in water chemistry (e.g., pH, DO)	•Shifts in pH •Increased growth of invasive plant species (e.g., *Hydrilla*) •Increased epiphytic growth/decreased health of host plants	Submerged aquatic vegetation, *Vallisneria americana*, Illinois pondweed
Increased minimum winter/spring temperatures (warmer)	•Increased range, abundance and diversity of exotic species (e.g., Blue tilapia, Brown hoplo, Mayan chichlid, Asian swamp eel) • Increased growth rates •Habitat degradation – increase in invasive plant range and density (e.g., *Hydrilla*, Water hyacinth, Water lettuce) •Habitat loss •Changes in reproductive cycle, earlier spawning (temp dependent species) •Changes in extent of habitat (*Hydrilla)* •Change in species composition – euryhaline species moving upstream	Waterfowl Gulf sturgeon, Centrarchidae, Cyprinidae

6.3.8 SOFTWATER STREAMS

Softwater Streams

FNAI types: Blackwater Stream

Habitat Description:

Typical Softwater Streams originate from sandy flats containing broad wetlands which collect rainfall and slowly release water into the stream. This habitat category has water with low pH, low carbonate, that may be stained by tannins and humic acids filtered from the drainage of swamps and marshes. The flow rate is usually gentle in smaller streams to moderate in larger, but is altogether influenced by seasonal local rainfall. These streams typically have sand or silt bottoms with varying amounts of aquatic vegetation. Plants include golden club, smartweed, sedges, and grasses. Softwater Streams differ from Alluvial Streams by having high, steep banks, and by lacking extensive floodplains and natural levees. This habitat is well distributed throughout Florida, except in the regions of north and central Florida dominated by Calcareous Streams, and in the Everglades/Big Cypress region of south Florida, where wetlands and coastal streams dominate the aquatic landscape. Most of the streams in this category are small natural streams originating in pinelands or swamps or small natural segments of otherwise channelized streams in south central Florida. Smaller Softwater Stream examples include Big Coldwater Creek, Pine Barren Creek, Big Escambia Creek, and Big Sweetwater Creek. Large Softwater Stream examples include the Blackwater, Wacasassa, Yellow, Perdido, Econfina, Aucilla, Sopchoppy, St. Mary's, or Ochlockonee rivers.

Conservation Status:

Current condition: Variable by size. Large Softwater Streams were considered good and declining, but small Softwater Streams were judged poor and declining. According to the SWAP, 19,401 miles (31,223 km) Softwater Stream habitat exists.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, increased average temperature, increased storm intensity

Ecological Consequences:

Altered fire regime, altered community structure and composition, increased disease and parasitism, decreased reproductive success, habitat change and shifts (expansion, fragmentation or loss)

Other Threats:

- Chemicals and toxins
- Conversion to agriculture
- Conversion to commercial/industrial development
- Conversion to housing and urban development
- **Groundwater withdrawal**
- Incompatible recreational activities
- Incompatible forestry practices
- Incompatible resource extraction–mining/drilling
- Invasive animals
- Invasive plants
- Nutrient loads–agriculture
- Nutrient loads–urban
- Roads
- **Surface water withdrawal and diversion**

Softwater Stream

Shift	Consequence	Example Species
Decreased rainfall / Longer dry periods / Drought	•Increase in abundance, prevalence and diversity of aquatic parasites •Altered community composition - changes in species composition of macroinvertebrates •Habitat fragmentation – loss of connectivity •Altered fire regime - riparian zone	American eel, Okaloosa darter, Blackmouth shiner, Bluenose shiner Macroinvertebrates,
Flood	•Change in abiotic resource – loss of stored organic carbon due to streambed scouring •Increased habitat quality – importation of woody debris	Invertebrates
Increased average summer temperature	•Increased parasite loads •Altered parasite composition •Habitat degradation – increased algal blooms •Increased mortality events (fish kills) •Altered growth/reproduction – protracted spawning season •Increased growth rates of aquatic vegetation •Community shifts from sportfish to rough fish •Increased prevalance of disease (Chytridiomycosis)	Largemouth bass, Florida gar, Bowfin, Gizzard shad, Threadfin shad, Black crappie, American shad, Striped bass, Centrarchidae *Hydrilla*, Bulrush, *Nuphar*, *Vallisneria*
Increased intensity of storms	•Increase in extent of habitat due to increased precipitation during storm events	Macroinvertebrates, Okaloosa darter

6.3.9 EPHEMERAL PONDS/WETLANDS

Ephemeral Ponds and Wetlands

FNAI types: None.

Habitat Description:

These depressions or wetland areas are wet only seasonally or in wet years. Therefore, it is difficult to determine the locations and characteristics of these communities across a landscape. This habitat type is not described or evaluated in the State Wildlife Action Plan.

Conservation Status:

Unknown.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in precipitation frequency, intensity and timing, increased temperatures

Ecological Consequences:

Altered community composition and structure, changes in phenology and physiology of plant and animal species, increased mortality of plant and animal species, decreased reproductivity and altered breeding phenology

Other Threats:

Not evaluated in the SWAP.

Ephemeral Ponds\Wetlands

Shift	Consequence	Example Species
Longer dry periods / Drought	•Habitat degradation •Habitat loss •Mortality •Reduced reproductive success •Altered community structure – woody encroachment	Flatwoods salamander, Gopher frog, Striped newt, Bog frog Panama City crayfish
Increased rainfall / Longer wet periods / Flood	•Altered community composition addition of predators (fish) •Increased mortality •Decreased reproductive success •Increased frequency of flooding events – transportation of fish to previously fishless ponds •Changes in predator prey relationships •Reduced reproductive success	Flatwoods salamander, frogs, salamanders
Change in timing of rainfall	•Changes in hydrology – timing of life cycle events (phenology)	Flatwoods salamander Panama City crayfish
Increased average summer temperature	•Habitat degradation/loss (warmer water temperatures/increased evaporation)	Frogs, salamanders

6.3.10 COASTAL TIDAL RIVER OR STREAM

Coastal Tidal River or Stream

FNAI types: None

Habitat Description:

Coastal Tidal River or Stream habitat includes the freshwater or brackish portions of a river or stream adjacent to an estuary or marine habitat in which the effects of tides cause the rise and fall of water levels. The effect of the tides at the upper limits of influence may lag several hours behind tides on the coast. The amount of water movement is controlled by the height of the tides, tidal range, downstream freshwater flow rates, rainfall, and wind. Saltwater wedges are formed in many of these systems, enabling numerous species a mechanism to move up or down river. Water flow is bidirectional in coastal tidal rivers and streams; as the tide rises, water flows toward the head of the river and, as the tide retreats, the water flows toward the coastal outlet. This habitat bridges the freshwater and marine realms, with aquatic communities ranging from tidal freshwater to tidal brackish; salinities can vary from freshwater to approximately that of seawater. This variation, along with temperature and water clarity, determines the flora and fauna of the Coastal Tidal River or Stream. Typical plants may include cord grass or submerged aquatic vegetation such as seagrasses and algae.

The Coastal Tidal River or Stream drains to the Gulf of Mexico or the Atlantic Ocean on Florida's entire coast and comprises the dominant stream habitat in the south Florida region. The longest or most extensive area of this habitat occurs in the lower St. Johns River. Other coastal bay systems such as Choctawhatchee Bay, Pensacola Bay, Tampa Bay, and Charlotte Harbor are also included in this habitat. Numerous small tidal creeks and coastal rivers are also included, especially in the Big Bend region of Florida's Gulf coast along with the lower portions of other large rivers including the Suwannee and Escambia.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, the combined total length of all of Florida's Coastal Tidal River or Stream is approximately 6,088 miles (9,798 km).

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in intensity and frequency of precipitation, changes in flood frequency and extent, increased storm intensity, SLR

Ecological Consequences:

Altered community composition, changes in the chemistry, phenology, and dynamics of flowing water, habitat loss, degradation, and fragmentation for some species, various impacts on wildlife and habitat due to changes in water chemistry (e.g. sedimentation, nutrients and salinity)

Other Threats:

- Channel modification/shipping lanes
- **Chemicals and toxins**
- Coastal Development
- Conversion to commercial/industrial development
- Conversion to housing and urban development
- Dam operations/incompatible release of water (quality, quantity, timing)
- Fishing gear impacts
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible recreational activities
- Incompatible resource extraction: mining/drilling
- Industrial spills
- Invasive animals
- Invasive plants
- Management of nature (beach nourishment and impoundments)
- **Nutrient loads–agriculture**
- **Nutrient loads–urban**
- Roads, bridges and causeways
- **Shoreline hardening**
- **Surface water and groundwater withdrawal**
- Vessel impacts

Coastal Tidal River or Stream

Shift	Consequence	Example Species
Drought	•Impacts to groundwater table •Reduced flow •Altered patterns of sedimentation •Habitat loss •Habitat degradation •Habitat fragmentation •Altered concentration of chemicals in runoff •Altered distribution of chemicals from runoff •Reduced surface runoff •Altered community composition	Fish
Changes in flood frequency or extent	•Changes in amount/timing of flow/runoff	
Increased intensity of storms	•Changes in surface runoff	
Sea level rise – Salinity shift	•Increased mortality	*Vallisneria americana*
Sea level rise - Inundation	•Altered community composition •Habitat degradation •Habitat loss	Suwannee bass

6.4 COASTAL, MARINE AND ESTUARINE HABITATS

Climatic Shift- Changes in Temperature Extremes

Ecological Consequences:

- Increased mortality of corals, manatees and other marine species due to water temperature fluctuations with extreme cold and hot temperatures
- Increased summer temperatures
  - Increased mortality due to increased infections by white pox disease and increased cyanobacteria blooms
  - Increased coral mortality due to loss of coral zooxanthellae and bleaching
  - Earlier physiological developments and larval release in plankton
  - Expansion of harmful algal bloom season and persistence
  - Increased fish kills due to less dissolved oxygen in the water
  - Altered development, hatching success and sex ratio in sea turtles due to increased sand temperature
  - Altered distribution of prey items due to changes in inshore water temperatures
  - Increased mortality due to increased infections by white pox disease and increased cyanobacteria blooms
  - Increased coral mortality due to loss of coral zooxanthellae and bleaching
  - Earlier physiological developments and larval release in plankton
- Minimum winter temperatures increase
  - Increased local extirpations of species at the southern extent of their range
  - Expansion of harmful algal blooms season and persistence
- Minimum winter temperatures decrease
  - Increased mortality of cold temperature sensitive species
  - Increased occurrence and severity of cold kill events
  - Limit northern extent of exotic species range (+)

Climatic Shift- Increased Storm Intensity

Ecological Consequences:

- Alteration of longshore transport process
- Decreased stability of systems and/or shift to more transitional communities
- Increased breaches of coastal areas leading to alterations in storm buffering due to (and leading to) changes in erosion patterns
- Increased runoff into coastal waters with increased flood frequency & storm intensity
- Increased mortality due to direct effects of storms
- Reduced recruitment due to habitat destruction as a result of storm damage
- Reduction or expansion of range by those species at the extremes of their range due to altered predator-prey interactions and resource quality
- Decreased genetic diversity due to habitat fragmentation and degradation and phenology changes leading to fragmented populations and reduction of effective population size
- Disruption of the interspecies dynamics due to varying spatial and temporal changes

Climatic Shift- Intensification of Hydrological Cycle

Ecological Consequences:

- Floods
  - Altered sediment build-up patterns in coastal marshes and estuaries
  - Habitat degradation at various temporal and spatial scales due to changes in the frequency and intensity of weather events
  - Reduced nesting grounds for sea turtles due to loss of barrier islands
  - Loss of habitat integrity due to issues such as sediment transport
  - Altered physical conditions of habitat creating barriers to species – leading to habitat fragmentation
  - Altered recruitment success of inshore species due to fluctuations in salinity levels in nursery areas close to shore
- longer wet periods
  - Increased mortality of larval stages of nearshore fish and invertebrate species due to salinity decrease as freshwater flows increase
  - Altered runoff and buffering ability of the system
- Droughts
  - Altered distribution of species due to increased inshore salinity levels as freshwater inflow is reduced
  - Alteration of distribution of habitats due to decreased freshwater input into inshore waters
  - Reduced effectiveness of dune stabilizing plants leading to increased erosion
  - Altered salinity levels and seasonal salinity profiles due to changes in the amount of freshwater entering coastal systems
  - Altered chemical concentrations in runoff
  - Altered water temperatures - varying in relation to proximity to source of runoff
  - Increased of pollutants in runoff due to lack of regular flushing of build-up
  - Altered patterns and loss of sediment build-up due to changes in runoff driven sedimentation rates and flow patterns
  - Reduction in habitat quality and area (volume) due to reduced stream flow
  - Reduced surface water runoff
  - Altered interactions between species that depend on seasonal availability of resources due to changes in the seasonality of wet/dry conditions
- Longer dry periods
  - Increased mortality of vegetation and larval stages of fish and invertebrates due to increased salinity as fresh water flows decrease
  - Increased risk of disease and mortality due to increased osmotic stress on less tolerant euryhaline species
- Increased Rainfall
  - Nearshore vegetation mortality increase due to salinity decrease as freshwater flows increase
  - Increased morality of larval stages of nearshore fish and invertebrate species due to salinity decrease as freshwater flows increase

- Increased coral mortality due to decreased light penetration (increased turbidity) as freshwater flows increase
    - Increased coral mortality due to increased nutrient loads from agricultural and urban areas as runoff increases (overgrowth of macroalgae)
    - Increased coral mortality due to disease outbreaks as runoff increases
    - Increase in frequency/severity of harmful algal blooms
- Decreased Rainfall
    - Reduced reproductive success in birds due to decreased availability of arthropods
    - Decreased freshwater flow and runoff into coastal systems
    - Decreased nursery and juvenile habitat
- Timing of precipitation
    - Increased mortality of vegetation and larval stages of fish and invertebrates due to increased salinity as water chemistry in bays and estuaries change
    - Altered predator/prey interactions due to changes in timing of migration

Climatic Shift- Salinity Shifts

Ecological Consequences:

- Increased habitat for species with broad osmoregulatory adaptations

Climatic Shift- Changes in Water Chemistry

Ecological Consequences:

- Changes in contribution of $CaCO_3$ expelled by fish
- Decreased coral reef health/productivity due to slowed calcification as ocean acidification increases
- Decreased shellfish production due to reduced carbonate ions as increased atmospheric CO_2 is absorbed at the ocean surface
- Decreased health/productivity of organisms that produce calcium carbonate due to reduced ocean carbonate-saturation as CO_2 increases
- Increased growth rate and earlier reproduction of mangroves due to high CO_2 (experimental lab project) under certain salinity levels (+)
- Decreased larval growth and reduced live settlement of coral when exposed to increased CO_2 in the atmosphere (experimentally tested)
- Increased biomass (above and below ground) of seagrass beds due to increased CO_2 (experimental study) (+)
- Decreased coral reef recruitment processes (fertilization, settlement, and post-settlement growth) due to increased atmospheric CO_2
- Increased mortality (events) in corals and shell-forming organisms due to decreased carbonate as CO_2 increases
- Increased plant growth (seagrasses) due to increased photosynthetic capacity

6.4.1 BAYS/INLETS/OPEN OCEAN

Inlet

FNAI type: None

Habitat Description:

Inlets are natural or man-made cuts in the shoreline that link coastal and inland water bodies. This habitat is defined as the subtidal area within a two-kilometer radius of the central part (i.e., throat) of the Inlet. These features tend to be hot spots of biodiversity and are critical in the recruitment of many fish and invertebrate species. Inlets provide habitat for the settling larvae from coastal areas and provide an emigration conduit for outgoing juveniles. They also are essential spawning habitat for several marine fishes.

Conservation Status:

Current condition: Unknown. Due to the lack of sufficient map data for this habitat category, no acreage estimates are currently available.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Increased temperatures, changes in intensity and frequency of precipitation, increased storm intensity

Ecological Consequences:

Changes in phenology and physiology of aquatic life, algal blooms and mortality associated with eutrophication, various impacts on wildlife and habitat due to changes in water chemistry (e.g. pH, sedimentation, and salinity)

Other Threats:

- Channel modification/shipping lanes
- Coastal development
- Dam operations/incompatible release of water (quality, quantity, timing)
- **Disruption of longshore transport of sediments**
- Fishing gear impacts
- **Harmful algal blooms**
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible recreational activities
- Industrial spills
- Invasive animals
- Invasive plants

Pelagic (Open Ocean)

FNAI type: None

Habitat Description:

The Pelagic environment includes the waters lying over the continental shelf (neritic zone) and waters beyond the continental shelf. The Pelagic community lives in the water column above the seafloor and below the surface. This community does not depend on the seabed, although its members may visit it occasionally. The community consists of free-swimming creatures known as nekton and less- or non-motile plankton.

In Florida, this environment extends three nautical miles off of the Florida east coast and nine nautical miles off of the Florida Gulf coast. Maximum depths vary from approximately 30 feet (9 m) in the Gulf of Mexico to more than 1,000 feet (304 m) off of the Florida Keys and southeast Florida.

Conservation Status:

Current condition: Unknown. Due to the lack of sufficient map data for this habitat category, no acreage estimates are currently available.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Increased temperatures, changes in intensity and frequency of precipitation, increased storm intensity

Ecological Consequences:

Changes in phenology and physiology of sea life, blooms and mortality associated with eutrophication, various impacts on wildlife and habitat due to changes in water chemistry (e.g. sedimentation and salinity), ocean circulation

Other Threats:

- Channel modification/shipping lanes
- Harmful algal blooms
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible wildlife and fisheries management strategies
- Invasive animals
- Key predator/herbivore loss
- Nutrient loads-urban

Bays/Inlets/Open Ocean

Shift	Consequence	Example Species
Increased precipitation	•Increased nutrient loads from runoff •Increased Harmful Algal Blooms (e.g., *Pyrodinium bahamense*) •Increased mortality	
Increased average summer temperature	Increased sea surface temperature leading to: •Changes in physical development •Changes in physiological processes •Phenological shifts and mismatches	Plankton (meroplankton, holozooplankton)
Drought	•Altered water temperatures •Increased salinity •Changes in chemical concentrations from runoff •Altered patterns of sedimentation •Altered distribution patterns of species •Habitat fragmentation •Habitat degradation	Oyster reefs
Flood	•Altered sediment transport •Decreased salinity	
Increased intensity of storms	•Altered longshore sediment transport •Habitat fragmentation •Habitat degradation	

6.4.2 BEACH/SURF ZONE

Beach/Surf Zone

FNAI type: Beach Dune

Habitat Description:

The Beach/Surf Zone is the long, often narrow strip of sand and shells between the tides. Daily flooding by salt water and moderate- to high-energy waves prohibit plant growth except for some inconspicuous algae. Low-energy beaches provide important spawning habitat for horseshoe crabs and feeding habitat for multiple species of shorebirds. Beach dunes are mounds of wind-blown sand that are periodically inundated by seawater during extreme high tides and storms. Vegetation on beach dunes varies regionally in Florida but is restricted to a few highly specialized terrestrial plants.

Florida beaches are important nesting sites for several species of shorebirds and wintering grounds for others. Beaches are also vital nesting sites for many sea turtles and support numerous other mammals and invertebrates. The surf zone is an important nursery and feeding habitat for many species of fish including permit and Florida pompano.

Conservation Status:

Current condition: Good and declining. According to the SWAP, 32,295 acres (13,069 ha) of Beach/Surf Zone habitat exist (Figure 6.16), of which 46% (14,858 ac; 6,013 ha) are in existing conservation or managed areas. Another 1% (312 ac; 126 ha) are Florida Forever projects and 5% (1,473 ac; 596 ha) are SHCA-identified lands. The remaining 48% (15,652 ac; 6,334 ha) are other private lands.

Climate Change Status:

Ranked in middle third of evaluated communities (SIVVA Score: 0.7 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value, placing it 18th in relation to the 30 coastal communities examined in Florida. According to an analysis of current land cover data, this habitat type is projected to experience severe declines due to SLR, with as much as 10,358 acres (~42% of the total for this habitat) lost with three meters of SLR. However, some of this habitat will likely be able to migrate with SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.14.

Table 6.14. Acreage calculations for Beach/Surf Zone and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	24,642	20,556	4,086
1 Meter SLR	5,024 (20.39%)	4,092 (19.91%)	933 (22.83%)
3 Meter SLR	5,334 (21.65%)	5,051 (24.57%)	283 (6.93%)

Figure 6.14. This map shows the locations and extent of Beach/Surf Zone land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

<u>Measurable Climatic Shifts:</u>

Changes in intensity and frequency of precipitation, increased storm intensity, SLR

<u>Ecological Consequences:</u>

Habitat loss, degradation or migration due to geomorphological changes or SLR, population declines or translocation of many species

<u>Other Threats</u>:

- **Channel modification/shipping lanes**
- Chemicals and toxins
- Coastal development
- Incompatible recreational activities
- Invasive animals
- **Shoreline hardening**

Beach/Surf Zone

Climatic Shift	Ecological Consequence	Example Species
Sea level rise - Inundation	• Erosion • Distribution of habitat • Loss of habitat • Reduced populations	Shorebirds Diamondback terrapin, Cedar key mole skink, sea turtles Beach mice
Increased intensity of storms	• Spread of invasive species • Loss of habitat/habitat degradation	Species dependent upon trees/vegetation for nesting/refugia
Flood	• Increased mortality • Altered community structure • Change in population trends	

6.4.3 COASTAL STRAND

Coastal Strand

FNAI types: Beach Dune, Coastal Berm, Coastal Grassland, Coastal Rock Barren, Coastal Strand

Habitat Description:

This habitat encompasses dunes and more landward areas typically described as coastal strand, as well as areas that may be described as upper beach and coastal rock formations. Coastal Strand is the vegetated zone that typically occurs between open beach and maritime hammock habitats. Coastal Strand occurs on deep, well-drained, sandy soils that are largely wind-deposited and washed or sorted by wave action to some extent. This habitat generally occurs in long, narrow bands along high-energy shorelines, parallel to the open waters of the Atlantic Ocean, Gulf of Mexico, and some coastal bays or sounds in both north and south Florida. Vegetation in this habitat is strongly affected by wind, wave action, and salt spray and consists of low-growing vines, grasses, and other herbaceous plants and salt-tolerant shrub species that, in some areas, may form dense thickets. Pioneer or early successional herbaceous vegetation characterizes foredune and upper beach areas with a gradual change to woody shrub species on the more protected and stabilized areas farther landward. Typical plant species of Coastal Strand include beach morning glory, railroad vine, sea oats, saw palmetto, Spanish bayonet, yaupon holly, wax myrtle, and sea grape; in southern Florida, cocoplum, nickerbean, and other more tropical species are present.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 14,855 acres (6,012 ha) of Coastal Strand habitat exist (Figure 6.17), of which 76% (11,317 ac; 4,580 ha) are in conservation or managed areas. Another 1% (90 ac; 36 ha) are in Florida Forever projects and 3% (471 ac; 191 ha) are in SHCA-designated lands. The remaining 20% (2,977 ac; 1,205 ha) are other private lands.

Climate Change Status:

Ranked in middle third of evaluated communities (SIVVA Score: 0.7 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value, placing it 15th in relation to the 30 coastal communities examined in Florida. This habitat type is projected to experience severe declines due to SLR, with as much as 5,006 acres (~75% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.15.

Table 6.15. Acreage calculations for Coastal Strand and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	6,688	6,185	503
1 Meter SLR	2,134 (31.91%)	1,835 (29.67%)	299 (59.44%)
3 Meter SLR	2,872 (42.94%)	2,775 (44.87%)	98 (19.48%)

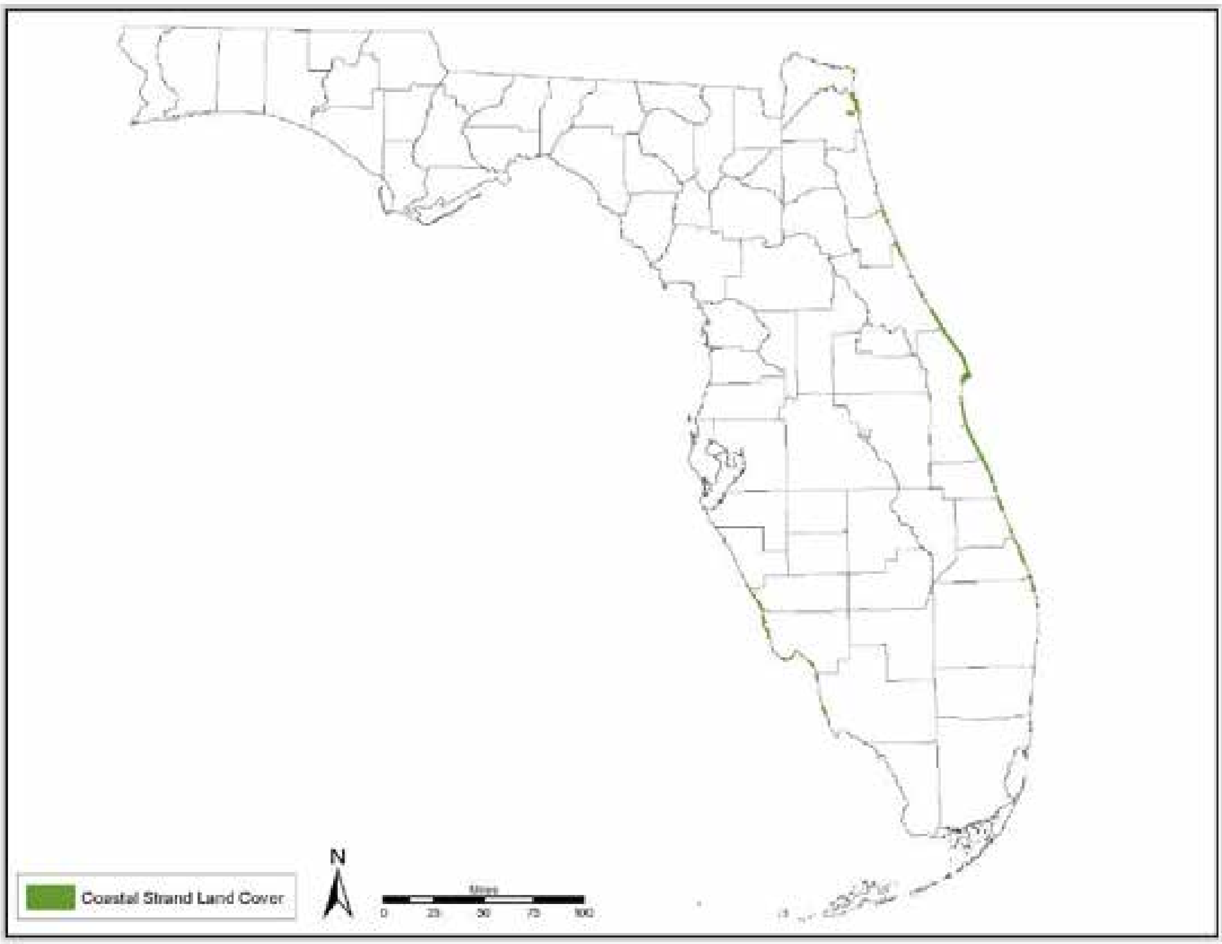


Figure 6.15. This map shows the locations and extent of Coastal Strand land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in intensity and frequency of precipitation, increased storm intensity, SLR

Ecological Consequences:

Altered community composition (reductions in native species, expansions of nonnatives), loss, degradation or migration of important species habitat due to SLR and other changes, other habitat or community declines due to geomorphological changes

Other Threats:

- Conversion to housing and urban development
- Conversion to recreation areas
- Incompatible fire
- Incompatible recreational activities
- **Invasive animals**
- **Invasive plants**
- Roads
- **Shoreline hardening**

Coastal Strand

Shift	Consequence	Example Species
Sea level rise - Inundation	• Erosion •Distribution of habitat •Loss of habitat •Reduced populations	Shorebirds Diamond back terrapin, Cedar key mole skink, sea turtles Beach mice
Increased intensity of storms	•Spread of invasive species •Loss of habitat/habitat degradation	Species dependent upon trees/vegetation for nesting/refugia
Flood	•Increased mortality •Altered community structure •Change in population trends	

"SEAWALLS IMPACT LOGGERHEAD SEA TURTLE NESTING BY REDUCING NESTING SUCCESS AND INCREASING THE LIKELIHOOD OF NESTS BEING WASHED AWAY DURING STORM EVENTS."

Rizkalla and Savage 2011

THE MEDIAN DATE OF LOGGERHEAD NESTING OCCURRED 10 DAYS EARLIER, THE JULIEN DAY OF NESTING WAS FOUND TO BE SIGNIFICANTLY CORRELATED WITH NEAR-SHORE SEA SURFACE TEMPERATURES.

Weishampel *et al*. 2004

6.4.4 SALT MARSH

Salt Marsh

FNAI types: Tidal Marsh

Habitat Description:

Salt Marsh is vegetated almost completely by herbaceous plants, primarily grasses, sedges, and rushes. This community type occurs within the intertidal zone of coastal areas and may be infrequently (high marsh) to frequently (low marsh) inundated by salt or brackish water. Salt Marsh develops where wave energies are low and where mangroves are absent. Mangroves may extirpate shade-intolerant marsh species. The size of a Salt Marsh depends on the extent of the intertidal zone in which it occurs. Salt Marshes of larger sizes are usually dissected by numerous tidal creeks. Areas that have low topographic relief and relatively high tidal ranges are likely to have larger Salt Marsh extents. Within Salt Marsh, plant species are often distributed unevenly, especially in transitional areas. Species distributions are affected by biotic and abiotic variables such as elevation, substrate type, degree of slope, wave energy, competing species, and salinity. Smooth cordgrass typically occupies the lower elevations and is usually adjacent to tidal creeks and pools. Needlerush dominates the slightly less frequently inundated zone. Vegetation at the higher elevations forms transitional areas to uplands and may contain species such as marsh-hay, glassworts, saltwort, saltgrass, sea ox-eye daises, marsh-elder, and saltbush as well as many other species.

The Salt Marsh habitat is among the most productive communities in the world. Primary production is greatly affected by soil salinity and tidal frequency. Salt Marshes vary in extent and species composition throughout Florida and support diverse local faunas.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 442,577 acres (179,105 ha) of Salt Marsh habitat exist (Figure 6.18), of which 71% (316,033 ac; 127,894 ha) are in conservation or managed areas. Another 6% (26,740 ac; 10,821 ha) are in Florida Forever projects and 8% (33,222 ac; 13,444 ha) are in SHCA-designated lands. The remaining 15% (66,582 ac; 26,945 ha) are other private lands.

Climate Change Status:

Ranked in final third of evaluated communities (SIVVA Score: 0.6 - 0.7). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value, placing it 22nd in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience severe declines due to SLR, with as much as 331,911 acres (~88% of the total for this habitat) projected to be lost with three meters of SLR, however, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.16.

Table 6.16. Acreage calculations for Salt Marsh and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	377,875	315,462	62,413
1 Meter SLR	315,500 (83.49%)	269,026 (85.28%)	46,474 (74.46%)
3 Meter SLR	16,411 (4.34%)	9,934 (3.15%)	6,476 (10.38%)

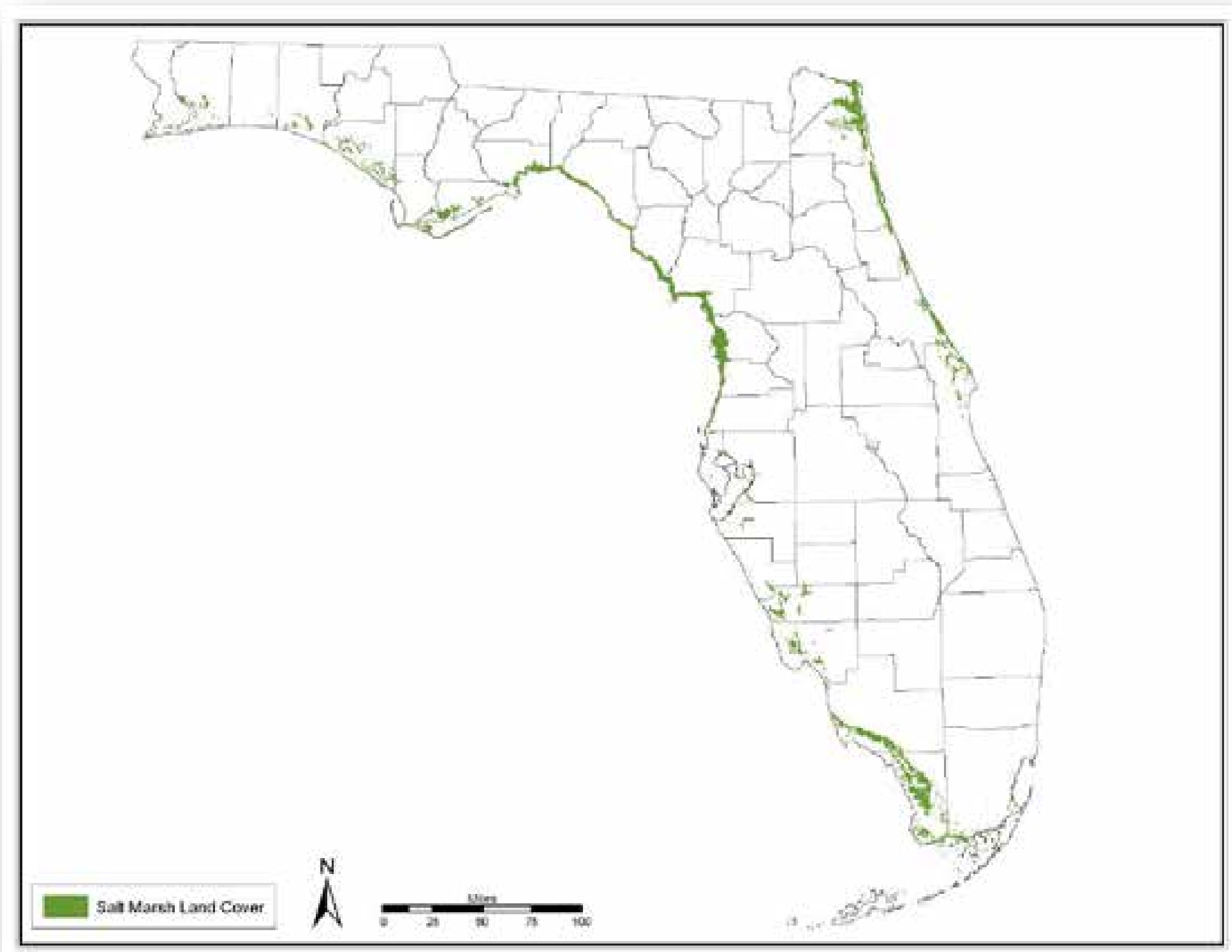


Figure 6.16. This map shows the locations and extent of Salt Marsh land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Altered water chemistry, changes in frequency and intensity of precipitation, SLR

Ecological Consequences:

Altered community structure and composition, changes in water quality, increased mortality, decreased reproductive success, habitat loss and degradation

Other Threats:

- Channel modification/shipping lanes
- **Chemicals and toxins**
- Coastal development
- Dam operations/incompatible release of water (quality, quantity, timing)
- Disruption of longshore transport of sediments
- Incompatible industrial operations
- Incompatible wildlife and fisheries management strategies
- Invasive plants
- Industrial spills
- Management of nature (beach nourishment and impoundments)
- Military activities
- Roads, bridges and causeways
- Shoreline hardening
- Surface water and groundwater withdrawal
- Vessel impacts

Salt Marsh

Shift	Consequence	Example Species
Sea level rise – Inundation	•Loss of nesting habitat •Increased mortality •Habitat loss •Habitat fragmentation •Reduced prey availability •Change in habitat extent	Seaside sparrows, Marsh wrens, Rails, Wading birds Diamondback terrapin, Atlantic salt marsh snake, Crocodile Salt marsh vole
Sea level rise- Salinity shift	•Loss of habitat •Altered community composition	Seaside sparrows, Wading birds Atlantic salt marsh snake Mink, Salt marsh vole

Salt Marsh Continued

Shift	Consequence	Example Species
Decreased precipitation / Longer dry periods	•Reduced reproductive success •Reduced prey availability Decreased freshwater input leading to increased salinity and: •Increased mortality of aquatic vegetation •Increased mortality of larval stages	Seaside sparrows, Marsh wrens Fish Crustaceans, Mollusks, Echinoderms, Polychaetes
Increased precipitation / Longer wet periods	•Increased pollution from runoff Decreased salinity leading to: •Decreased recruitment •Increased mortality of aquatic vegetation •Increased mortality of larval stages	Fish Crustaceans, Mollusks, Echinoderms, Polychaetes
Altered water chemistry (e.g., pH, DO)	Increased CO_2 leading to: •Increased growth	*Spartina alterniflora*

6.4.5 MANGROVE

Mangrove Swamp

FNAI types: Tidal Swamp

Habitat Description:

Mangroves form dense, brackish-water swamps along low-energy shorelines and in protected, tidally influenced bays of southern Florida. This community type is composed of freeze-sensitive tree species and, with some limited exceptions, mangroves which are distributed south of Cedar Key on the Gulf coast and south of St. Augustine on the Atlantic coast. These swamp communities are usually composed of red mangrove, black mangrove, and white mangrove. Depending on slopes and amounts of disturbance, mangrove swamps may progress in zones of single species from seaward (red mangrove) to landward (white mangrove) areas. Buttonwoods usually occur in areas above high tide. Often vines, such as rubber vines and morning-glory, climb over mangroves, especially at swamp edges.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 588,434 acres (238,131 ha) of Mangrove Swamp habitat exist (Figure 6.19), of which 88% (515,783 ac; 208,730 ha) are in existing conservation or managed areas. Another 2% (10,376 ac; 4,199 ha) are in Florida Forever projects and 3% (16,997 ac; 6,878 ha) are in SHCA-designated lands. The remaining 7% (45,278 ac; 18,323 ha) are other private lands.

Climate Change Status:

Ranked in final third of evaluated communities (SIVVA Score: 0.7 – 0.8). The SIVVA report evaluated this habitat type's vulnerability, ecosystem status, and conservation value, placing it 21st in relation to 30 coastal communities examined in Florida. This habitat type is projected to experience severe declines due to SLR, with as much as 540,679 acres (~88% of the total for this habitat) projected to be lost with three meters of SLR, however, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR . The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.17.

Table 6.17. Acreage calculations for Mangrove and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	613,137	583,445	29,691
1 Meter SLR	539,840 (88.05%)	518,758 (88.91%)	21,083 (71.01%)
3 Meter SLR	839 (0.14%)	535 (0.09%)	304 (1.02%)

A REDUCTION IN EXTREME COLD EVENTS HAS ALLOWED MANGROVES TO EXPAND NORTHWARD.

Cavanaugh *et al*. 2014

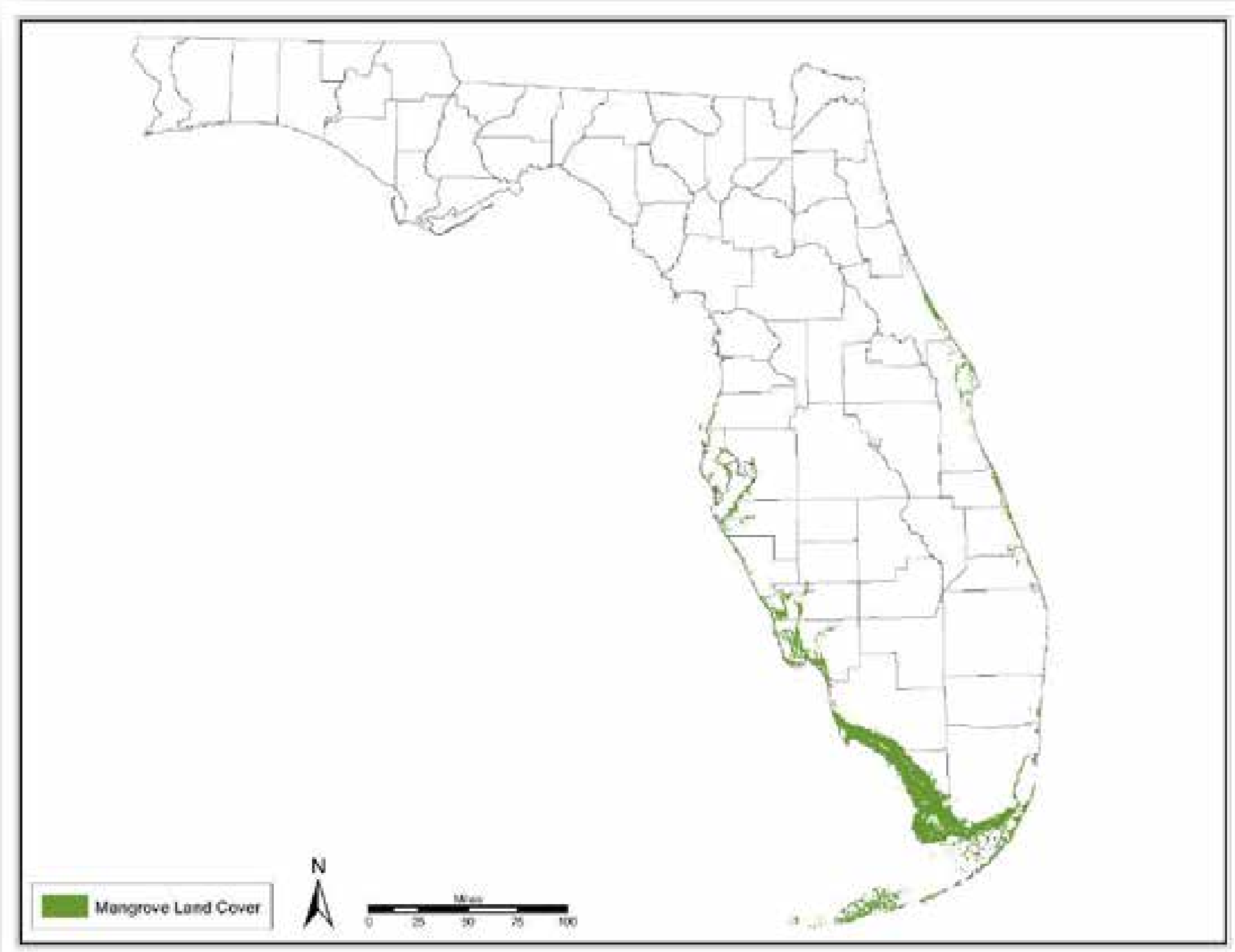


Figure 6.17. This map shows the locations and extent of Mangrove land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Altered water chemistry, changes in frequency, intensity and timing of precipitation, increased storm intensity, SLR

Ecological Consequences:

Changes in water quality and biotic community, increased mortality, decreased recruitment, habitat loss and degradation

Other Threats:

- Channel modification/shipping lanes
- Chemicals and toxins
- Coastal development

- Dam operations/incompatible release of water (quality, quantity, timing)
- Fishing gear impacts
- Harmful algal blooms
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible recreational activities
- Incompatible wildlife and fisheries management strategies
- Industrial Spills
- Invasive animals
- Invasive plants
- Management of nature (beach nourishment and impoundments)
- Nutrient loads–urban
- Roads, bridges and causeways
- Shoreline hardening
- Surface water and groundwater withdrawal
- Vessel impacts

Mangrove

Shift	Consequence	Example Species
Increased intensity of storms	•Habitat degradation	Wading birds, White crowned pigeon, Mangrove cuckoo
Sea Level Rise – Inundation	•Reduced availability of prey species •Loss of nesting habitat •Loss of nursery habitat •Shift in spatial distribution	Wading birds, White crowned pigeon, Mangrove cuckoo Atlantic salt marsh snake, American crocodile Fish
Decreased precipitation / Longer dry periods	Increased salinity leading to: •Shifts in species range •Decreased recruitment •Increased mortality	American crocodile Fish Crustaceans, Mollusks, Echinoderms, Polychaetes
Increased precipitation / Longer wet periods	Decreased salinity leading to: •Decreased recruitment •Increased mortality	Fish Crustaceans, Mollusks, Echinoderms, Polychaetes
Changes in water chemistry (e.g., pH, DO)	Increased CO_2 leading to: •Increased growth rate •Earlier reproduction	Mangroves
Changes in timing of precipitation	Altered water chemistry affecting: •Reproduction •Survival of larvae	

6.4.6 BIVALVE REEF

Bivalve Reef

FNAI type: Mollusk Reef

Habitat Description: This habitat is comprised of dense, expansive concentrations of sessile mollusks that attach to hard substrates and each other. Bivalve Reefs occur in both intertidal and subtidal zones to depths of 40 feet (12 m). In Florida the most extensive examples of this habitat, dominated by oysters, are restricted to estuarine environments where salinity concentrations range from 15 to 30 parts per thousand. Events or processes that alter freshwater deliveries to estuaries are detrimental to this habitat. The Bivalve Reef habitat is a diverse ecological community that provides nursery grounds, refugia, and foraging areas to a wide variety of wildlife species.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, approximately 13,586 acres (5,498 ha) of oyster reef (a subtype of Bivalve Reef habitat) are accurately mapped. However, spatial data are lacking for most oyster and other Bivalve Reefs.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in intensity and frequency of precipitation, changes in water chemistry

Ecological Consequences:

Changes in physiology of sea life, blooms and mortality associated with eutrophication, various impacts on wildlife and habitat due to changes in water chemistry (e.g. sedimentation and salinity)

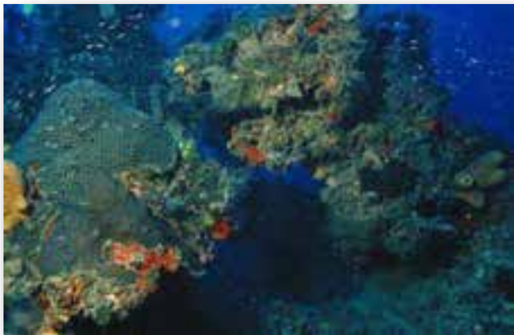
Other Threats:

- Channel modification/shipping lanes
- Coastal development
- **Dam operations/incompatible release of water (quality, quantity, timing)**
- Harmful algal blooms
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible recreational activities
- Incompatible wildlife and fisheries management strategies
- Invasive animals
- Management of nature (beach nourishment and impoundments)
- **Nutrient loads–urban**
- Roads, bridges and causeways
- Surface water and groundwater withdrawal

Bivalve Reef

Shift	Consequence	Example Species
Drought	•Altered patterns of sedimentation •Increased salinity •Changes in concentration and distribution of chemicals in runoff	
Flood	•Altered patterns of sedimentation •Decreased salinity – affects recruitment success •Habitat degradation	
Changes in water chemistry (e.g., pH, DO)	Changes in physiological processes	Shell-forming organisms

6.4.7 CORAL REEF



> "CLIMATE CHANGE IMPACTS THREATEN CORAL REEF ECOSYSTEMS THROUGH INCREASED MASS CORAL AND DISEASE, SEA LEVEL RISE, AND STORM ACTIVITY. ADDITIONALLY, INCREASING ATMOSPHERIC CARBON DIOXIDE HAS ALREADY BEGUN TO REDUCE CALCIFICATION RATES IN REEF-BUILDING AND REEF-ASSOCIATED ORGANISMS BY ALTERING SEA WATER CHEMISTRY THROUGH DECREASES IN PH (OCEAN ACIDIFICATION). IN THE LONG TERM, FAILURE TO ADDRESS THE IMPACTS OF RISING TEMPERATURES AND OCEAN ACIDIFICATION COULD MAKE MANY OTHER MANAGEMENT EFFORTS FUTILE."
>
> NOAA Coral Reef Conservation Program 2009

FNAI types: Coral Reef

Habitat Description: A Coral Reef is an epibenthic community; a concentrated topographic complex of massive corals and other sessile organisms (algae, bryozoans) that build calcium carbonate (limestone) skeletons. The structural complexity provides habitat for a highly diverse flora and fauna that live all or portions of their lives on Coral Reefs.

Two major Coral Reef types are recognized: patch reefs and offshore bank reefs. Bank Reefs are further defined by zones (e.g., reef flat, spur and groove). The types of Coral Reefs found off the coast of Florida include the shallow-wave resistant reefs in the region from Dry Tortugas to Martin County; deeper (30-130 ft; 10-40 m) reefs in the same region; the Oculina Banks seaward of Palm Beach to Vero Beach. Deep water (165-265 ft; 50-80 m) structures such as Pulley Ridge and the Florida Middle Grounds occur along the west Florida shelf break in federal waters.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, approximately 1,400,000 acres (566,560 ha) of Coral Reef are present in Florida.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in water chemistry, changes in precipitation frequency and intensity, increased temperatures and temperature extremes, SLR.

Ecological Consequences:

Increased disease, mortality and stress for a variety of plants and animals due to water temperature and chemistry changes, altered community composition, decline in biodiversity, habitat loss, degradation, and fragmentation for some species

Other Threats:

- Channel modification/shipping lanes
- **Chemicals and toxins**
- Coastal development
- **Dam operations/incompatible release of water (quality, quantity, timing)**
- **Disruption of longshore transport of sediments**
- Fishing gear impacts
- Harmful algal blooms
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible recreational activities
- Incompatible resource extraction: mining/drilling
- Industrial spills
- Invasive plants
- **Key predator/herbivore loss**
- Management of nature (beach nourishment and impoundments)
- **Nutrient loads (urban)**
- Roads, bridges and causeways
- **Shoreline hardening**
- Vessel impacts

Coral Reef

Shift	Consequence	Example Species
Sea level rise - Inundation	• Increased mortality events	Corals
Increased rainfall	Increased runoff leading to: •Increased nutrients •Increased turbidity •Increased disease outbreaks •Increased algal growth •Increased mortality	Corals Reef dependent species
Increased average summer temperatures	•Increased harmful cyanobacteria, microalgal and marcroalgal blooms •Increased loss of coral zooanthellae and bleaching •Increased disease (white pox)	Sea fans (*Gorgonia* spp) *Monastrea, Acropora palmata*
Changes in temperature extremes	• Increased stress on plants and animals •Increased mortality	*Montastraea faveolata, Montastraea cavernosa, Porites astreoides*
Changes in water chemistry (e.g., pH, DO)	Increased CO_2 leading to: •Decreased recruitment processes •Increased mortality •Reduced growth and live settlement •Reduced coral diversity and abundance	Anthozoa *Acropora palmata, Porites asteroides*
Drought	•Increased pollutant build-up •Habitat degradation/fragmentation •Increased salinity	

> "WHILE MITIGATING THE RATE OF CLIMATE CHANGE WILL LARGELY DEPEND ON REDIRECTING NATIONAL AND INTERNATIONAL POLICIES ON GREENHOUSE GAS EMISSIONS, THE ABILITY FOR CORAL REEFS TO SURVIVE CLIMATE CHANGE REQUIRES ENHANCING RESILIENCE THROUGH LOCAL MANAGEMENT ACTIONS."
>
> NOAA Coral Reef Conservation Program 2009

6.4.8 SUBMERGED AQUATIC VEGETATION

Seagrass

FNAI types: Algal Bed, Seagrass Bed, Composite Substrate

Habitat Description:

Seagrasses are marine flowering plants adapted to grow and reproduce in the underwater environment. Florida estuaries and nearshore coastal waters contain the nation's largest seagrass resources (more than two-million acres), as well as its two most extensive, contiguous seagrass beds (i.e., Florida Bay and the Big Bend region). Factors that affect the establishment and growth of seagrass include light availability, water temperature, salinity, sediment composition, nutrient levels, wave energy, and tidal range. Seagrass most often occurs in areas of low to moderate current velocities where the water is clear; thereby allowing sunlight to penetrate to the leaf blades. Seagrass communities are highly productive, faunally rich, and ecologically important systems. Hundreds to thousands of species of flora and fauna may inhabit seagrass habitats utilizing food, substrate, and shelter provided by the plants. Seagrasses also stabilize sediments and help maintain water clarity.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 2,419,458 acres (979,120 ha) of seagrass beds exist.

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system.

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, changes in water chemistry, SLR

Ecological Consequences:

Increased mortality due to water and pollution levels, habitat loss and degradation or shifts in habitat extent

Other Threats:

- Boating impacts
- Channel modification/shipping lanes
- Chemicals and toxins
- Coastal development
- Dam operations/incompatible release of water (quality, quantity, timing)
- Disruption of longshore transport of sediments
- Fishing gear impacts
- Harmful algal blooms
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible recreational activities
- Industrial spills
- Invasive animals
- Invasive plants
- Key predator/herbivore loss
- Management of nature (beach nourishment and impoundments)
- Nutrient loads–urban
- Roads, bridges and causeways
- Shoreline hardening
- Surface water and groundwater withdrawal
- Vessel impacts

Submerged Aquatic Vegetation

Shift	Consequence	Example Species
Sea level rise - Inundation	•Altered sediment transport •Shifts in habitat distribution and extent	*Thalassia, Halimeda* Species dependent upon SAV
Changes in water chemistry (e.g., pH, DO)	Increased CO_2 leading to: •Increased growth	*Zostera*
Decreased precipitation / Longer dry periods	Decreased freshwater input leading to increased salinity and: •Increased mortality of aquatic vegetation •Increased mortality of larval stages	Fish Crustaceans, Mollusks, Echinoderms, Polychaetes
Increased precipitation / Longer wet periods	•Increased pollution from runoff Decreased salinity leading to: •Increased mortality of aquatic vegetation •Increased mortality of larval stages	Fish Crustaceans, Mollusks, Echinoderms, Polychaetes

6.4.9 TIDAL FLAT

Tidal Flat

FNAI types: None

Habitat Description:

Tidal flats are non-vegetated areas of sand or mud protected from wave action and composed primarily of mud transported by tidal channels. An important characteristic of the tidal flat environment is its alternating tidal cycle of submergence and exposure to the atmosphere.

Conservation Status:

Current condition: Poor and declining. According to the SWAP, 442,500 acres (179,073 ha) of Tidal Flat habitat exist (Figure 6.20), of which 71% (316,000 ac; 127,881 ha) are protected in reserves and easements. Another 14% (60,000 ac; 24,281 ha) are proposed for acquisition. The remaining 15% (66,500 ac; 26,912 ha) are other private lands.

Climate Change Status:

A SIVVA score not created. This habitat type is projected to experience sizeable declines due to SLR, with as much as 4,504 acres (~11% of the total for this habitat) projected to be lost with three meters of SLR. The noncumulative values for public and private lands (and both combined) for one and three meters of SLR are included in Table 6.18. However, it is likely that at least some of the projected loses of this habitat could actually migrate with SLR.

Table 6.18. Acreage calculations for Tidal Flat and projected inundations or loses of existing habitat.

	Acres (% Total)		
	Statewide	**Public Lands**	**Private Lands**
Total	42,570	32,719	9,851
1 Meter SLR	4,417 (10.38%)	3,286 (10.04%)	1,131 (11.48%)
3 Meter SLR	87 (0.20%)	42 (0.13%)	45 (0.46%)

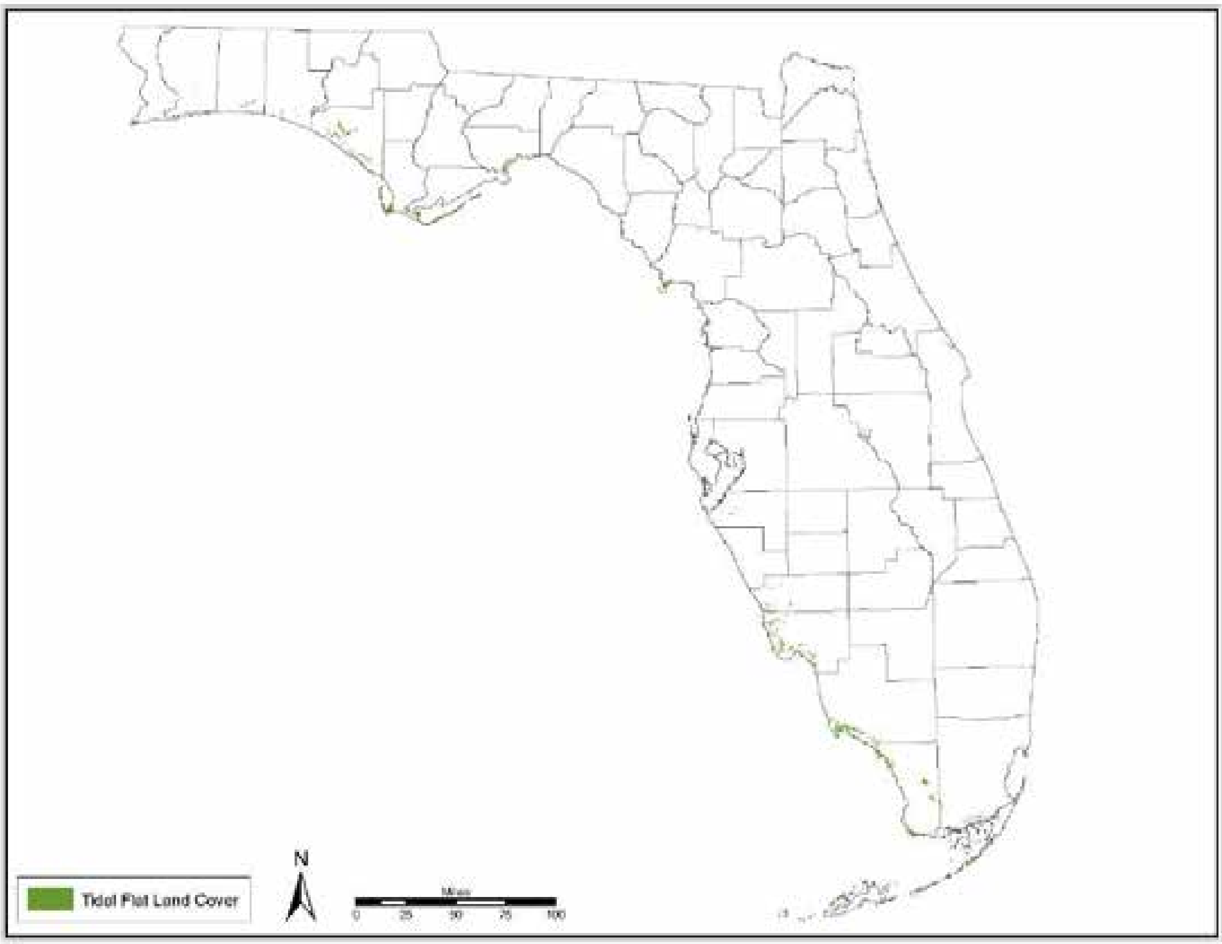


Figure 6.18. This map shows the locations and extent of Tidal Flat land cover across the state. For a map examining the impact of SLR on this community, please consult Appendix 2.

Measurable Climatic Shifts:

Changes in frequency and intensity of precipitation, SLR

Ecological Consequences:

Mortality and reduced prey availability, habitat loss and degradation

Other Threats:

- Channel modification/shipping lanes
- Chemicals and toxins
- Coastal development
- Dam operations/incompatible release of water (quality, quantity, timing)
- Disruption of longshore transport of sediments

- Fishing gear impacts
- Harmful algal blooms
- Incompatible industrial operations
- Incompatible recreational activities
- Industrial spills
- Invasive animals
- Management of nature (beach nourishment and impoundments)
- Roads, bridges and causeways
- Shoreline hardening
- Surface and groundwater withdrawal
- Vessel impacts

Tidal flat

Shift	Consequence	Example Species
Sea level rise - Inundation	•Loss of foraging habitat •Reduced prey availability •Loss of loafing habitat	Shorebirds, Wading birds, Migratory birds
Changes in precipitation	•Altered sedimentation patterns	Shorebirds, Wading birds, Migratory birds

6.4.10 HARDBOTTOM

Hardbottom

FNAI types: Consolidated Substrate, Octocoral Bed, Sponge Bed

Habitat Description:

Hard Bottom is characterized as mixed communities of algae, sponges, octocorals and stony corals. This habitat occurs in subtidal, intertidal, and supratidal zones throughout Florida's coastal waters. Hard Bottom is composed of attendant epibenthic biota on a rocky substrate composed of coquina, limestone, or relic coral, molluscan, and annelid reefs. Coquina is a limestone composed of broken shell debris. Limestone rock (many different strata) occurs as high- or low-relief outcrops of calcium carbonate. Relic reefs are the skeletal remains of once-living reefs such as the Vermetid Reef built by worm-like gastropod mollusks, Petaloconchus. These reefs are only known to be found in shallow waters seaward of the outer islands in the Ten Thousand Islands area of southwest Florida.

Hard Bottom biological communities are structured by depth and latitude and inhabited by sessile, planktonic, epifaunal, and pelagic plants and animals; infaunal organisms are present in interstitial soft bottom substrate. In the region south of Stuart on the east coast and Bay Port on the west coast, subtidal hard bottom communities are characteristically inhabited by soft corals (octocorals) and sponges. Octocoral Beds have dense concentrations of sea fans, sea plumes, and sea feathers. Mobile species found in octocoral beds include flamingo tongue shell, purple shrimp, and basket starfish. Sponge beds include the branching, vase, tube, Florida loggerhead, and sheepswool sponges. Other mobile fauna found in both the octocoral beds and the sponge beds include amphipods, isopods, burrowing shrimp, crabs, sand dollars, and many species of fish. Although the coral species found in Hard Bottom habitat are not reef-building, they do contribute to the three-dimensional nature of the areas by increasing the surface area for sessile organisms and by providing important refuges for a variety of fish and invertebrates.

Conservation Status:

Current condition: Poor and declining. Due to the lack of sufficient map data for this habitat category, no acreage estimates are currently available

Climate Change Status:

Unknown. A SIVVA score not created and SLR impact was not calculated, as this is a strictly aquatic system

Measurable Climatic Shifts:

Changes in water chemistry, increased precipitation

Ecological Consequences:

Blooms and mortality associated with eutrophication, various impacts on wildlife and habitat due to changes in water chemistry (e.g. sedimentation and salinity)

Other Threats:

- Channel modification/shipping lanes
- **Chemicals and toxins**
- **Dam operations/incompatible release of water (quality, quantity, timing)**
- Disruption of longshore transport of sediments
- Fishing gear impacts
- **Harmful algal blooms**
- Incompatible fishing pressure
- Incompatible industrial operations
- Incompatible wildlife and fisheries management strategies
- Invasive animals
- Invasive plants
- Key predator/herbivore loss
- Management of nature (beach nourishment and impoundments)
- Roads, bridges and causeways
- Shoreline hardening
- Vessel impacts

Hardbottom

Shift	Consequence	Example Species
Changes in water chemistry (e.g., pH, DO)	•Altered accretion/sedimentation •Changes in physiological processes	Fish Shellfish Bryozoans, Foraminifera
Increased rainfall	Increased runoff leading to: •Increased nutrients •Increased turbidity •Increased algal growth •Increased contaminants	Fish Shellfish Infauna

7 VULNERABILITY ASSESSMENTS

Vulnerability assessments are a fundamental part of climate change adaptation planning and in regards to natural resource planning are commonly done on the species, habitat or species level. Assessing the vulnerability of species or habitats to climate change provides insight into management activities to enhance resiliency and can be used to identify components that are most vulnerable to impending climate change. In general vulnerability will have three elements; exposure, sensitivity and adaptive capacity (Figure 7.1). Evaluation of exposure should include extent and rate of climate change projections, sensitivity will account for the stress of exposure. Climatic factors can impact species in a physiological capacity, such as exceeding heat tolerances. Climatic factors can also influence in an indirect capacity by impacting ecological relationships, including foraging, competition and predator-prey relationships. The adaptive capacity component will account for the ability of a species (or habitat) to tolerate the changing environment (Glick *et al*. 2011). Reducing vulnerability will involve decreasing exposure or sensitivity or enabling increased adaptive capacity.

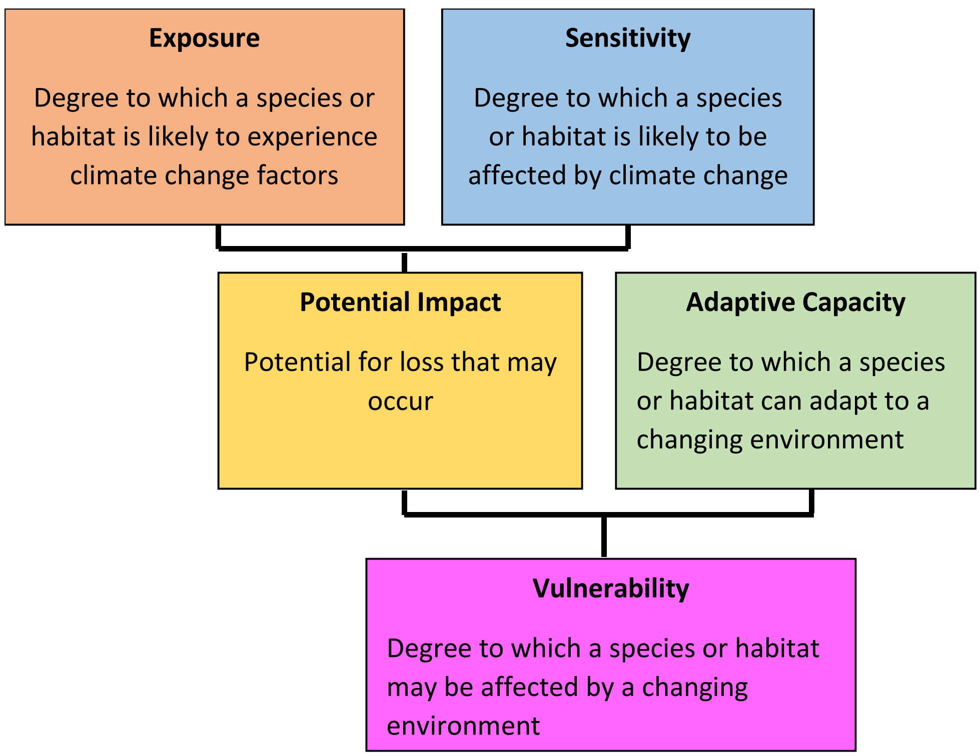


Figure 7.1. Vulnerability assessment framework, definitions modified from Glick et al. 2011.

Vulnerability assessments can be used to prioritize adaptive management activities and response for species that are perceived to be more at risk to maximize use of limited resources (Dubois *et al.* 2011). Vulnerability assessment tools are detailed in Section 10.1, new tools are frequently being developed and research should be undertaken to ensure the tool selected best meets the needed outcomes and represents the information available. Scenarios can be important part of the vulnerability assessment process and are developed to lay a foundation for possible outcomes, based on presumptions that may change, including GHG levels, land development, and technological advances. Scenarios should be used as guidance but not assumed to be an absolute depiction of future conditions. Scenarios and current trends should be utilized to inform the vulnerability assessment process when available and can include sea level rise, downscaled precipitation projections, downscaled temperature projections, water quality trends, tide gauges, river gauges and done at different timescales (sources for scenarios and current trends can be found in Section 10.2.2). The below are summaries of vulnerability assessments that were done in partnership with or funded by FWC and are only examples of the multitude of vulnerability assessment options (for more please see Section 10.1.2). Vulnerability assessments should be used to inform and develop adaptation activities.

Defenders of Wildlife collaborated with FWC to assess 21 species vulnerability using NatureServe's Climate Change Vulnerability Index (CCVI), including many species of greatest conservation need (as categorized by FWC) and a few non-native invasive species. The response of each species to projected changes in precipitation, temperature and SLR to factors such diet, habitat, dispersal ability was evaluated. Figure 41 shows the CCVI scores for the assessed species, and as a group reptiles were evaluated as highly vulnerable. Diamondback terrapin (*Malaclemys terrapin*), Loggerhead sea turtle (*Caretta caretta*), the Atlantic salt marsh snake (*Nerodia clarkia taeniata*), American crocodile (*Crocodylus acutus*), Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) and the Salt marsh skipper (*Panoquina panoquin*) were identified as extremely vulnerable to climate change through the CCVI assessment effort. Of note is the consideration of the various life stages for species being considered, the short-tailed hawk was assessed as "Not Vulnerable/Presumed Stable" when the breeding habitat was considered, but when the winter habitat was evaluated the score was assessed as "Moderately Vulnerable" (Dubois *et al.* 2011). For some species it may be critical to assess vulnerability for various life stages to identify adaptations strategies that are appropriate to the life stage that is most vulnerable and thus identify adaptation activities that would have greatest impact.

An additional assessment process was performed concurrently with CCVI and utilized projections created previously that included SLR, population growth, land and water planning policies, and availability of funding resources resulting in future land-use map products to produce five scenarios which were combined with species-habitat models. Through this "spatially explicit vulnerability analysis" (SEVA), six species were assessed, American Crocodile (*Crocodylus acutus*), Key deer (*Odocoileus virginianus clavium*), Least tern (*Sternula antillarum*), Atlantic salt marsh snake (*Nerodia clarkia taeniata*), Short-tailed hawk (*Buteo brachyurus*) and Florida panther (*Puma concolor coryi*). The habitats of the American crocodile and Key deer were evaluated to be impacted by the projected combinations of SLR and land use changes (Flaxman and Vargas-Moreno 2011).

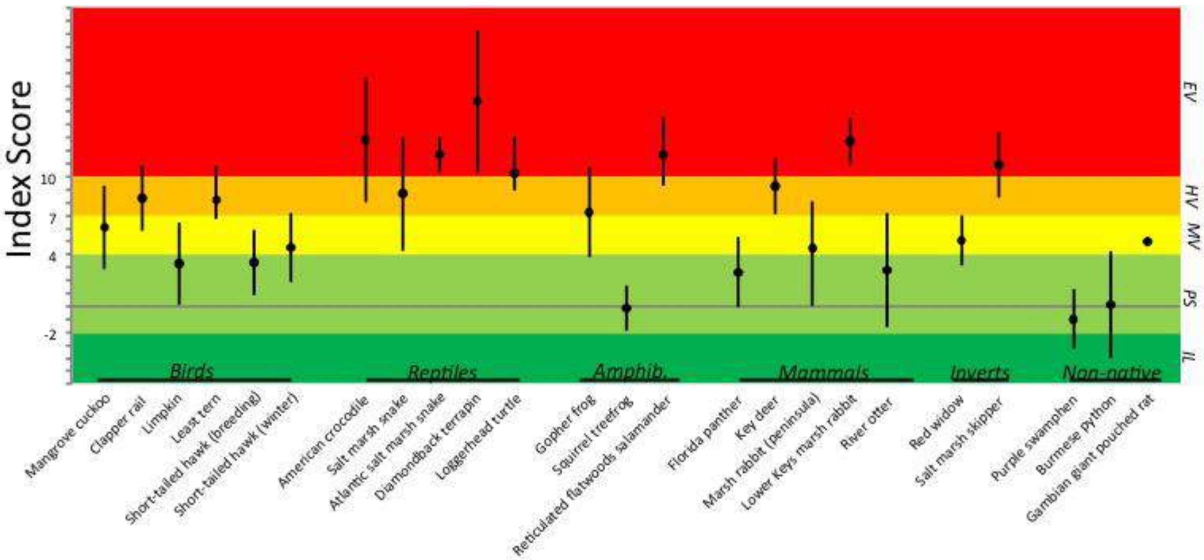


Figure 7.2. CCVI scores of species analyzed. The black circle represents the index score, with the range of score being indicated by the black line emanating from each circle. Categorical colors for the ranks are as follows: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Not Vulnerable/Presumed Stable" (green), "Not Vulnerable/Increase Likely (dark green). Figure from Dubois et al. 2011.

Partially funded through FWC's State Wildlife Grants Program, a Standardized Index for Vulnerability and Value Assessment (SIVVA) spreadsheet-based tool was developed (http://noss.cos.ucf.edu/publications/sivva), with a focus on the impacts of SLR to species evaluated and could incorporate assessments previously performed, such as CCVI. This vulnerability assessment tool was created to gauge vulnerability of 30 variables across four modules, Vulnerability, Lack of Adaptive Capacity, Conservation Value, and Information Availability (Table 7.1). There is flexibility to place emphasis, by use of weighted averages, on one or two modules or to treat each module equally and incorporates uncertainty (Reece and Noss 2014). The SIVVA project evaluated species vulnerability to SLR, changes in projected land-use and climate factors. Species with populations in southern Florida, especially the Keys demonstrated high vulnerability in the SIVVA process (Reece and Noss 2014). Species analyzed included those that were evaluated previously under the study summarized above (Reece and Noss 2014), species where more than 50% of tracked occurrences in the FNAI fell within the area projected to be inundated by 2 m of SLR 2100 and additional species selected by FWC as species of greatest conservation need. Experts identified 10 species likely to be extinct by 2100, shown in Table 7.2 but not all were included in the published SIVVA table (Reece *et al*. 2013). Evaluations included plants and animals, with the results of completed SIVVA studies compiled in Table 7.3 (Reece and Noss 2014, Reece *et al.* 2013). Full SIVVA scores were published for 40 species with seven species being duplicated, resulting in 73 of the species compiled in Table 7.3. Lack of information should not preclude further consideration regarding vulnerability, species such as the Keys scaly cricket (*Cycloptilum irrgularis*), Mangrove long-horned beetle (*Heterachthes sablensis*), and the Antillean spreadwing (*Lestes spumarius*) were all ranked as being at high risk of extinction which were not included in the published SIVVA score table (Reece *et al.* 2013).

The vulnerability of natural communities was also evaluated, using a spreadsheet-based tool, SIVVA-NatCom that evaluates ecosystem status, vulnerability and conservation value of the assessed habitat (Noss *et al*. 2014). The SIVVA-NatCom scores for habitats that were evaluated are available in Figure 7.2, the six habitats determined to be of highest priority were Keys Cactus Barren, Pine Rockland, Rockland. Hammock, Maritime Hammock, Glades Marsh and Keys Tidal Rock Barren. Similar to the species-level SIVVA scores, SIVVA-NatCom evaluations found that natural communities in southern Florida, especially the Keys demonstrated high vulnerability (Noss *et al*. 2014).

Table 7.1. SIVVA modules and assessment criteria included for each module (Reece and Noss 2014).

SIVVA Module	Scoring Criteria
Vulnerability (Exposure + Sensitivity)	1. SLR
	2. Erosion
	3. Barriers to movement
	4. Temperature
	5. Precipitation
	6. Proportion of range protected
	7. Population fragmentation
	8. Increasing salinity
	9. Storm surge or run-off
	10. Biotic interactions
	11. Synergistic threats
	12. Disturbance regime
Adaptive Capacity	1. Migration
	2. Phenotypic plasticity
	3. Genetic diversity
	4. Adaptive Rate (generation time, birth rate, fecundity)
	5. Demographic capacity
	6. Colonization potential
Conservation Value	1. Level of endemism
	2. Disjunct populations
	3. Keystone species
	4. Phylogenetic distinctiveness
	5. Economic value (including ecosystem services)
	6. Federal or State Listing
	7. Probability of recovery
Information Availability	1. Published literature
	2. Demographic/niche models
	3. Population genetic data
	4. Response to SLR
	5. Response to climate change

Table 7.2. Species considered highly likely to be extinct by 2100, under 2 m SLR conditions. Table adapted from Reece and Noss, 2013.

Species	SIVVA VU Score	Primary Threats
Florida grasshopper sparrow *Ammodramus savannarum floridanus*	0.72	Habitat loss, potentially invasive fire ants and/or disease
Miami blue *Cyclargus thomasi bethunebakeri*	0.94	Habitat loss, mosquito control, SLR
Florida duskywing *Ephyriades brunnea floridensis*	0.95	SLR and barriers to migration
Gulf Coast solitary bee *Hesperapis oraria*	0.93	Small range, SLR
Key Deer *Odocoileus virginianus clavium*	0.86	SLR and barriers to dispersal, genetic swamping or competition with mainland deer if moved to mainland
Florida Keys tree snail *Orthalicus reses nesodryas*	0.91	Habitat loss to development, SLR
Key Tree cactus *Pilosocereus robinii*	0.91	Collection, habitat loss, SLR and storm surge
Bartram's scrub-hairstreak *Strymon acis bartrami*	0.91	Invasive ants, small range, habitat degradation
Lower Keys rabbit *Sylvilagus palustris hefneri*	0.90	Lack of freshwater, SLR, barriers to dispersal
Key ringneck snake *Diadophis punctatus acricus*	0.91	SLR and barriers to dispersal, genetic swamping with mainland species if moved

*Table 7.3. Compiled list of species analyzed using SIVVA, showing the individual species scores for Vulnerability (VU), Lack of Adaptive Capacity (LAC), Conservation Value (CV) and Information Availability (IA). Four of the five weighting schemes from Reece et al 2013 are included below 1: 45/25/20/10 percentage weighting averaging for VU, LAC, CV and IA, respectively, 2: 25/25/25/25 weighting, 3: 20/20/50/10 weighting, and 4: 15/15/35/35 weighting. Species are sorted based on their average ranked rating, with color schema being red (most vulnerable), orange, yellow and green (least vulnerable). A color of green does not indicate a species is not vulnerable to climate change, but is less vulnerable than others scored within the table. * Reece and Noss 2014, a Watson et al. 2015, all others are from Noss et al. 2013. *** genus name listed in Noss et al. 2013 is Rana, but in SWAP species is listed as Lithobates*

Species	VU	LAC	CV	IA	Score Ranking Option			
					1	2	3	4
Key deer, *Odocoileus virginianus clavium*	0.87	0.69	0.61	0.73	6	2	3	2
Miami Blue, *Cyclargus thomasi bethunebakeri**	0.94	0.93	0.49	0.63	2	1	7	5
Florida panther, *Puma concolor coryi*	0.73	0.79	0.70	0.67	12	3	2	1
Key tree cactus, *Pilosocereus robinii**	0.91	0.89	0.55	0.51	3	4	5	12
Florida duskywing, *Ephyriades brunnea floridensis**	0.95	0.97	0.67	0.22	1	5	1	19
Mangrove terrapin, *Malaclemys terrapin rhizophorarum**	0.86	0.81	0.48	0.64	9	7	18	11
Loggerhead turtle, *Caretta caretta*	0.72	0.72	0.63	0.74	28	6	9	3
Florida Semaphore Cactus, *Opuntia corallicola**	0.74	0.92	0.55	0.53	15	10	12	14
Florida scrub jay, *Aphelocoma coerulescens**	0.75	0.64	0.62	0.76	33	8	10	4
Whooping crane, *Grus americana**	0.65	0.86	0.66	0.57	34	11	4	8
Keys marsh rabbit, *Sylvilagus palustris hefneri*	0.90	0.54	0.51	0.78	18	12	27	7
Key Largo cotton mouse, *Peromyscus gossypinus allapaticola**	0.72	0.81	0.53	0.69	30	9	17	9
Schaus' Swallowtail, *Heraclides aristodemus ponceanus**	0.89	0.78	0.47	0.53	10	14	24	18
Snail kite, *Rostrhamus sociabilis plumbeus**	0.81	0.55	0.71	0.55	32	18	6	10
Florida tree snail, *Liguus fasciatus**	0.80	0.83	0.57	0.39	17	20	15	24
Truncate, Urocoptid *Cochlodinella poeyana**	0.94	0.92	0.55	0.17	4	22	11	40
Florida grasshopper sparrow, *Ammodramus savannarum floridanus**	0.72	0.90	0.51	0.54	27	14	19	17
Big Pine Partridge Pea, *Chamaecrista lineata keyensis**	0.82	0.89	0.46	0.47	14	17	29	22
Amethyst Hairstreak, *Chlorostrymon maesites**	0.89	0.83	0.64	0.17	8	30	8	36
Snowy plover, *Charadrius alexandrinus nivosus**	0.88	0.64	0.47	0.66	21	16	38	15
Florida Keys Tree Snail, *Orthalicus reses nesodryas**	0.91	0.85	0.57	0.19	7	31	14	42
Perdido Key Beach Mouse, *Peromyscus polionotus trissyllepsis**	0.82	0.51	0.52	0.83	42	13	35	6
Blue Spring Hydrobe Snail, *Aphaostracon asthenes**	0.66	1.00	0.59	0.31	35	23	13	29
Beetle, *Branchus floridanus**	0.89	0.79	0.50	0.35	12	29	26	35
Salt marsh vole, *Microtus pennsylvanicus dukecampbelli**	0.80	0.83	0.50	0.42	23	25	30	27
Cape Sable Thoroughwort, *Eupatorium frustratum**	0.75	0.87	0.53	0.39	31	26	21	28

Keys mudcloak, *Hojeda inaguensis**	0.91	1.00	0.46	0.17	5	27	20	56
Wedge spurge, *Chamaesyce deltoidea serpyllum**	0.82	0.90	0.45	0.39	16	23	36	34
Red-cockaded woodpecker, *Picoides borealis**	0.71	0.73	0.51	0.67	46	18	34	13
Hawskbill turtle, *Eretmochelys imbricata**	0.81	0.65	0.48	0.65	37	20	41	16
Aboriginal Prickly Apple, *Harrisia aboriginum**	0.80	0.92	0.50	0.28	19	33	24	40
Kemp's ridley sea turtle, *Lepidochelys kempii*[a]	0.629	0.804	0.636	0.445	50	32	16	20
Key Largo woodrat, *Neotoma floridana smalli**	0.73	0.81	0.53	0.47	41	27	28	23
Key ring-necked snake, *Diadophis punctatus aricus*	0.91	0.88	0.40	0.31	11	33	42	49
Simpsons' prickly apple, *Harrisia simpsonii**	0.79	0.90	0.50	0.28	24	37	33	43
Leatherback turtle, *Dermochelys coriacea**	0.80	0.65	0.57	0.43	44	38	31	26
Nickerbean blue, *Cyclargus ammon**	0.86	0.63	0.60	0.28	36	43	22	38
Klots' skipper, *Euphyes pilatka klotsi**	0.91	0.71	0.50	0.31	20	40	37	43
Woodruff's polyphyllan scarab beetle, *Polyphylla woodruffi*	0.80	0.90	0.46	0.31	25	36	39	46
Lower Florida Keys striped mud turtle, *Kinosternon baurii (FL Keys)**	0.86	0.79	0.48	0.31	22	39	39	47
Florida bonneted bat, *Eumops floridanus*	0.73	0.56	0.63	0.44	51	45	32	25
Mangrove clapper rail, *Rallus longirostris insularum*	0.80	0.78	0.41	0.50	38	35	49	33
Florida purplewing, *Eunica tatila tatilista**	0.76	0.79	0.58	0.25	43	42	23	48
Atlantic salt marsh snake, *Nerodia clarkii taeniata*	0.82	0.74	0.47	0.38	39	41	45	38
Peninsula ribbonsnake, *Thamnophis sauritus sackenii*	0.85	0.69	0.50	0.31	40	46	42	52
Striped newt*, Notophthalmus perstriatus*	0.60	0.71	0.52	0.53	60	44	48	29
Mangrove Cuckoo, *Coccyzus minor*	0.820	0.690	0.500	0.330	45	49	44	50
Strohecker's ivory-spotted long-horned beetle, *Eburia stroheckeri*	0.85	0.88	0.43	0.17	26	50	47	67
Roseate spoonbill, *Platalea ajaja*[a]	0.696	0.578	0.527	0.527	58	51	50	31
Florida toadwood, *Cupania glabra*	0.89	0.77	0.47	0.17	28	53	46	66
Okaloosae darter, *Etheostoma okaloosae*	0.52	0.75	0.52	0.53	63	52	51	32
Key Vaca racoon, *Procyon lotor auspicatus*	0.80	0.73	0.38	0.44	48	46	54	51
Black skimmer, *Rynchops niger*	0.80	0.76	0.33	0.46	49	46	57	54
Florida bog frog, *Rana okaloosae****	0.58	0.73	0.43	0.54	62	54	55	37
Eastern oyster, *Crassostrea virginica*[a]	0.642	0.292	0.470	0.804	71	58	63	21
Florida prairie warbler, *Setophaga discolor paludicola*	0.89	0.57	0.38	0.44	47	55	56	57
American oystercatcher, *Haematopus palliatus*[a]	0.751	0.616	0.391	0.488	54	57	59	53
Wilson's plover, *Charadrius wilsonia*[a]	0.751	0.756	0.351	0.400	52	56	60	60
Marsh brownsnake, *Storeria dekayi*	0.74	0.63	0.50	0.28	55	60	52	63
Johnson's Seagrass, *Halophila johnsonii*	0.75	0.53	0.51	0.33	59	61	53	62
Silver glen springs cave crayfish, *Procambarus attiguus*	0.76	0.74	0.39	0.28	53	59	58	69
Short-tailed hawk, *Buteo brachyurus*	0.69	0.53	0.47	0.36	64	63	62	65
American crocodile, *Crocodylus acutus*	0.72	0.33	0.48	0.51	67	65	64	58

Coralberry, *Symphoricarpos orbiculatus*	0.79	0.67	0.30	0.33	57	62	71	72
Clapper rail, *Rallus crepitansa*[a]	0.622	0.440	0.420	0.558	73	64	70	59
Smallflower lilythorn, *Catesbaea parviflora*	0.79	0.50	0.41	0.28	61	68	66	73
Spotted trout, *Cynoscion nebulosus*[a]	0.474	0.364	0.480	0.661	82	69	72	45
Sea lavender, *Argusia gnaphalodes*	0.82	0.63	0.31	0.28	56	65	73	77
Red drum, *Sciaenops ocellatus*[a]	0.564	0.265	0.511	0.583	81	72	68	55
Sherman's short-tailed shrew, *Blarina shermani*	0.54	0.76	0.48	0.17	69	71	61	78
Miami cave crayfish, *Procambarus milleri*	0.62	0.61	0.40	0.33	70	70	69	71
Mottled duck, *Anas fulvigula*[a]	0.663	0.305	0.493	0.456	75	74	67	64
Least tern, *Sternula antillarum*	0.64	0.44	0.35	0.58	74	67	79	61
Keys green june beetle, *Cotinis aliena*	0.72	0.50	0.46	0.22	65	76	65	79
Frosted flatwoods salamander, *Ambystoma cingulatum*	0.60	0.60	0.39	0.33	72	73	75	74
West coast dune sunflower, *Helianthus debilis vestitus*	0.78	0.43	0.38	0.28	66	78	77	80
Squirrel treefrog, *Hyla squirella*	0.57	0.53	0.32	0.49	77	75	80	70
Dusky-handed tailless whip scorpion, *Paraphrynus raptator*	0.78	0.38	0.44	0.17	68	80	74	82
Reticulated flatwoods salamander, *Ambystoma bishopi*	0.57	0.60	0.39	0.33	76	77	76	76
Blue crab, *Callinectes sapidus*[a]	0.516	0.173	0.524	0.517	83	82	78	68
Gopher frog, *Rana capito****	0.51	0.57	0.34	0.42	80	79	81	75
Slashcheek goby, *Ctenogobius pseudofasciatus*	0.60	0.53	0.31	0.33	78	80	83	81
Miami chafer beetle, *Cyclocephala miamiensis*	0.60	0.57	0.33	0.17	79	83	82	83

The Gulf Coast Vulnerability Assessment (GCVA) evaluated four habitats and 11 species in six ecoregions (Table 7.4) utilizing SIVVA and SIVVA-NatCom. Habitats were selected based on data availability and models. Species were selected based on with distribution throughout the Gulf and would be representative of other species. Three of the Gulf Coast ecoregions defined for the study include portions of Florida (Figure 7.3), the Coastal Florida Coastal Plain (CFCP), South Florida Coastal Plain (SFCP) and the Southern Coastal Plain (SCP) ecoregions. The SCP ecoregion extends beyond Florida's panhandle into Alabama, Mississippi and Louisiana (Watson *et al.* 2015).

Table 7.4. Habitats and representative species assessed by the GCVA (Watson et al. 2015).

GVCA Habitat Type Evaluated	SWAP Habitat Type	Representative Species Evaluated
Mangrove	Mangrove Swamp	Roseate spoonbill
Tidal emergent marsh	Salt Marsh	blue crab, clapper rail, mottled duck, spotted sea trout
Oyster reef	Bivalve Reef	Eastern oyster, American oystercatcher, red drum
Barrier island	Coastal Strand	black skimmer, Kemp's ridley sea turtle, Wilson's plover

Figure 1: GCVA subregions: (a) Full extent of EPA Level III Terrestrial Ecoregions, and (b) modified to reflect new subregions for purposes of the GCVA.

Figure 7.3. Gulf Coast Vulnerability Assessment Ecoregions, the three ecoregions that include Florida the SCP, CFCP and SFCP, with the data for those three regions being summarized in this guide. Original caption shown (Watson et al. 2015).

Each of the four evaluated habitats were scored using SIVVA-NatCom for each of the three ecoregions that include Florida, the resulting vulnerabilities are compiled in Table 7.5 (Watson *et al*. 2015). The species evaluations are compiled in a similar manner with each ecoregion's assessment for that particular species shown (Table 7.6), but also included previously in Table 7.3 noted with a superscript "a" to display the data in context with other completed work utilizing the same methodology. A map depicting the assessed vulnerability for the clapper rail is shown in Figure 7.4.

Table 7.5. Assessed vulnerability of habitats, using same color ramp schema as the original assessment red (high) to green (low). The SCP ecoregion extends beyond Florida (Watson et al. 2015).

	Ecoregion Vulnerability		
Habitat	**SCP***	**CFCP**	**SFCP**
Barrier Island	high	high	
Mangrove	moderate	high	high
Oyster Reef	moderate	moderate	moderate
Tidal Emergent Marsh	high	high	very high

7 Vulnerability

Table 7.6. Assessed vulnerability of species, using same color ramp schema as the original assessment red (high) to green (low). The SCP ecoregion extends beyond Florida (Watson et al. 2015).

	Ecoregion Vulnerability		
Species	**SCP***	**CFCP**	**SFCP**
American oystercatcher	high	high	high
Black skimmer	high	moderate	high
Blue crab	low	low	low
Clapper rail	moderate	moderate	high
Eastern oyster	moderate	moderate	moderate
Kemp's ridley sea turtle	high		
Mottled duck	moderate	moderate	moderate
Red drum	moderate	low	low
Roseate spoonbill	high	high	moderate
Spotted trout	moderate	low	low
Wilson's plover	high	high	high

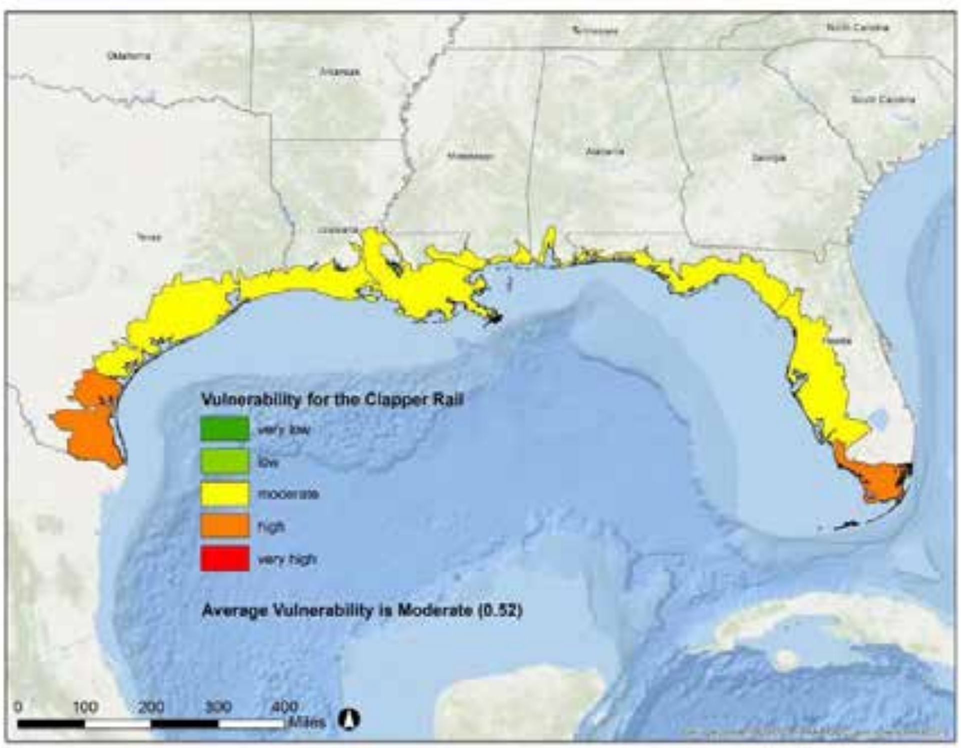


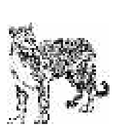
Figure 14: Vulnerability of Clapper Rail

Figure 7.4. Map depiction of clapper rail vulnerability assessed by the GCVA, shown with original caption (Watson et al. 2015). Assessed to be highly vulnerable in the SCFP ecoregion.

The above summaries of a select few vulnerability assessments completed in Florida and was intended to be a snapshot of vulnerability assessments that FWC participated in or funded. Several species were assessed by the differing methodologies, such as Least tern, Short-tailed hawk, Florida panther and Key deer, a complete list of species evaluated by the various studies can be found in Table 7.7.

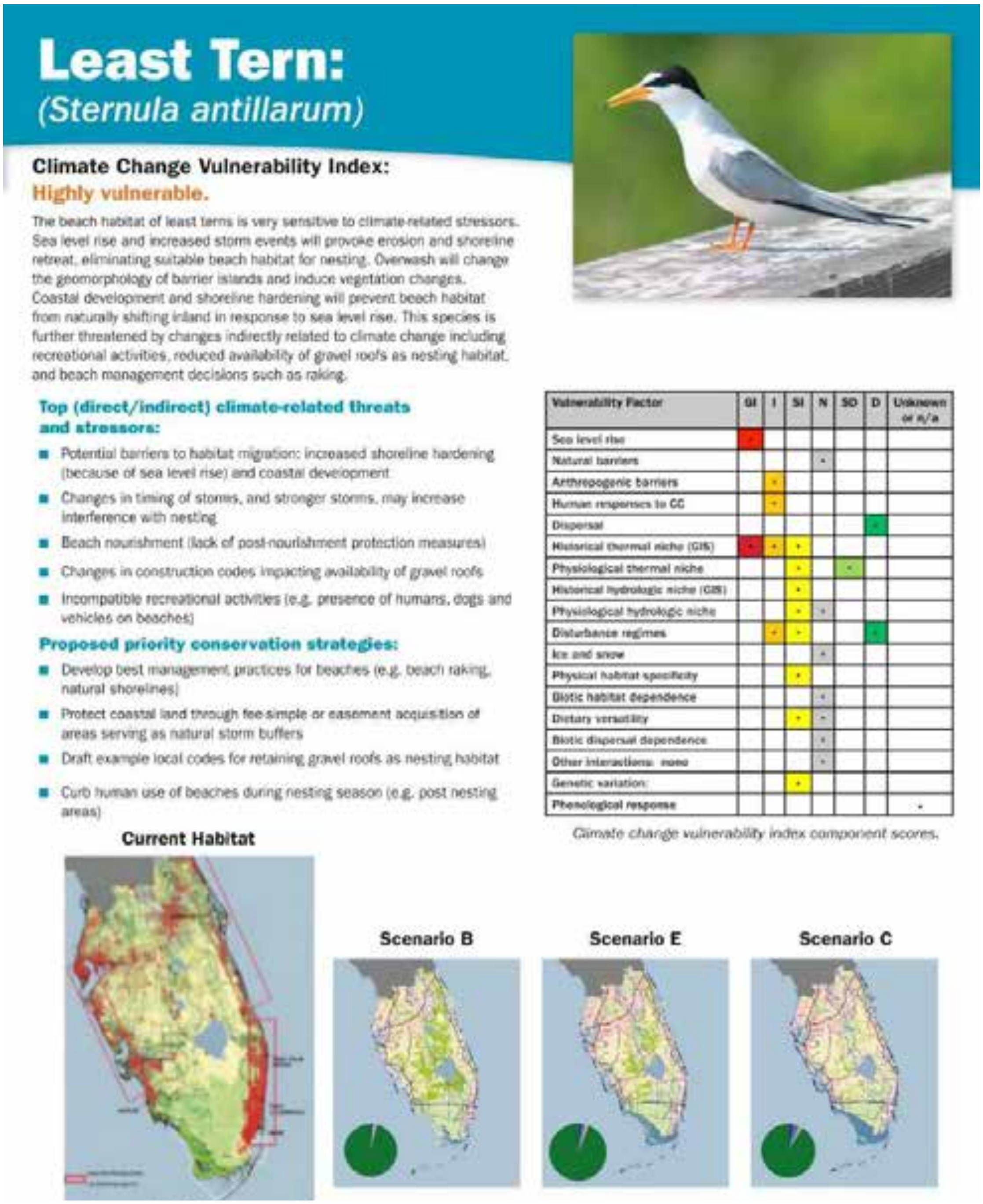
*Table 7.7. Compilation of species that were included in vulnerability assessments. ***Genus name Lithobates used in SWAP.*

Taxon	**Species**	Reece and Noss 2014	Reece *et al.* 2013	Watson *et al.* 2015	Dubois *et al.* 2011	Flaxman and Vargas-Moreno 2011
Amphibian						
	Florida bog frog, *Rana okaloosae******	x				
	Frosted flatwoods salamander, *Ambystoma cingulatum*	x				
	Gopher frog, *Rana capito******	x			x	
	Reticulated flatwoods salamander, *Ambystoma bishopi*	x			x	
	Squirrel treefrog, *Hyla squirella*	x			x	
	Striped newt, *Notophthalmus perstriatus*	x				
Bird						
	American oystercatcher, *Haematopus palliatus*			x		
	Black skimmer, *Rynchops niger*	x		x		
	Clapper rail, *Rallus crepitansa*			x	x	
	Florida grasshopper sparrow, *Ammodramus savannarum floridanus*		x			
	Florida prairie warbler, *Setophaga discolor paludicola*	x				
	Florida scrub jay, *Aphelocoma coerulescens*		x			
	Least tern, *Sternula antillarum*	x			x	x
	Limpkin, *Aramus guarauna*				x	
	Mangrove clapper rail, *Rallus longirostris insularum*	x				
	Mangrove cuckoo, *Coccyzus minor*	x			x	
	Mottled duck, *Anas fulvigula*			x		
	Purple swamphen, *Porphyrio porphyrio*				x	
	Red-cockaded woodpecker, *Picoides borealis*		x			
	Roseate spoonbill, *Platalea ajaja*			x		
	Short-tailed hawk, *Buteo brachyurus*	x			x	x
	Snail kite, *Rostrhamus sociabilis plumbeus*		x			

	Snowy plover, *Charadrius alexandrinus nivosus*		x			
	Whooping crane, *Grus americana*		x			
	Wilson's plover, *Charadrius wilsonia*			x		
Fish						
	Okaloosae darter, *Etheostoma okaloosae*	x				
	Red drum, *Sciaenops ocellatus*			x		
	Slashcheek goby, *Ctenogobius pseudofasciatus*	x				
	Spotted sea trout, *Cynoscion nebulosus*			x		
Invertebrate						
	Amethyst hairstreak, *Chlorostrymon maesites*		x			
	Beetle, *Branchus floridanus*		x			
	Blue crab, *Callinectes sapidus*			x		
	Blue spring hydrobe snail, *Aphaostracon asthenes*		x			
	Dusky-handed tailless whip scorpion, *Paraphrynus raptator*	x				
	Eastern oyster, *Crassostrea virginica*			x		
	Florida duskywing, *Ephyriades brunnea floridensis*		x			
	Florida Keys tree snail, *Orthalicus reses nesodryas*		x			
	Florida purplewing, *Eunica tatila tatilista*		x			
	Florida tree snail, *Liguus fasciatus*		x			
	Keys green june beetle, *Cotinis aliena*	x				
	Keys mudcloak, *Hojeda inaguensis*		x			
	Klots' skipper, *Euphyes pilatka klotsi*		x			
	Miami blue, *Cyclargus thomasi bethunebakeri*		x			
	Miami cave crayfish, *Procambarus milleri*	x				
	Miami chafer beetle, *Cyclocephala miamiensis*	x				
	Nickerbean blue, *Cyclargus ammon*		x			
	Red widow, *Latrodectus bishopi*				x	
	Salt marsh skipper, *Panoquina panoquin*				x	
	Schaus' swallowtail, *Heraclides aristodemus ponceanus*		x			
	Silver glen springs cave crayfish, *Procambarus attiguus*	x				
	Strohecker's ivory-spotted long-horned beetle, *Eburia stroheckeri*	x				
	Truncate, Urocoptid *Cochlodinella poeyana*		x			
	Woodruff's polyphyllan scarab beetle, *Polyphylla woodruffi*	x	x			
Mammal						
	Florida bonneted bat, *Eumops floridanus*	x			x	
	Florida panther, *Puma concolor coryi*	x	x		x	x
	Gambian giant pouched rat, *Cricetomys gambianus*				x	
	Key deer, *Odocoileus virginianus clavium*	x	x		x	x
	Key Largo cotton mouse, *Peromyscus gossypinus allapaticola*		x			
	Key Largo woodrat, *Neotoma floridana smalli*		x			
	Key Vaca racoon, *Procyon lotor auspicatus*	x				

	Keys marsh rabbit, *Sylvilagus palustris hefneri*	x	x			
	Marsh rabbit, *Sylvilagus palustris*				x	
	Perdido Key beach mouse, *Peromyscus polionotus trissyllepsis*		x			
	River otter, *Lontra canadensis*				x	
	Salt marsh vole, *Microtus pennsylvanicus dukecampbelli*		x			
	Sherman's short-tailed shrew, *Blarina shermani*	x				
Plant						
	Aboriginal prickly apple, *Harrisia aboriginum*		x			
	Big Pine partridge pea, *Chamaecrista lineata keyensis*		x			
	Cape Sable thoroughwort, *Eupatorium frustratum*		x			
	Coralberry, *Symphoricarpos orbiculatus*	x				
	Florida Semaphore Cactus, *Opuntia corallicola*		x			
	Florida toadwood, *Cupania glabra*	x				
	Johnson's seagrass, *Halophila johnsonii*	x				
	Key tree cactus, *Pilosocereus robinii*		x			
	Sea lavender, *Argusia gnaphalodes*	x				
	Simpsons' prickly apple, *Harrisia simpsonii*		x			
	Smallflower lilythorn, *Catesbaea parviflora*	x				
	Wedge spurge, *Chamaesyce deltoidea serpyllum*		x			
	West coast dune sunflower, *Helianthus debilis vestitus*	x				
Reptile						
	American crocodile, *Crocodylus acutus*	x			x	x
	Atlantic salt marsh snake, *Nerodia clarkii taeniata*	x	x		x	x
	Burmese python, *Python bivittatus*				x	
	Diamondback terrapin, *Malaclemys terrapin*				x	
	Hawskbill turtle, *Eretmochelys imbricata*		x			
	Kemp's ridley sea turtle, *Lepidochelys kempii*			x		
	Key ring-necked snake, *Diadophis punctatus aricus*	x				
	Leatherback turtle, *Dermochelys coriacea*		x			
	Loggerhead turtle, *Caretta caretta*	x	x		x	
	Lower Florida Keys striped mud turtle, *Kinosternon baurii*		x			
	Mangrove terrapin, *Malaclemys terrapin rhizophorarum*	x	x			
	Marsh brownsnake, *Storeria dekayi*	x				
	Peninsula ribbonsnake, *Thamnophis sauritus sackenii*	x				

The Least tern was analyzed in 3 of the 5 assessments in Table 7.7. The information from two early assessment efforts (Dubois *et al*. 2011 and Flaxman and Vargas-Moreno 2011) was summarized in the SWAP (Figure 7.5) and assessed using the SIVVA protocol and was found to be in the lower quartile of species assessed in that effort (Reece and Noss 2014). The Atlantic salt marsh snake was also assessed in 4 of the 5 efforts, including the summarized information included in the SWAP shown in Figure 7.6 (Dubois *et al*. 2011 and Flaxman and Vargas-Moreno 2011) and assessed using the SIVVA protocol and was found to be in the middle of species assessed in that effort (Reece *et al*. 2013). Similarly the key deer was assessed in 4 of the 5 efforts, including the summarized information included in the SWAP shown in Figure 7.7 (Dubois *et al*. 2011 and Flaxman and Vargas-Moreno 2011) and assessed using the SIVVA protocol and was found to be one of the most vulnerable species assessed (Reece *et al*. 2013).



Least Tern:
(Sternula antillarum)

Climate Change Vulnerability Index:
Highly vulnerable.

The beach habitat of least terns is very sensitive to climate-related stressors. Sea level rise and increased storm events will provoke erosion and shoreline retreat, eliminating suitable beach habitat for nesting. Overwash will change the geomorphology of barrier islands and induce vegetation changes. Coastal development and shoreline hardening will prevent beach habitat from naturally shifting inland in response to sea level rise. This species is further threatened by changes indirectly related to climate change including recreational activities, reduced availability of gravel roofs as nesting habitat, and beach management decisions such as raking.

Top (direct/indirect) climate-related threats and stressors:

- Potential barriers to habitat migration: increased shoreline hardening (because of sea level rise) and coastal development
- Changes in timing of storms, and stronger storms, may increase interference with nesting
- Beach nourishment (lack of post-nourishment protection measures)
- Changes in construction codes impacting availability of gravel roofs
- Incompatible recreational activities (e.g. presence of humans, dogs and vehicles on beaches)

Proposed priority conservation strategies:

- Develop best management practices for beaches (e.g. beach raking, natural shorelines)
- Protect coastal land through fee-simple or easement acquisition of areas serving as natural storm buffers
- Draft example local codes for retaining gravel roofs as nesting habitat
- Curb human use of beaches during nesting season (e.g. post nesting areas)

Vulnerability Factor	GI	I	SI	N	SD	D	Unknown or n/a
Sea level rise	•						
Natural barriers				•			
Anthropogenic barriers		•					
Human responses to CC		•					
Dispersal						•	
Historical thermal niche (GIS)	•	•	•				
Physiological thermal niche			•		•		
Historical hydrologic niche (GIS)			•				
Physiological hydrologic niche			•	•			
Disturbance regimes		•	•			•	
Ice and snow				•			
Physical habitat specificity			•				
Biotic habitat dependence				•			
Dietary versatility			•	•			
Biotic dispersal dependence				•			
Other interactions: none				•			
Genetic variation:			•				
Phenological response							•

Climate change vulnerability index component scores.

Current Habitat

Scenario B

Scenario E

Scenario C

Figure 7.5. Least tern summarized vulnerability assessment information from the SWAP from Dubois et al. 2011 and Flaxman and Vargas-Moreno 2011.

Atlantic Salt Marsh Snake:
(Nerodia clarkii taeniata)

Climate Change Vulnerability Index:
Extremely vulnerable.

The Atlantic salt marsh snake, one of three subspecies of salt marsh snake in Florida, will be significantly impacted by sea level rise and potential changes in hydrology that will impact mangrove and salt marsh habitat. Populations at Cape Canaveral and Canaveral Sea Shore have the highest adaptation potential; populations outside this area may be trapped between rising seas and coastal development.

Top climate-related threats and stressors:

- Increased coastal and interior development resulting in habitat loss and fragmentation
- Sea level rise resulting in inundation of habitat
- Species range shifts and disrupted biotic functions (e.g. loss of species required to generate habitat, reduced availability of key prey species, Atlantic race could be replaced by mangrove race as mangroves shift northward)
- Stronger hurricanes and storm events that limit habitat formation

Proposed priority conservation strategies:

- Restore habitat using dredge soils
- Protect salt marsh migration corridors via fee simple or easement acquisition
- Model vegetation succession with downscaled sea level rise models
- Rezone low elevation areas

Vulnerability Factor	GI	I	SI	N	SD	D	Unknown or n/a
Sea level rise	•						
Natural barriers				•			
Anthropogenic barriers		•					
Human responses to CC		•	•	•	•		
Dispersal				•	•	•	
Historical thermal niche (GIS)	•	•					
Physiological thermal niche			•		•		
Historical hydrologic niche (GIS)		•					
Physiological hydrologic niche	•	•	•				
Disturbance regimes		•	•				
Ice and snow				•			
Physical habitat specificity				•	•		
Biotic habitat dependence				•			
Dietary versatility				•			
Biotic dispersal dependence				•			
Other: competition for nest sites			•	•			
Genetic variation:		•					
Phenological response							•

Climate change vulnerability index component scores.

Current Habitat

Atlantic Salt Marsh Snake	Low	Medium	High
Habitat inundated	17%	80%	94%
Other habitat impacts	1%	1%	2%
Current habitat not changed	82%	19%	6%

Figure 7.6. Atlantic salt marsh snake summarized vulnerability assessment information from the SWAP from Dubois et al. 2011 and Flaxman and Vargas-Moreno 2011.

Key Deer:
(Odocoileus virginianus clavium)

Climate Change Vulnerability Index:
Highly vulnerable.

Sea level rise and land use change are expected to impact 32-75% of key deer habitat. In addition to this direct displacement, sea level rise will lead to increased salinity of freshwater drinking sources, a primary limiting resource for key deer. Changes in precipitation will also affect hydrological conditions, further increasing the salinization of watering holes. Storm water surge from strong storm events can also impact watering holes for months. Death due to highway mortality is also a significant factor for this species.

Top climate-related threats and stressors:

- Sea-level rise resulting in inundation and habitat loss
- Natural barriers (water) to migration off of the Keys
- Drought resulting in loss of habitat and drinking water supply
- Stronger storm events resulting in loss of habitat

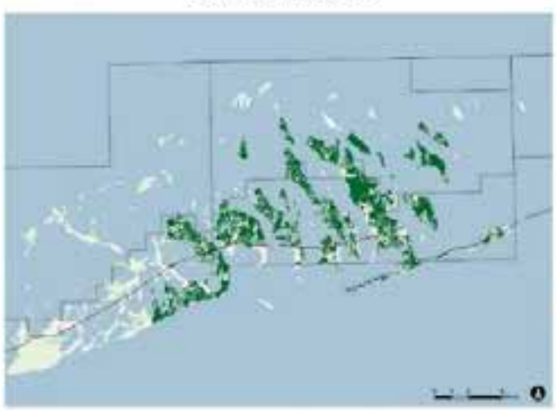
Proposed priority conservation strategies:

- Develop a habitat conservation plan
- Fill/remove mosquito ditches
- Use fee-simple or easement acquisition to protect habitat, including road underpasses
- Research disease and disease management
- Implement an appropriate fire regime
- Standardize monitoring of salinity of freshwater drinking sources

Vulnerability Factor	GI	I	SI	N	SD	D	Unknown or n/a
Sea level rise		•					
Natural barriers	•						
Anthropogenic barriers				•			
Human responses to CC				•	•	•	
Dispersal					•		
Historical thermal niche (GIS)	•						
Physiological thermal niche				•			
Historical hydrologic niche (GIS)		•					
Physiological hydrologic niche		•	•				
Disturbance regimes			•				
Ice and snow				•			
Physical habitat specificity				•	•		
Biotic habitat dependence				•			
Dietary versatility				•			
Biotic dispersal dependence				•			
Other interactions: none				•			
Genetic variation		•	•				
Phenological response							•

Climate change vulnerability index component scores.

Current Habitat



Key Deer	Low	Medium	High
Habitat inundated	32%	60%	74%
Other habitat impacts	1%	1%	<1%
Current habitat not changed	66%	40%	26%

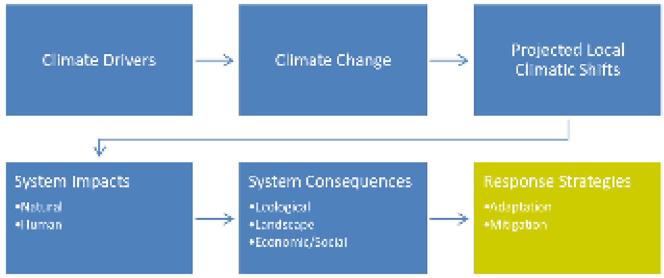
Scenario B

Scenario C

Scenario E

Figure 7.7. Key deer summarized vulnerability assessment information from the SWAP from Dubois et al. 2011 and Flaxman and Vargas-Moreno 2011.

8 GENERAL CLIMATE CHANGE ADAPTATION STRATEGIES



Adaptation strategies are those that better enable management to plan for and react to climate change impacts, the effects of which will serve to exacerbate anthropogenic related stresses to natural communities. Twelve common adaptation strategy categories were identified and used to begin development of more specific adaptation strategies to be used for the previously identified ecological consequences.

Common Adaptation Strategy Categories:

- Create special protections (for: keystone species, corridors, processes, habitats)
- Reduce anthropogenic stresses (e.g., pollution, development, overharvest)
- Ensure genetic diversity (species or ecosystems)
- Restore altered ecosystems to original function
- Create or maintain refugia
- Relocate species
- Anticipate and prepare for shifting wildlife movement patterns
- Maintain key ecosystems services
- Monitoring and planning to support adaptive management goals
- Ensure legislative and regulatory flexibility to climate change
- Increase awareness and knowledge of stakeholders
- Promote sustainable use of resources (subsistence, recreational, and commercial)

Using these categories and other materials, eight advisory statements were developed to aid in the development of adaptation strategies. These general statements are more practical rules of thumb to remember when defining strategies. They can be applied to a wide variety of situations, habitats, and species. The statements are outlined below:

1. *Actions need to be implemented at a range of management levels.*

   Measures designed to address climate change impacts on fish and wildlife species should be implemented at levels appropriate to maximize desired outcomes; this may include delivery at one or more organizational levels including state, regional and local.

2. *Actions should rely on sound planning that promotes the investment of resources in reliable strategies.*

    Sound planning is essential if the investment of resources for conservation is to be as effective as possible.

3. *Actions need to be focused on achieving clearly defined objectives and integrated with other policies and other natural resource management plans that have been developed.*

    Integration will facilitate the achievement of desired outcomes through comprehensive coverage of the issues and coordinated effort. Implementation activities developed to overcome climate change impacts need to be coordinated with existing policy objectives and planning processes for conservation of fish and wildlife species. Existing policies, programs, and legislation for natural resource conservation should be reviewed at all levels of management and government to ensure efficiencies and benefits are maximized.

4. *Planning and management for natural resource management activities need to be flexible, adaptive, and creative.*

    Natural resource management decisions for addressing the impacts of climate change on fish and wildlife species will be continually revised in the future as understanding evolves and new information is applied through a process of adaptive management.

5. *A risk management approach should be incorporated into adaptation planning.*

    Risk management processes will help reduce the probability that negative impacts may occur, while being prepared to manage the consequences should those impacts take place.

6. *Actions should maximize conservation for priority fish and wildlife species.*

    Emphasize conservation in areas where a) fish and wildlife species are under immediate threat from climate change impacts, and b) the activities undertaken will significantly improve adaptation for vulnerable species.

7. *Management activities should increase ecosystem resilience to better address the uncertainty associated with projected climate change impacts.*

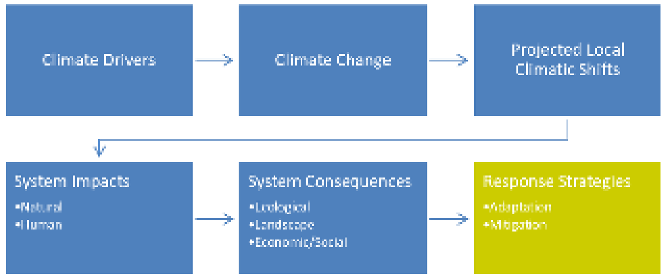
    Measures developed for adapting to climate change impacts can be focused on increasing the resilience of ecosystems, thereby increasing the likelihood of successful adaptation by species and decreasing the risk of ecosystem collapse.

8. *Management strategies should account for critical thresholds of species and ecosystems.*

    For all species and ecosystems there is a need to understand the points at which climatic (e.g., temperature or CO_2 concentration) and ecological (e.g., population density or mortality rate) thresholds exist, beyond which significant, sometimes irreversible, changes may occur.

Further national or regional resources on climate change adaptation are included in the resources section of this guide. To better demonstrate how these advisory statements and strategy categories can be used in specific situations, it is more useful to demonstrate how these adaptation strategies apply to particular habitats and ecological consequences, as is done in the following section.

9 CLIMATE CHANGE ADAPTATION STRATEGIES FOR HABITATS AND COMMUNITIES



Climate change adaptation is defined in the National Wildlife Federation's Climate Smart Conservation guide as the adoption and implementation of goals and strategies designed to prepare for and adjust to current and future climatic changes, and the associated impacts on natural systems and human communities (Stein *et al*. 2014). The impacts of climate change will be felt across a multitude of systems in the human and natural world. Using an adaptation approach is vital in the face of these growing climate pressures. Simply conserving species or habitats where they exist under present conditions, may not sufficient to meet FWC's mission in the future. Allowing for and encouraging landward migration of coastal habitats and vertical growth of habitats (e.g. oyster reefs, mangrove) due to SLR are adaptive management activities that could promote species resilience (Noss *et al*. 2014). Similarly, considering changing climate is a necessity for future development of human land use.

For wildlife and natural resource managers, considering how predicted or possible climatic changes may impact various conservation goals and strategies and subsequently modifying existing strategies (or creating new ones) to compensate is what it means to appropriately practice climate change adaptation. Strategies should target processes that encourage ecosystem resilience, reduce external stressors and safeguard genetic diversity. This section will describe methods for practicing such adaptation and provide a variety of examples.

9.1 ADAPTATION STRATEGY DEVELOPMENT

FWC worked with Defenders of Wildlife to develop a multi-phased approach to identifying adaptation strategies for this adaptation guide based on the climate impact assessment previously completed by the working groups. The focus for developing adaptation strategies was to link those strategies to the ecological consequences identified by the working groups in the previous impact assessment. In April 2014, Defenders of Wildlife hosted a meeting in which the working groups refined and implemented this process. During the meeting, a number of adaptation strategies were generated that contributed to the development of this adaptation guide. After exploring processes for developing strategies, the working groups decided that a coarse-filter model that grouped habitats with similar needs from the 2012 SWAP, would be the most appropriate scale at which to identify strategies for this adaptation guide. Coarse-filters, as defined by this group, are broad categories of habitats or communities that in turn have more specific habitats or communities nested within them. A cross-walk of these coarse-filters and the associated habitats (those identified in Section 6 of this guide) are included in Table 9.1, those with an asterisk do not have adaptation strategies at this time, but will be added in the future but may have case studies.

Climate change is an overarching issue and occurs at a scale that will require coordination between federal, state and local governments, NGOs and researchers to collaborate to achieve results that will benefit wildlife, natural communities and the built environment. Many land use planning decisions and actions are done at the local level, but many tools and relevant data layers related to climate change are generated at the state or federal level making collaboration and outreach to enable informed decisions. Some strategies in the following section could be more effective if done in collaboration to avoid duplication of efforts, maximize resources and benefits.

Table 9.1. Coarse-filter targets developed by the working group.

Coarse-filter target	Examples of habitats nested within target (fine-filter targets)
Connected Waters	Calcareous Stream, Freshwater Marsh and Wet Prairie, Lakes, Large Alluvial Stream, Natural Lakes, Reservoir/Impoundments, Softwater Stream
Disturbed Areas *	Industrial Pineland, Grassland/Pastureland, Disturbed/Transitional
Forested Wetlands	Hydric Hammock, Bottomland Hardwood Forests, Bay Swamp, Cypress Swamp, Hardwood Swamp, Floodplain Forest
Groundwater Springs & Aquatic Caves	Calcareous Stream, Springs, Spring Run Stream
Isolated Waters	Seepage Stream, Ephemeral Ponds/Wetlands, Depression Marshes, Cypress Domes, Ponds
Offshore*	Outer shelf (deep water, generally beyond normal wave action), Sargassum mats, Euplanktonic zone
Open Ocean (High Seas)*	Euphotic Zone, Pelagic zones
Open Ocean (High Seas)*	Shelf edge, Deep ocean floor
Prairies/Grasslands*	Dry Prairie
Shoreface-nearshore (sublittoral)	Coral Reef, Hardbottom, Bays/Inlets/Open Ocean, Bivalve Reef, Annelid Reef, Submerged Aquatic Vegetation, sand and mud
Shoreline-Backshore	Beach/Surf Zone, Coastal Strand
Shoreline-Foreshore	Bays/Inlets/Open Ocean, Coastal Tidal River or Stream, Mangrove, Bivalve Reef, Coral Reef, Saltmarsh, Tidal Flat, Grass flats, Submerged Aquatic Vegetation
Upland Forest-Pine Rockland*	Pine Rockland
Subtidal/Neritic (Sublittoral)*	Pelagic/Demersal
Upland Forest-Scrub*	Oak Scrub, Sand Pine Scrub, Rosemary Scrub
Upland Forest*	Natural Pineland, Tropical Hardwood Hammock, Scrubby Flatwoods, Sandhill, Hardwood Hammock

9.2 ADAPTATION STRATEGIES FOR COARSE-FILTERS

The impact assessment process evaluated most of the habitats in the SWAP. Habitats were grouped into coarse-filters with shared vulnerabilities in which similar adaptation strategies could be developed and applied. The adaptation strategies outlined in this section can and should be applied to specific habitats and communities, though may not be applicable to every habitat within the same coarse filter. The bulleted list can serve as a list of options, those chosen should actions that would be most appropriate to defined management goals and objectives. Specific site conditions and the expertise of land managers should strategy selection, the adaptation strategies are by no means a fully inclusive list. Rather, these should be viewed as a starting point to help in the development of a comprehensive adaptation strategy for a management area, habitat, or community.

A brief description of each coarse-filter (including the habitats and communities it contains) along with the relevant adaptation strategies that were developed by the working groups are outlined in the following subsections. The primary climatic shifts, impacts and consequences from those shifts, and the direct and enabling adaptation strategies are all outlined in great detail for each of the coarse-filters. These adaptation strategy sections provide detailed ways to respond to specific climate change impacts and consequences through strategies that either directly modify the ecology of the communities through top-down management or enabling relevant members of the surrounding community to make changes or accept existing or proposed adaptation plans. Previous evaluation determined that protecting existing habitat for as long as possible was the preferred action to protect species from climate change impacts, followed by protecting future habitats. Protecting the ecological integrity and encouraging healthy conditions of habitats will “buy time” for the habitats to adjust to changing conditions and protect areas that will likely be converting to critical habitats (e.g. salt marsh, mangrove, pine rockland). Adaptation strategies should reduce vulnerability of a species or habitat will involve decreasing exposure or sensitivity or enabling increased adaptive capacity.

For each coarse filter there are three ecological consequence sections:

- Altered disturbance regime
- Hydrologic Factors
- Altered habitats
- Altered population health and survival

Each ecological consequence section has proposed activities listed under sub-headings: actions to reduce risk, research/monitoring and outreach activities. Checkmark entries within lists are meant to serve as resources including example tools or reports completed that may serve as a starting point. Select case studies are also included under relevant coarse filters.

9.2.1 CONNECTED WATERS

Coarse Filter Description: Connected waters consist of rivers, lakes, and wetlands that form a larger connected wetland and aquatic system.

Habitat Categories Included: Calcareous Stream, Freshwater Marsh and Wet Prairie, Large Alluvial Stream, Natural Lakes, Reservoir/Impoundments, Softwater Stream

Primary Climatic Shifts:

- **Changes in Precipitation** - Amount, Duration, Timing
- **Changes in extreme events** - Flood, Drought
- **Sea Level Rise-** Salinity, Inundation

Ecological Consequence: Altered Disturbance Regime

Outcomes can include changes to: surface runoff, natural fire regime, and erosional factors

Actions to reduce risk:

- Design stream crossings to accommodate future conditions and with fish and wildlife passage incorporated
  - ✓ Stream Simulation Design - http://1.usa.gov/1SmSU0H
  - ✓ Climate-Friendly Stream Crossings toolkit - http://bit.ly/1RJhLOB
  - ✓ Georgia's Stream Crossing Handbook- http://1.usa.gov/1q2jGFf
  - ✓ Massachusetts DOT Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams - http://bit.ly/1ZKZXpg
  - ✓ Massachusetts Stream Crossing Handbook - http://1.usa.gov/1SmRsLH
  - ✓ NOAA Fisheries Service- Considering Climate Change in project design (http://www.habitat.noaa.gov/pdf/flood_frequency_estimates.pdf)
  - Publically funded culverts should be sized and set at elevations to properly accommodate increased stream flow conditions and fauna passage (encourage the same of privately funded culverts)
  - Inventory culverts
    - ✓ Northwest Florida Stream crossing field survey procedures- http://1.usa.gov/25wC74Y
- Participate in High Water Mark Initiative efforts with local communities or separately after flooding events - https://www.fema.gov/high-water-mark-initiative
- Track flooding frequency and extent to inform capital projects (road improvements, culvert replacements)

- Restore riparian areas to increase water retention and uptake of soils and reduce impacts of flood events, erosion, and sedimentation.
  - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
  - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
  - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
  - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
  - Provides habitat corridors for wildlife to traverse along waterways
- Restore floodplains
  - ✓ Floodplain Restoration and Stormwater Management: Guidance and Case Study – (http://bit.ly/1TTiqzU)
  - ✓ USDA NRCS- Natural Channel and Floodplain Restoration – (http://1.usa.gov/1QP5qow)
  - ✓ FSA Conservation Reserve Program- Floodplain Wetlands Initiative – (http://1.usa.gov/1L6JhWB)
- Maintain floodplains as undeveloped areas
- Protect wetlands for floodwater storage
- Practice prescribed fire management to maintain fuel loads and natural conditions
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands

Outreach (internal and external):

- Implement outreach to increase public understanding of the benefits of fire management and increased wildfire risks due to climate change
  - ✓ Example messages and audiences have been identified in "East Gulf Coastal Plain Joint Venture- A Burning Issue Prescribed Fire and Fire-adapted Habitats of the East Gulf Coastal Plain" - http://bit.ly/1Y2JITE
  - ✓ United States Forest Service- Social Science to improve Fuels Management - http://1.usa.gov/1RjXI5T
- Work with communities on to reduce stormwater runoff and improve water quality
  - ✓ Montgomery County Rainscapes - encourages reducing stormwater runoff from private, institutional and commercial properties through technical and financial assistance (http://bit.ly/1Y5UjND)
  - ✓ Retrofit Existing Stormwater Infrastructure – the Chesapeake Stormwater Network has compiled a long list of stormwater retrofitting resources
  - ✓ Incorporating Low Impact Development into Municipal Stormwater Programs – (http://1.usa.gov/1Qohr7c)
  - ✓ Low Impact Development- Urban Design Tools - (http://bit.ly/1VTCBvw)

- Work with counties, local municipalities and regional planning councils to incorporate natural resources adaptation strategies in comprehensive plans and hazard planning efforts, reviewing draft plans as personnel time allows
    - Make example plans that incorporate natural resources adaptation strategies available
    - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
    - ✓ Incorporating Sea Level Change Scenarios at the Local Level- (http://1.usa.gov/1L6F6dz)
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Educate planners on importance of habitat preservation (including serving as hazard buffers), climate change and incorporation into long range planning efforts
    - ✓ Ribbons of Life- booklet developed by Alachua County regarding buffer zone benefits along waterways (http://bit.ly/1UClXSx)
    - ✓ Hillsborough County Environmental Protection Commission Tech Memo- Developing Scientifically-based Ecological Buffers to Protect the Watershed in Hillsborough County, FL- (http://bit.ly/1ppn3p6)
    - ✓ Climate-Friendly Stream Crossings toolkit - http://bit.ly/1RJhLOB

Ecological Consequence: Hydrologic Factors

Outcomes can include changes to: hydrology, flood frequency/extent, groundwater, streamflow, water levels, hydroperiod, sediment transport, drought/flood cycles, water temperature, water chemistry, pollutants, nutrient loading, sedimentation (turbidity)

Actions to reduce risk:

- Design stream crossings to accommodate future conditions and with fish and wildlife passage incorporated
    - ✓ Northwest Florida Stream crossing field survey procedures- http://1.usa.gov/25wC74Y
    - ✓ Stream Simulation Design - http://1.usa.gov/1SmSU0H
    - ✓ Climate-Friendly Stream Crossings toolkit - http://bit.ly/1RJhLOB
    - ✓ Georgia's Stream Crossing Handbook- http://1.usa.gov/1q2jGFf

- ✓ Massachusetts DOT Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams - http://bit.ly/1ZKZXpg
    - ✓ Massachusetts Stream Crossing Handbook - http://1.usa.gov/1SmRsLH
    - Publically funded culverts should be sized and set at elevations to properly accommodate increased stream flow conditions and fauna passage (encourage the same of privately funded culverts)
- Restore and/or protect riparian buffers to reduce sheetflow stormwater runoff, to decrease non-climate stressors
    - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
    - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
    - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
    - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
    - Look for opportunities to provide incentives
        - ✓ Financial assistance for buffers – University of Minnesota extension has compiled a list of mostly federal sources of buffer incentive programs (http://bit.ly/1QWg3vS)
    - Provide habitat corridors for wildlife to traverse along waterways
- Participate in High Water Mark Initiative efforts with local communities or separately after flooding events - https://www.fema.gov/high-water-mark-initiative
- Encourage best management practices to reduce sources of land-based pollutant and nutrient loads impacting species and habitats
    - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Promote management practices that discourage the application of pesticides in the rainy season
- Modification of stormwater outfalls that negatively affect habitats, and/or install BMP treatments upstream of sensitive habitats
- Incentives for municipal and agricultural water conservation
    - ✓ Local Fl water conservation incentive programs (http://bit.ly/1L6K366)
    - ✓ SWFWMD Water Conservation – (http://bit.ly/1njXuE0)
    - ✓ SFWMD Water Conservation – (http://bit.ly/1UCywgL)
    - ✓ Broward Water Partnership- (www.conservationpays.com)
- Policies and incentives for reducing impervious surface
    - ✓ Impervious Cover TMDL's are a new approach being piloted to address the impacts of urbanization on water quality (http://1.usa.gov/21K0PiF)
- Collaborate with other agencies to ensure new water control structures have consideration for the public natural resources (natural habitats and wildlife downstream)

- Policies that encourage water management districts to manage for in-stream flow
- Modify water management (timing & amount of releases from water control structures)
- Engage in partnerships to encourage consistent water management programs across jurisdictional boundaries
- Reduce roadway and paved area construction near aquatic systems to maintain natural hydrology
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands.
- Reduce bare ground adjacent to flowing waters and the riparian buffers, enforce erosion control measures
    - ✓ FL DEP - Muddy Water Blues Workshops for stakeholders to learn about erosion control methods (http://bit.ly/1QvQxM4)
- Reduce point and nonpoint sources of pollutants and nutrients (N, P, toxins, etc.) from agricultural and residential land uses
    - ✓ Leaves, nutrient pollution and homeowner outreach in Wisconsin - http://bit.ly/1RsfnZL
    - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
    - ✓ Urban Fertilizer Management – Chesapeake Stormwater Network has compiled a list of urban fertilizer resources (http://bit.ly/1OUJyXz)
    - ✓ UF IFAS – Pesticide and water quality resources (http://bit.ly/1RMEXuZ)
    - ✓ University of California - pesticide impacts on water quality (http://bit.ly/1OVcCye)
- Upgrades of municipal sewage systems
- Limit armoring along the bank

Research/Monitoring:

- Monitor pollutants
- Monitoring of stream flows
    - ✓ FL USGS Water Science Center – currently maintains over 500 streamflow stations across the state (http://on.doi.gov/1QvSZlO)

Outreach (internal and external):

- Engage hunting and angling communities to support minimum river and stream flows
- Actively engage with communities to minimize urban encroachment
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)

- Enhance outreach efforts to correlate water quality and habitat health to improve public stewardship and support actions to improve water quality
    - ✓ Climate Change and the Occurrence of Harmful Algal Blooms- http://bit.ly/1QtXAEQ
    - ✓ Leaves, nutrient pollution and homeowner outreach in Wisconsin - http://bit.ly/1RsfnZL
- Promote water use and allocation measures to protect critical habitats
- Incentives and education for private landowners on appropriate use of fertilizer and pesticides and the impacts on water quality
    - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
    - ✓ Urban Fertilizer Management – Chesapeake Stormwater Network has compiled a list of urban fertilizer resources (http://bit.ly/1OUJyXz)
    - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
    - ✓ UF IFAS – Pesticide and water quality resources (http://bit.ly/1RMEXuZ)
    - ✓ University of California - pesticide impacts on water quality (http://bit.ly/1OVcCye)
    - ✓ Think about personal pollution - http://www.tappwater.org/

Ecological Consequence: Altered habitats

Outcomes can include changes to: community composition, dominant species, salinity, habitat extent, habitat quality, habitat condition, spatial/temporal functions, fish migration patterns, relative species abundances, spatial distribution, habitat fragmentation, abundance of fish and game species, habitat degradation, habitat fragmentation

Actions to reduce risk:

- Design stream crossings to accommodate future conditions and with fish and wildlife passage incorporated
    - ✓ Northwest Florida Stream crossing field survey procedures- http://1.usa.gov/25wC74Y
    - ✓ Stream Simulation Design - http://1.usa.gov/1SmSU0H
    - ✓ Climate-Friendly Stream Crossings toolkit - http://bit.ly/1RJhLOB
    - ✓ Georgia's Stream Crossing Handbook- http://1.usa.gov/1q2jGFf
    - ✓ Massachusetts DOT Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams - http://bit.ly/1ZKZXpg
    - ✓ Massachusetts Stream Crossing Handbook - http://1.usa.gov/1SmRsLH
    - Publically funded culverts should be sized and set at elevations to properly accommodate increased stream flow conditions and fauna passage (encourage the same of privately funded culverts)

- Restore/modify channels to create habitat diversity
  - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
  - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
  - Establish river corridor easements that allow natural river channel migration
- Reconnect rivers to floodplains by removing restrictions (e.g., removing dams, modify culverts, berm and levee removal)
  - ✓ Floodplain Restoration and Stormwater Management: Guidance and Case Study – (http://bit.ly/1TTiqzU)
  - ✓ USDA NRCS- Natural Channel and Floodplain Restoration – (http://1.usa.gov/1QP5qow)
  - ✓ FSA Conservation Reserve Program- Floodplain Wetlands Initiative – (http://1.usa.gov/1L6JhWB)
  - ✓ Stream Simulation Design- US Forest Service, An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings (http://1.usa.gov/1pqlaY1)
  - ✓ For channelized systems with limited room- Two-Stage Channel Design (http://1.usa.gov/1QyAvxE)
- Encourage migration of habitats, remove barriers when feasible to allow inland shifts of coastal forested habitats affected by increased salinity
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
- Establish protections for transitional habitats that will provide for range shifts and serve as potential climate refugia, allowing shift in community composition where appropriate
- Identify important (and potentially resilient) aquatic systems and wetland areas to serve as refugia, prioritize inclusion in land protection planning efforts
- Maintain/improve habitat quality to enhance the resilience of aquatic habitats to changing conditions
- Preserve aquatic systems and buffers that are not yet impacted by human development
- Identify and prioritize protection of corridors between aquatic systems and associated upland habitats to promote species migration corridors
- Encourage landowner cost share programs and enrollment in conservation easements to increase habitat base
  - ✓ NRCS EQIP - (http://1.usa.gov/1VWAbMx)
  - ✓ FL HB7157 – tax exemption for real property used for conservation properties (http://www.dep.state.fl.us/lands/arc_conservation.htm)
  - ✓ UF IFAS – (https://edis.ifas.ufl.edu/uw194)
- Strengthen protection of waterbodies
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands
- Expand protected areas to increase the representation of connected waters and minimize risk of loss across the landscape

- Reconnect fragmented habitat, when feasible
- Restore and/or protect riparian buffers to reduce sheetflow stormwater runoff, to reduce non-climate stressors e.g., non-point source pollution and runoff from impervious surfaces
    - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
    - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
    - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
    - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
    - Look for opportunities to provide incentives
        - ✓ Financial assistance for buffers – University of Minnesota extension has compiled a list of mostly federal sources of buffer incentive programs (http://bit.ly/1QWg3vS)
- Develop strategies to deal with changes in river and lake access points
- Manage for redundancy of habitat types
- Select native plant species for restoration efforts that are expected to be better adapted to future climate conditions, especially after extreme storm events (e.g., hurricanes)
- Promote protection of native species, when feasible
- Manage connected lake systems as a complex to provide variable habitat staggered among years, throughout the complex
- Avoid timber harvest near shoreline in favor of harvesting methods that maintain a greater canopy cover (e.g., patch/selection cuts); if clearcuts are unavoidable, limit cuts to small areas that are narrow and irregular in shape
    - ✓ FL Dept. of Agriculture and Consumer Services – Silviculture Best Management Practices (http://bit.ly/1oVdxJD)
- Remove/restore ditches to deter saltwater intrusion and restore natural water flow

Research/Monitoring:

- Analyze fisheries surveys for shifting populations
- Research succession in terms of different communities using these habitats
- Monitor salt wedge intrusion in rivers
    - Monitor upstream migration of barnacles at existing sampling sites
- Monitor community movements (e.g. *Vallisneria americana* beds moving with salinity shifts)
- Monitor aquatic systems for introductions/increases in invasive species; treat areas per prescription

Outreach (internal and external):

- Educate on disposal options of fishing gear if a fishery is no longer viable due to population shifts
- Engage hunting and angling communities to support watershed planning and wetland conservation programs
- Work with stakeholders to identify educational opportunities
- Work with volunteers to control invasive species
  - ✓ http://www.fleppc.org/landowners.htm - landowners guide to exotic plants (http://bit.ly/1S6Fg4b)
- Actively engage with communities to minimize urban encroachment
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)

Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: phenology, biotic interactions, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, species ranges/extent of occurrence, community dynamics, quality or health of fish and game species, abundance of fish and game species

Actions to reduce risk:

- Re-evaluate fishery management and water quality standards where doing so could increase recruitment
- Remove physical barriers to fish and wildlife movement
  - ✓ FishXing – software to assist engineers, hydrologists and fish biologists evaluate and design culverts for fish passage (http://www.stream.fs.fed.us/fishxing/)
  - ✓ Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual – (http://wdfw.wa.gov/publications/00061/)
  - ✓ Stream Simulation Design - http://1.usa.gov/1SmSU0H
  - ✓ Climate-Friendly Stream Crossings toolkit - http://bit.ly/1RJhLOB
  - ✓ Georgia's Stream Crossing Handbook- http://1.usa.gov/1q2jGFf
  - ✓ Massachusetts DOT Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams - http://bit.ly/1ZKZXpg
  - ✓ Massachusetts Stream Crossing Handbook - http://1.usa.gov/1SmRsLH
- Identify and prioritize protection of corridors between aquatic systems and between these areas and associated upland habitats to promote species migration corridors.

- Work with local municipalities and counties to target water quality improvement projects directly impacting priority recruitment areas
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Use harvest regulations to protect adult sport fish and game species
- When possible, enhance habitat to improve fish recruitment during drought

Research/Monitoring:

- Monitor disease prevalence and occurrence (spatially and temporally)

Outreach (internal and external):

- Work with local fishing and boating industries to promote minimum impact through habitat use activities
- Education of recreational users on the importance of phenology factors and how they relate to regulations/closures
- Educate and work with fisheries participants to recognize and report irregularities in phenology indicators

9.2.2 GROUNDWATER SPRINGS AND AQUATIC CAVES

Coarse Filter Description: Groundwater springs and aquatic caves consist of groundwater driven or influenced formations and flows and their immediately affected areas.

Habitat Categories Included: Calcareous Streams, Springs and Spring run streams, aquatic caves

Primary Climatic Shifts:

- **Changes in Precipitation** - Amount, Duration, Timing
- **Changes in extreme events** - Flood, Drought
- **Sea Level Rise-** Salinity, Inundation
- **Changes in air temperature-** increased average summer temperatures, decreased minimum winter/spring temperature, temperature extremes

Ecological Consequence: Altered Disturbance Regime

Outcomes can include changes in: natural fire regime, sediment transport processes and erosional forces.

Actions to reduce risk:

- Restore riparian areas to increase water retention and uptake of soil retention and reduce impacts of flood events, erosion, and sedimentation
  - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
  - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
  - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
  - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
- Maintain floodplains as undeveloped areas
- Practice prescribed fire management to maintain fuel loads and natural conditions
- Restrict development and other land uses that alter disturbance processes in sensitive areas
- Regulate and reduce human disturbance (mining, drilling and recreation)

Outreach (internal and external):

- Implement outreach to increase public understanding of the benefits of fire management and increased wildfire risks due to climate change
  - ✓ Example messages and audiences have been identified in "East Gulf Coastal Plain Joint Venture- A Burning Issue Prescribed Fire and Fire-adapted Habitats of the East Gulf Coastal Plain" - http://bit.ly/1Y2JITE
  - ✓ United States Forest Service- Social Science to improve Fuels Management - http://1.usa.gov/1RjXI5T
- Work with communities to improve stormwater runoff negatively impacting natural habitats and encourage groundwater recharge options through low impact development and retrofits
  - ✓ Montgomery County Rainscapes - encourages reducing stormwater runoff from private, institutional and commercial properties through technical and financial assistance (http://bit.ly/1Y5UjND)
  - ✓ Retrofit Existing Stormwater Infrastructure – the Chesapeake Stormwater Network has compiled a long list of stormwater retrofitting resources
  - ✓ Incorporating Low Impact Development into Municipal Stormwater Programs – (http://1.usa.gov/1Qohr7c)
  - ✓ Low Impact Development- Urban Design Tools - (http://bit.ly/1VTCBvw)

- Work with counties, local municipalities and regional planning councils to incorporate natural resources adaptation strategies in comprehensive plans and hazard planning efforts, reviewing draft plans as personnel time allows
    - Provide example plans that incorporate natural resources adaptation strategies
    - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)

Ecological Consequence: Hydrologic Factors

Outcomes can include changes to: hydrology, flood frequency/extent, groundwater table (recharge), streamflow, water levels, hydroperiod, drought/flood cycles, pollutant transport, nutrient loading, nutrients, water temperatures, sediment loadings (turbidity)

Actions to reduce risk:

- Restore and/or protect riparian buffers to reduce stormwater runoff from adjacent development, look for opportunities to incentivize riparian buffer protection or restoration
    - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
    - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
    - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
    - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
- Encourage best management practices to reduce sources of land-based pollutant and nutrient loads impacting groundwater quality
    - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Promote management practices that discourage the application of pesticides in the rainy season
- Incentives for municipal and agricultural water conservation
    - ✓ Local Fl water conservation incentive programs (http://bit.ly/1L6K366)
    - ✓ SWFWMD Water Conservation – (http://bit.ly/1njXuE0)

- ✓ SFWMD Water Conservation – (http://bit.ly/1UCywgL)
- ✓ Broward Water Partnership- (www.conservationpays.com)

- Policies and incentives for reducing impervious surface and encouraging low impact development to encourage groundwater recharge
  - ✓ Impervious Cover TMDL's are a new approach being piloted to address the impacts of urbanization on water quality (http://1.usa.gov/21K0PiF)
  - ✓ Chesapeake Stormwater Network - Impervious surface disconnection resources – (http://bit.ly/1RkZMkr)
- Policies that encourage water management districts to manage for in-stream flow, enforce minimum flows to prevent harmful draw down of groundwater and allow recharge
- Modify water management (timing & amount of releases from water control structures)
- Engage in partnerships to encourage consistent water management programs across jurisdictional boundaries
- Reduce roadway and paved area construction near aquatic systems to maintain natural drainage patterns
- Reduce bare ground adjacent to flowing waters (enforce erosion control measures for adjacent construction sites and other disturbances)
  - ✓ FL DEP - Muddy Water Blues Workshops for stakeholders to learn about erosion control methods (http://bit.ly/1QvQxM4)
- Reduce point and nonpoint sources of pollutants and nutrients (N, P, toxins, etc.) from agricultural and residential land use activities
  - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
- Maintain floodplains as undeveloped areas
- Promote water use and allocation measures to protect critical habitats
- Improve riparian zone and floodplain connectivity between rivers and floodplains (e.g., removing dams, replacing culverts)
  - ✓ Floodplain Restoration and Stormwater Management: Guidance and Case Study – (http://bit.ly/1TTiqzU)
  - ✓ USDA NRCS- Natural Channel and Floodplain Restoration – (http://1.usa.gov/1QP5qow)
  - ✓ FSA Conservation Reserve Program- Floodplain Wetlands Initiative – (http://1.usa.gov/1L6JhWB)
  - ✓ Stream Simulation- US Forest Service, An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings (http://1.usa.gov/1pqIaY1)
- Maintain canopy cover near spring runs to reduce thermal stress and evaporation
- Restrict development and other land uses (mining, drilling and recreation) that alter disturbance processes in around springs and spring runs

Research/Monitoring:

- Monitor pollutants
- Monitor water clarity
- Monitoring of stream flows
  - ✓ FL USGS Water Science Center – currently maintains over 500 streamflow stations across the state (http://on.doi.gov/1QvSZlO)
- Monitor groundwater table
  - ✓ FL USGS Water Science Center – currently maintains over 100 groundwater monitoring stations across the state (http://on.doi.gov/1Qr2q4B)

Outreach (internal and external):

- Engage hunting and angling communities to support minimum river and stream flows
- Actively engage with communities to minimize urban encroachment
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Enhance outreach efforts to correlate water quality and habitat health to improve public stewardship and support actions to improve water quality
- Education for private landowners on appropriate use fertilizers and pesticides and impacts on water quality, potentially incentives to reduce use
  - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
  - ✓ Urban Fertilizer Management – Chesapeake Stormwater Network has compiled a list of urban fertilizer resources (http://bit.ly/1OUJyXz)
  - ✓ UF IFAS – Pesticide and water quality resources (http://bit.ly/1RMEXuZ)
  - ✓ University of California - pesticide impacts on water quality (http://bit.ly/1OVcCye
- Work with communities and agencies to stabilize shorelines
  - ✓ Ribbons of Life- booklet developed by Alachua County regarding buffer zone benefits along waterways (http://bit.ly/1UClXSx)
  - ✓ Hillsborough County Environmental Protection Commission Tech Memo- Developing Scientifically-based Ecological Buffers to Protect the Watershed in Hillsborough County, FL- (http://bit.ly/1ppn3p6)
- Work with agencies and communities to reduce surface runoff and maintain or improve water quality and reduce runoff into spring runs
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
  - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/

Ecological Consequence: Altered habitats

Outcomes can include changes in: community composition, dominant species (e.g. species-specific flood induced mortality), salinity, habitat extent, habitat quality and condition, spatial/temporal functions, migration patterns of fish, change in relative species abundances, habitat fragmentation, abundance of fish and game species, loss of wetland communities and associated species in south Florida (Everglades), habitat degradation

Actions to reduce risk:

- Restore/modify channels to create habitat diversity
- Maintain/improve habitat quality to enhance the resilience of aquatic habitats to changing conditions
- Identify and protect resilient (high ecological integrity and functionally healthy) aquatic ecosystems and buffers that are not yet impacted by development
- Identify and prioritize protection of corridors between aquatic systems and between these areas and associated upland habitats to promote species migration corridors.
- Restore and/or protect riparian buffers to reduce stormwater sheetflow, to decrease non-climate stressors
    - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
    - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
    - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
    - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
    - Look for opportunities to provide incentives
        - ✓ Financial assistance for buffers – University of Minnesota extension has compiled a list of mostly federal sources of buffer incentive programs (http://bit.ly/1QWg3vS)
- Maintain canopy cover near spring runs to reduce thermal stress and evaporation
- Maintain local habitats and microhabitats especially for aquatic caves (e.g., plant trees to keep temperature down, remove or prevent the growth of harmful algae)
- Encourage landowner cost share programs
    - ✓ FL HB7157 – tax exemption for real property used for conservation properties (http://www.dep.state.fl.us/lands/arc_conservation.htm)
    - ✓ UF IFAS – (https://edis.ifas.ufl.edu/uw194)

Research/Monitoring:

- Analyze fisheries surveys for shifting populations
- Research succession in terms of different communities using these habitats
- Monitor salt wedge intrusion in streams
- Monitor community movements (e.g. *Vallisneria americana* beds moving with salinity shifts)
- Monitor aquatic systems for introductions/increases in invasive species; treat areas per prescription
- Monitor native vegetation as density and distribution increases for other native, more tolerant species
- Set photo monitoring stations

Outreach (internal and external):

- Engage hunting and angling communities to support watershed planning and wetland conservation programs
- Work with stakeholders to identify educational opportunities
- Work with volunteers to control invasive species
    - ✓ http://www.fleppc.org/landowners.htm - landowners guide to exotic plants (http://bit.ly/1S6Fg4b)
- Actively engage with communities to minimize urban encroachment
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Encourage citizen scientists to increase tracking of populations temporally and spatially (to track phenology), contribute to national efforts

Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: phenology mismatches, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, species ranges/extent of occurrence, community dynamics, quality or health of fish and game species, abundance of fish and game species, habitat availability for critical life cycle events

Actions to reduce risk:

- Maintain access to springs and spring runs for all species, remove physical barriers to fish movement
  - ✓ FishXing – software to assist engineers, hydrologists and fish biologists evaluate and design culverts for fish passage (http://www.stream.fs.fed.us/fishxing/)
  - ✓ Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual – (http://wdfw.wa.gov/publications/00061/)

Research/Monitoring:

- Monitor disease prevalence and occurrence (spatially and temporally)

Outreach (internal and external):

- Educate and work with fisheries participants to recognize and report irregularities in phenology indicators
- Engage hunting and angling communities to support minimum river and stream flows
- Ensure public know how to report new disease occurrences for fish and game
- Encourage citizen scientists to increase tracking of populations temporally and spatially (to track phenology), contribute to national efforts

9.2.3 ISOLATED WATERS

Coarse Filter Description: Isolated waters are lakes, and wetlands that are not connected to other freshwater habitats.

Habitat Categories Included: Ephemeral Ponds/Wetlands, Ponds, Lakes, Depression Marshes, Cypress Domes

Primary Climatic Shifts:

- **Changes in Precipitation** - Amount, Duration, Timing
- **Changes in extreme events** - Flood, Drought
- **Sea Level Rise**- Groundwater intrusion

Ecological Consequence: Altered Disturbance Regime

Outcomes can include: altered natural fire regime, altered sediment transport processes, changes in surface runoff, and altered erosion.

Actions to reduce risk:

- Restore riparian areas to increase water retention and uptake of soil retention and reduce impacts of flood events, erosion, and sedimentation
  - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
  - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
  - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
  - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
- Maintain floodplains as undeveloped areas
- Practice prescribed fire management to maintain fuel loads and natural conditions

Outreach (internal and external):

- Implement outreach to increase public understanding of the benefits of fire management and increased wildfire risks due to climate change
  - ✓ Example messages and audiences have been identified in "East Gulf Coastal Plain Joint Venture- A Burning Issue Prescribed Fire and Fire-adapted Habitats of the East Gulf Coastal Plain" - http://bit.ly/1Y2JITE
  - ✓ United States Forest Service- Social Science to improve Fuels Management - http://1.usa.gov/1RjXI5T
- Work with communities to improve stormwater runoff negatively impacting natural habitats and encourage groundwater recharge options through low impact development and retrofits
  - ✓ Montgomery County Rainscapes - encourages reducing stormwater runoff from private, institutional and commercial properties through technical and financial assistance (http://bit.ly/1Y5UjND)
  - ✓ Retrofit Existing Stormwater Infrastructure – the Chesapeake Stormwater Network has compiled a long list of stormwater retrofitting resources
  - ✓ Incorporating Low Impact Development into Municipal Stormwater Programs – (http://1.usa.gov/1Qohr7c)
  - ✓ Low Impact Development- Urban Design Tools - (http://bit.ly/1VTCBvw)

Ecological Consequence: Hydrologic Factors

Outcomes can include changes to: hydrology, flood frequency/extent, groundwater table (recharge), water levels, hydroperiod, drought/flood cycles, pollutants, nutrient loading, nutrients, water temperatures, sediment loadings (turbidity)

Actions to reduce risk:

- Restore and/or protect riparian buffers to reduce sheetflow stormwater runoff, to decrease non-climate stressors
  - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
- Encourage best management practices to reduce sources of land-based pollutant and nutrient loads impacting species and habitats
  - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
  - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Policies and incentives for decreasing impervious surface
  - ✓ Impervious Cover TMDL's are a new approach being piloted to address the impacts of urbanization on water quality (http://1.usa.gov/21K0PiF)
  - ✓ Chesapeake Stormwater Network - Impervious surface disconnection resources – (http://bit.ly/1RkZMkr)
- Modify water management (timing & amount of releases from water control structures), promote water use and allocation measures to protect critical habitats, including possible incentives for municipal and agricultural water conservation
- Engage in partnerships to encourage consistent management programs across jurisdictional boundaries
- Reduce roadway and paved area construction near aquatic systems to maintain natural drainage patterns
  - ✓ Reduce bare ground adjacent to isolated wetlands (enforce erosion control measures for adjacent construction sites and other disturbances) FL DEP - Muddy Water Blues Workshops for stakeholders to learn about erosion control methods (http://bit.ly/1QvQxM4)
- Maintain floodplains as undeveloped areas and protect wetlands for floodwater storage
- When possible, enhance habitat to improve fish recruitment during drought
- Create, maintain and enforce minimum flows to prevent harmful drawdown of groundwater and allow recharge

- Maintain natural canopy cover levels to reduce increased temperatures and evaporation of the water
  - May include reducing canopy cover along streams and within ephemeral wetlands that historically had a more herbaceous community structure
- Conduct hydrological restoration of disturbed areas to slow runoff and increase water retention and increase hydroperiod
- Reduce roadway and paved area construction near aquatic systems to maintain natural hydrology

Research/Monitoring:

- Monitoring of groundwater table
  - ✓ FL USGS Water Science Center – currently maintains over 100 groundwater monitoring stations across the state (http://on.doi.gov/1Qr2q4B)

Outreach (internal and external):

- Actively engage with communities to minimize urban encroachment
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Enhance outreach regarding impacts of fertilizer which contribute to increased nutrient loads
  - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
  - ✓ Urban Fertilizer Management – Chesapeake Stormwater Network has compiled a list of urban fertilizer resources (http://bit.ly/1OUJyXz)
  - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources
- Enhance outreach efforts to correlate water quality and habitat health to improve public stewardship and support actions to improve water quality
- Promote proper use of pesticides
  - ✓ UF IFAS – Pesticide and water quality resources (http://bit.ly/1RMEXuZ)
  - ✓ University of California - pesticide impacts on water quality (http://bit.ly/1OVcCye
- Engage hunting and angling communities to support water conservation efforts
- Encourage landowners/public land managers to exclude roads from lake edges or through wetlands
- Work with small municipalities, counties and industry to address unpaved road sediment and stormwater runoff issues

- ✓ The University of New Hampshire Technology Transfer Center – compilation of resources related to sedimentation from dirt roads and bmp's (http://bit.ly/2555Hhx)
- ✓ Better Unpaved Roads for Nature and People –(http://bit.ly/1U8Z22M)
- ✓ Rural Roads Active Management Program - Champlain Watershed Improvement Coalition of New York (http://bit.ly/1RPxlFL)

- Work with communities to improve stormwater runoff negatively impacting natural habitats and encourage groundwater recharge options through low impact development
  - ✓ Montgomery County Rainscapes - encourages reducing stormwater runoff from private, institutional and commercial properties through technical and financial assistance (http://bit.ly/1Y5UjND)
  - ✓ Retrofit Existing Stormwater Infrastructure – the Chesapeake Stormwater Network has compiled a long list of stormwater retrofitting resources
  - ✓ Incorporating Low Impact Development into Municipal Stormwater Programs – (http://1.usa.gov/1Qohr7c)
  - ✓ Low Impact Development- Urban Design Tools - (http://bit.ly/1VTCBvw)

Ecological Consequence: Altered habitats

Outcomes can include changes to: community composition, dominant species, habitat extent, habitat quality and condition, spatial/temporal functions, relative species abundances, spatial distribution, habitat fragmentation, abundance of fish and game species, habitat degradation, current access locations, species-specific flood induce mortality, soil chemistry

Actions to reduce risk:

- Use GIS and other tools to identify important (and potentially resilient) wetland areas and to ensure that a variety of these habitats are included in land protection planning
- Restore and/or protect riparian buffers to reduce sheetflow stormwater runoff, to decrease non-climate stressors
  - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
- Maintain/improve habitat quality to enhance the resilience of isolated waters to changing conditions, selecting plant species that are expected to be better adapted to future climate conditions
- Preserve aquatic systems and buffers that are not yet impacted by human development
- Strengthen protection of isolated waterbodies

- Develop strategies to deal with changes in lake access points
  - ✓ National Park Service- installed vertical bars on docks to improve boater safety during drought periods (http://1.usa.gov/1pv4lN6)
  - ✓ Michigan Sea Grant- Helping Marina and Harbor Operators Respond to Climate Change (http://bit.ly/1LrxLFu)
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
- Select plant species for restoration efforts that are expected to be better adapted to future climate and hydrological conditions, especially after extreme storm events (e.g., hurricanes)
- Encourage harvest of non-native species
- Promote protection of native species, when feasible
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands
- Avoid timber harvest adjacent to wetlands in favor of harvesting methods that maintain a greater canopy cover (e.g., patch/selection cuts); if clearcuts are unavoidable, limit cuts to small areas that are narrow and irregular in shape
  - ✓ FL Dept. of Agriculture and Consumer Services – Silviculture Best Management Practices (http://bit.ly/1oVdxJD)
- Work with small municipalities and counties to address unpaved road sediment to ephemeral wetlands
  - ✓ The University of New Hampshire Technology Transfer Center – compilation of resources related to sedimentation from dirt roads and bmp's (http://bit.ly/2555Hhx)
  - ✓ Better Unpaved Roads for Nature and People –(http://bit.ly/1U8Z22M)
  - ✓ Rural Roads Active Management Program - Champlain Watershed Improvement Coalition of New York (http://bit.ly/1RPxIFL)
- Strengthen protection of water bodies that are most vulnerable to climate change
- Reconnect fragmented habitat, where appropriate
- Encourage landowner enrollment in conservation easements to increase habitat base
  - ✓ NRCS EQIP - (http://1.usa.gov/1VWAbMx)
  - ✓ FL HB7157 – tax exemption for real property used for conservation properties (http://www.dep.state.fl.us/lands/arc_conservation.htm)
  - ✓ UF IFAS – (https://edis.ifas.ufl.edu/uw194)
- Maintain canopy cover near run to reduce warming and evaporation of water
- Maintain local habitats and microhabitats especially (e.g., plant trees to keep temperature down, remove or prevent the growth of harmful algae)
- Restore natural hydrology
- Monitor isolated waters for introductions/increases in invasive species; treat areas per prescription.
- Consider allowing shift in community composition, where appropriate
- Promote water use and allocation measures to protect critical habitats

- Work with small municipalities and counties to address unpaved road sediment and runoff issues
    - ✓ The University of New Hampshire Technology Transfer Center – compilation of resources related to sedimentation from dirt roads and bmp's (http://bit.ly/2555Hhx)
    - ✓ Better Unpaved Roads for Nature and People –(http://bit.ly/1U8Z22M)
    - ✓ Rural Roads Active Management Program - Champlain Watershed Improvement Coalition of New York (http://bit.ly/1RPxlFL)

Research/Monitoring:

- Set up photo stations to monitor habitat conditions

Outreach (internal and external):

- Engage hunting and angling communities to support watershed planning and wetland conservation programs
- Work with volunteers to control invasive species
    - ✓ http://www.fleppc.org/landowners.htm - landowners guide to exotic plants (http://bit.ly/1S6Fg4b)
- Actively engage with communities to minimize urban encroachment
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Encourage citizen scientists to increase tracking of populations temporally and spatially (to track phenology), contribute to national efforts

Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: phenology mismatches, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, species ranges/extent of occurrence, community dynamics, quality or health of fish and game species, abundance of fish and game species, habitat availability on critical annual life cycle events

Actions to reduce risk:

- Re-evaluate fishery management, habitat management and water quality standards where doing so could increase recruitment
- Identify and prioritize protection of corridors between aquatic systems and between these areas and associated upland habitats to promote species migration corridors.
- Use harvest regulations to protect game species
- When possible, enhance habitat to improve fish recruitment during drought
- Use harvest regulations to protect adult sport fish

Research/Monitoring:

- Monitor disease prevalence and occurrence (spatially and temporally)
- Research relocate threatened/endangered species to appropriate sites newly created by climate change trends

Outreach (internal and external):

- Educate and work with fisheries participants to recognize and report irregularities in phenology indicators
- Ensure public know how to report new disease occurrences for fish and game
- Encourage citizen scientists to increase tracking of populations temporally and spatially (to track phenology), contribute to national efforts

9.2.4 FORESTED WETLANDS

Coarse Filter Description: Forested wetlands are areas with varying associations of wetland-dependent or adapted conifers and hardwood trees. However, all of these areas are predominantly forested and at least seasonally inundated or saturated.

Habitat Categories Included: Cypress Swamp, Floodplain Forests, Forested Wetlands, Hydric Hammock, Bottomland Hardwood Forests, Bay Swamp

Primary Climatic Shifts:

- **Changes in Precipitation** - Amount, Duration, Timing
- **Changes in extreme events** - Flood, Drought
- **Sea Level Rise-** Salinity, Inundation

Ecological Consequence: Altered Disturbance Regime

Outcomes can include changes to: natural fire regime and erosion.

Actions to reduce risk:

- Restore riparian areas to increase water retention and uptake of soil retention and reduce impacts of flood events, erosion, and sedimentation
  - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
  - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
  - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
  - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
- Maintain floodplains as undeveloped areas and protect forested wetlands for floodwater storage
- Participate in High Water Mark Initiative efforts with local communities or separately after flooding events - https://www.fema.gov/high-water-mark-initiative
- Practice prescribed fire management to maintain fuel loads and natural conditions
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands
- Publically funded culverts should be sized and set at elevations to properly accommodate increased stream flow and fauna passage (encourage the same of privately funded culverts)
- Inventory culverts
  - ✓ Northwest Florida Stream crossing field survey procedures- http://1.usa.gov/25wC74Y

Outreach (internal and external):

- Implement outreach to increase public understanding of the benefits of fire management and increased wildfire risks due to climate change
  - ✓ Example messages and audiences have been identified in "East Gulf Coastal Plain Joint Venture- A Burning Issue Prescribed Fire and Fire-adapted Habitats of the East Gulf Coastal Plain" - http://bit.ly/1Y2JITE
  - ✓ United States Forest Service- Social Science to improve Fuels Management - http://1.usa.gov/1RjXI5T

- Work with communities on to reduce stormwater runoff and improve water quality
    - ✓ Montgomery County Rainscapes - encourages reducing stormwater runoff from private, institutional and commercial properties through technical and financial assistance (http://bit.ly/1Y5UjND)
    - ✓ Retrofit Existing Stormwater Infrastructure – the Chesapeake Stormwater Network has compiled a long list of stormwater retrofitting resources
    - ✓ Incorporating Low Impact Development into Municipal Stormwater Programs – (http://1.usa.gov/1Qohr7c)
    - ✓ Low Impact Development- Urban Design Tools - (http://bit.ly/1VTCBvw)
- Work with counties, local municipalities and regional planning councils to incorporate natural resources adaptation strategies in comprehensive plans and hazard planning efforts, reviewing draft plans as personnel time allows
    - Provide example plans that incorporate natural resources adaptation strategies
    - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
    - ✓ Incorporating Sea Level Change Scenarios at the Local Level- (http://1.usa.gov/1L6F6dz)

Ecological Consequence: Hydrologic Factors

Outcomes can include changes to: hydrology, flood frequency/extent, groundwater, streamflow, water levels, hydroperiods, drought/flood cycles, pollutants, nutrient loading, turbidity

Actions to reduce risk:

- Restore and/or protect riparian buffers to reduce runoff, incentivize when possible
    - MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
- Encourage best management practices to reduce sources of land-based pollutant and nutrient loads impacting species and habitats
    - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Promote management practices discouraging pesticide application in the rainy season
- Collaborate with other agencies to ensure new water control structures have consideration for the public natural resources (natural habitats and wildlife downstream)

- Policies and incentives for decreasing impervious surfaces
  - ✓ Impervious Cover TMDL's are a new approach being piloted to address the impacts of urbanization on water quality (http://1.usa.gov/21K0PiF)
  - ✓ Chesapeake Stormwater Network - Impervious surface disconnection resources – (http://bit.ly/1RkZMkr)
- Participate in High Water Mark Initiative efforts with local communities or separately after flooding events - https://www.fema.gov/high-water-mark-initiative
- Encourage water management districts to manage for in-stream flow
- Modify water management (timing & amount of releases from water control structures)
- Engage in partnerships to encourage consistent water management programs across jurisdictional boundaries
- Reduce roadway and paved area construction near sensitive systems to maintain natural hydrology
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands.
- Reduce bare ground adjacent to sensitive coastal habitats, enforce erosion control measures
  - ✓ FL DEP - Muddy Water Blues Workshops for stakeholders to learn about erosion control methods (http://bit.ly/1QvQxM4)
- Reduce point and nonpoint sources of pollutants and nutrients (N, P, toxins, etc.) from agricultural and residential land use activities
  - ✓ Leaves, nutrient pollution and homeowner outreach in Wisconsin - http://bit.ly/1RsfnZL
  - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
  - ✓ Urban Fertilizer Management – Chesapeake Stormwater Network has compiled a list of urban fertilizer resources (http://bit.ly/1OUJyXz)
  - ✓ UF IFAS – Pesticide and water quality resources (http://bit.ly/1RMEXuZ)
  - ✓ University of California - pesticide impacts on water quality (http://bit.ly/1OVcCye)
  - ✓ Think about personal pollution - http://www.tappwater.org/
- Maintain floodplains as undeveloped areas and protect interior forested wetlands for floodwater storage
- Promote water use and allocation measures to protect critical habitats, including possible incentives for municipal and agricultural water conservation
- Improve riparian zone and re-connect floodplains (e.g., removing dams, replacing culverts)
  - ✓ Floodplain Restoration and Stormwater Management: Guidance and Case Study – (http://bit.ly/1TTiqzU)
  - ✓ USDA NRCS- Natural Channel and Floodplain Restoration – (http://1.usa.gov/1QP5qow)
  - ✓ FSA Conservation Reserve Program- Floodplain Wetlands Initiative – (http://1.usa.gov/1L6JhWB)
  - ✓ Stream Simulation- US Forest Service, An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings (http://1.usa.gov/1pqIaY1)

- Reduce roadway and paved area construction near forested wetlands to maintain natural hydrology
- Reconnect fragmented habitat, when feasible
- When possible, enhance habitat to improve fish recruitment during drought
- Remove ditches to deter saltwater intrusion and restore natural water flow
- Publically funded culverts should be sized and set at elevations to properly accommodate increased stream flow and fauna passage (encourage the same of privately funded culverts)

Research/Monitoring:

- Monitor pollutants
- Monitoring of stream flows
    - ✓ FL USGS Water Science Center – currently maintains over 500 streamflow stations across the state (http://on.doi.gov/1QvSZlO)

Outreach (internal and external):

- Engage hunting and angling communities to support minimum river and stream flows
- Actively engage with communities to minimize urban encroachment
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Education regarding on appropriate use fertilizers and pesticides and impacts on water quality, potentially incentives to reduce use
    - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
    - ✓ Urban Fertilizer Management – Chesapeake Stormwater Network has compiled a list of urban fertilizer resources (http://bit.ly/1OUJyXz)
    - ✓ UF IFAS – Pesticide and water quality resources (http://bit.ly/1RMEXuZ)
    - ✓ University of California - pesticide impacts on water quality (http://bit.ly/1OVcCye
- Enhance outreach efforts to correlate water quality and habitat health to improve public stewardship and support actions to improve water quality
- Actively engage with communities to minimize urban encroachment
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)

Ecological Consequence: Altered habitats

Outcomes can include changes to: community composition, dominant species, salinity, habitat extent, habitat quality, habitat condition, spatial/temporal functions, fish migration patterns, relative species abundances, spatial distribution, habitat fragmentation, abundance of fish and game species, habitat degradation, habitat fragmentation

Actions to reduce risk:

- Restore/modify channels to create habitat diversity
- Encourage migration of habitats, remove barriers when feasible to allow inland shifts of coastal forested habitats affected by increased salinity
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
- Identify and prioritize protection of corridors between forested wetland areas and associated upland habitats to promote species migration
- Identify important (and potentially resilient) aquatic systems and wetland areas to serve as refugia and provide opportunities for range shifts, prioritize inclusion in land protection planning efforts to ensure redundancy of protected forested wetland types and minimize risk of loss across the landscape
- Maintain/improve habitat quality to enhance the resilience of forested wetland and aquatic habitats to changing conditions
- Improve riparian zone and floodplain connectivity by removing restrictions between rivers and floodplains (e.g., removing dams and culvert modification)
    - ✓ Floodplain Restoration and Stormwater Management: Guidance and Case Study – (http://bit.ly/1TTiqzU)
    - ✓ USDA NRCS- Natural Channel and Floodplain Restoration – (http://1.usa.gov/1QP5qow)
    - ✓ FSA Conservation Reserve Program- Floodplain Wetlands Initiative – (http://1.usa.gov/1L6JhWB)
    - ✓ Stream Simulation- US Forest Service, An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings (http://1.usa.gov/1pqlaY1)
    - ✓ For channelized systems with limited room- Two-Stage Channel Design (http://1.usa.gov/1QyAvxE)
- Preserve forested wetlands and aquatic systems and their buffers that are not yet impacted by human development
- Strengthen protection of water bodies that are most vulnerable to climate change
- Reconnect fragmented habitat
- Develop strategies to deal with changes in river and lake access points
- Wetland soil manipulation (disking, etc.) to improve habitat quality
- Ensure redundancy of habitat types

- Select native plant species for restoration efforts that are expected to be better adapted to future climate conditions, especially after extreme storm events (e.g., hurricanes)
- Encourage harvest of non-native species
- Consider allowing shift in community composition, where appropriate
- Promote protection of native species, when feasible
- Encourage the passage of state regulations with supporting local level zoning and planning ordinances to strengthen protection of forested wetlands.
- Encourage landowner cost share programs and enrollment in conservation easements to increase habitat base
    - ✓ NRCS EQIP - (http://1.usa.gov/1VWAbMx)
    - ✓ FL HB7157 – tax exemption for real property used for conservation properties (http://www.dep.state.fl.us/lands/arc_conservation.htm)
    - ✓ UF IFAS – (https://edis.ifas.ufl.edu/uw194)
- Restore and/or protect riparian buffers to reduce stormwater runoff from adjacent development, look for opportunities to incentivize riparian buffer protection or restoration
    - ✓ MD DNR Riparian Forest Buffer Design and Maintenance- http://bit.ly/1LBIVHH
    - ✓ USDA Stream Restoration - (http://go.usa.gov/BvNA)
    - ✓ Proper Functioning Condition- methodology for assessing riparian areas and wetlands (http://on.doi.gov/1SlM7J1)
    - ✓ Stream restoration – the Chesapeake Stormwater Network has compiled stream restoration resources (http://bit.ly/1Qvd1JC)
    - Look for opportunities to provide incentives
        - Financial assistance for buffers – University of Minnesota extension has compiled a list of mostly federal sources of buffer incentive programs (http://bit.ly/1QWg3vS)
- Avoid timber harvest near shoreline in favor of harvesting methods that maintain a greater canopy cover (e.g., patch/selection cuts); if clearcuts are unavoidable, limit cuts to small areas that are narrow and irregular in shape
    - ✓ FL Dept. of Agriculture and Consumer Services – Silviculture Best Management Practices (http://bit.ly/1oVdxJD)
- Remove ditches to deter saltwater intrusion and restore natural water flow

Research/Monitoring:

- Analyze fisheries surveys for shifting populations
- Research succession in terms of different communities using these habitats
- Monitor natural community shifts
- Monitor aquatic systems for introductions/increases in invasive species; treat areas per prescription
- Monitor vegetation as density and distribution shift with environmental changes
- Set photo monitoring stations

Outreach (internal and external):

- Engage hunting and angling communities to support watershed planning and wetland conservation programs
- Work with stakeholders to identify educational opportunities
- Work with volunteers to control invasive species
  - ✓ http://www.fleppc.org/landowners.htm - landowners guide to exotic plants (http://bit.ly/1S6Fg4b)
- Actively engage with communities to minimize urban encroachment
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Encourage citizen scientists to increase tracking of populations temporally and spatially (to track phenology), contribute to national efforts

Ecological Consequence: Altered Population Health & Survival

Outcomes can include change in: phenology, biotic interactions, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, species ranges/extent of occurrence, community dynamics, quality or health of fish and game species, abundance of fish and game species, habitat availability for critical life cycle events

Actions to reduce risk:

- Re-evaluate fishery management and water quality standards where doing so could increase recruitment
- Remove physical barriers to fish movement
  - ✓ FishXing – software to assist engineers, hydrologists and fish biologists evaluate and design culverts for fish passage (http://www.stream.fs.fed.us/fishxing/)
  - ✓ Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual – (http://wdfw.wa.gov/publications/00061/)
- Identify and prioritize protection of corridors between aquatic systems and between these areas and associated upland habitats to promote species migration corridors.
- Work with local municipalities and counties to target water quality improvement projects directly impacting priority recruitment areas
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)

- ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
- ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/

- Use harvest regulations to protect adult sport fish and game species
- Encourage construction of movement passages
- When possible, enhance habitat to improve fish recruitment during drought

Research/Monitoring:

- Monitor disease prevalence and occurrence (spatially and temporally)

Outreach (internal and external):

- Work with local fishing and hunting industries to promote minimum impact through habitat use activities
- Education of recreational users on the importance of phenology factors and how they relate to regulations/closures
- Educate and work with fisheries participants to recognize and report irregularities in phenology indicators
- Engage hunting and angling communities to support minimum river and stream flows
- Ensure public know how to report new disease occurrences for fish and game
- Encourage citizen scientists to increase tracking of populations temporally and spatially (to track phenology), contribute to national efforts

9.2.5 SHOREFACE – NEARSHORE (SUBLITTORAL)

Coarse Filter Description: Zone of Nearshore currents, includes STS and EEZ, Upper mixing zone of thermocline, euphotic zone

Habitat Categories Included: Coral Reef, hard bottom, sand and mud (soft bottom), Bays/Inlets/Open Ocean, Submerged Aquatic Vegetation

Primary Climatic Shifts:

- **Changes in Precipitation** - Amount, Duration, Timing
- **Changes in extreme events** - Floods, droughts
- **Changes in water temperature profiles -**Ocean currents (upwelling); Circulation (polar ice melt and SLR)
- **Changes in CO_2** – Acidification

> “The news about coral reef ecosystems is alarming. Rapid warming, accelerating pollution, and destructive fishing are decimating coral reefs faster than they can adapt for survival.”
>
> NOAA Coral Reef Conservation Program. 2009. NOAA Coral Reef Conservation Program Goals & Objectives 2010-2015. http://coralreef.noaa.gov/aboutcrcp/strategy/currentgoals/resources/3threats_go.pdf

- **Sea Level Rise**- Height, zonation

Ecological Consequence: Altered Disturbance Regime

Outcomes can include changes to: surface runoff, sediment transport processes (coast to ocean), coastal accretion and sedimentation and patterns of erosion

Actions to reduce risk:

- Restore and/or protect coastal vegetation and upland buffers to reduce the impact of increased disturbance events (stormwater runoff and sediment transport)
  - ✓ Model Coastal Riparian Buffer Ordinance for Georgia’s Local Governments – (http://bit.ly/1Y6W2Cs)
- Manage surface water runoff in order to minimize impacts on sensitive nearshore coastal habitats
- Require coastal counties to address foreshore habitat conservation and adaptation in all comprehensive planning activities-for example restricting development and other land uses that alter disturbance processes that adversely impact sensitive nearshore coastal habitats
  - Provide example plans that incorporate natural resources adaptation strategies
  - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
  - ✓ Incorporating Sea Level Change Scenarios at the Local Level- (http://1.usa.gov/1L6F6dz)
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)

- ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7

- Reduce human activities affecting runoff and sediment transport that pose a threat to nearshore coastal habitats
  - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Restrict development and other land uses that alter disturbance processes in sensitive areas, set up buffer reserves and management areas

Research/Monitoring:

- Continue and expand disturbance monitoring activities with the goal of establishing early warning systems and management responses to address impacts on nearshore coastal habitats
- Evaluate and research the removal of sediment from sensitive habitats
- Assess impact of beach renourishment activities and develop adaptive management plans to minimize effects
- Research "zone of impact" for specific habitats prone to disturbance from specific coastal counties/communities
- Research existing coastal county plans for natural resources adaptation inclusion
- Sediment traps between nearshore coastal habitats (especially SAV) and the source of sediment

Outreach (internal and external):

- Work with counties, local municipalities and regional planning councils to incorporate natural resources adaptation strategies in comprehensive plans and hazard planning efforts, reviewing draft plans as personnel time allows
  - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
  - ✓ Incorporating Sea Level Change Scenarios at the Local Level- (http://1.usa.gov/1L6F6dz)
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)

- ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)

- Educate planners on importance of coastal habitat preservation (including serving as hazard buffers), climate change and incorporation into long range planning efforts
    - Provide example plans that incorporate natural resources adaptation strategies
    - ✓ TNC Conservation Gateway – climate risk and resilience resources (http://bit.ly/21w2Cme)

Ecological Consequence: Hydrologic Factors

Outcomes can include changes to: pollutants, nutrient loading, sedimentation (turbidity), salinity, periodicity of upwelling (and predictability), currents, anoxic/hypoxic conditions, temperature

Actions to reduce risk:

- Restore and/or protect upland buffers to reduce runoff
    - ✓ Model Coastal Riparian Buffer Ordinance for Georgia's Local Governments – (http://bit.ly/1Y6W2Cs)
- Encourage best management practices to reduce sources of land-based pollutant and nutrient loads impacting species and habitats that are highly vulnerable to climate change
    - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Promote management practices that discourage the application of pesticides in the rainy season
- Modification of stormwater outfalls that negatively affect nearshore habitats, and/or install BMP treatment upstream of sensitive habitats
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Cooperate with agencies and user groups outside of Florida to manage water flow and sedimentation

Research/Monitoring:

- Monitor toxic levels of pollutants
- Research flooding and sedimentation trends
- Research differences in natural vs. human influenced sedimentation and pollution on SAV, mangrove, fringing reefs

Outreach (internal and external):

- Actively engage with communities to minimize urban encroachment
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Enhance outreach efforts to correlate water quality and habitat health to improve public stewardship and support actions to improve water quality, especially nutrients

Ecological Consequence: Altered habitats

Outcomes can include changes to: habitat extent, spatial/temporal functions and distribution, fish migration patterns, relative species diversity/richness, reef smothering (sedimentation, macroalgae), salinity, habitat fragmentation, species composition, community structure, productivity, degraded habitats

Actions to reduce risk:

- Develop coordinated foreshore habitat management plans that establish a connected network of protected areas across the entire Florida shoreline
- Establish protections for transitional habitats that will provide for range shifts and serve as potential climate refugia
- Restore nearshore habitats
- Restore or create new bivalve or annelid reefs
- Anticipate shift in reef community dynamics and develop scenarios to aid in the survival and management of priority species
    - Develop proactive sustainability plans to offset changes and shifts in zonation
    - Prioritize model development to aid in this goal
- Limited direct management options; address by minimizing risk and increasing resilience through additional marine protections (see pattern)
- Re-evaluate restoration and enhancement activities to address need for broader coverage at different spatial and temporal scales at the community level rather than species
- Establish more protected areas and reserves with diverse stakeholder buy-in (private/public partnerships) and stewardship
- Evaluate alternate/cyclical/rotational use of habitats for recreational and commercial activities
- Assess current FWC species and habitat management process to develop a multispecies/habitat approach for integration at the community or ecosystem level
- Recover impacted shoreline habitats with species adapted to changing conditions
- Re-direct or limit boating or other recreational and commercial pressures at sensitive sites where intense use could further reduce habitat cover

Research/Monitoring:

- Analyze fisheries surveys for shifting populations
- Research succession in terms of different communities using these habitats
- Assess existing restoration programs and identify opportunities for expanding multispecies cultures, integrated aquaculture opportunities
- Assess extent of onshore dredging activity impact and establish additional buffers/protected zones
- Develop sets of indicators for phenology responses
- Develop ecological-response models for habitat transitions in response to climate change
- Educate recreational users on the importance of phenology factors and how they relate to regulations/closures
- Research expanding live-rock techniques to larger scale to promote recolonization
- Monitor, map, and research shifts in communities; identify sensitive and resilient species

Outreach (internal and external):

- Work with stakeholders to identify educational opportunities
  - ✓ Sea Level Rise Adaptation Strategy Role-Play Game - http://bit.ly/21a43Xk
- Engage volunteers for reef restoration, protection and stewardship efforts
- Encourage oyster shell recycling efforts
  - ✓ Oyster recovery partnership shell recycling list (http://oysterrecovery.org/florida/)
- Promote more environmental awareness and stewardship
  - ✓ Coastal Florida Adopt-A-Wetland Training Manual - http://bit.ly/1QtT7lP
- Work with local fishing, boating, and diving industries to promote minimum impact through habitat use activities
  - ✓ FL FWC- derelict trap clean-up information (http://bit.ly/1TrYPr4)
  - ✓ WeCrabNJ.org – uses Community Based Social Marketing to encourage behavior changes to prevent fishing gear and other debris from ending up in coastal waters, providing training and outreach materials

Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: phenology, bleaching events, direct mortality due to algal outbreaks, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, migration patterns, trophic interactions, nutrient distributions, migratory patterns, changes in life history dynamics, trophic dynamics, fish migration patterns, local extinctions, relative species abundances, community health, food web stability, loss of keystone species

Actions to reduce risk:

- Re-evaluate fishery management and water quality standards where doing so could increase recruitment
- Re-direct or limit boating or other recreational and commercial pressures at sensitive sites where intense use could further reduce habitat cover
- Greater attention to phenology cues
- Assess current FWC species and habitat management process to develop a multispecies/habitat approach for integration at the community or ecosystem level
- Develop broad based species recovery and management plans with more emphasis on incentivizing and stewardship
- Evaluate educational programs and initiatives on species protection, adoption, and recovery to expand public participation

Research/Monitoring:

- Monitor disease prevalence and occurrence (spatially and temporally)
- Monitor settlement rates
- Continue reef monitoring efforts
- Monitor phenology
- Research potential synergistic effects of multi-climate change drivers on already stressed systems and model outcomes for management

Outreach (internal and external):

- Work with local fishing, boating and diving industries to promote minimum impact through habitat use activities
- Educate and work with fisheries participants to recognize and report irregularities in phenology indicators
- Evaluate adopt-a-species programs at all educational and public levels

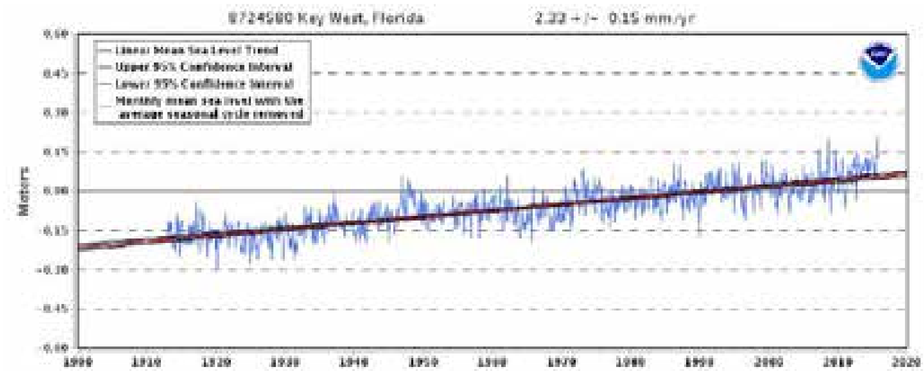
9.2.6 SHORELINE – FORESHORE

Coarse Filter Description: The foreshore portion of shoreline is the area between the median high water line and median low water line (owned by the state) and is thus, tidally influenced. These habitats serve as important fish nursery areas and being nearshore are also susceptible to degradation from adjacent development.

Habitat Categories Included: Bays/Inlets/Open Ocean, Coastal Tidal River or Stream, Mangrove, Bivalve Reef, Coral Reef, Salt Marsh, Tidal Flat, Submerged Aquatic Vegetation, Grass flats, Annelid reef

Primary Climatic Shifts:

- **Changes in Precipitation** - Amount, Duration, Timing
- **Changes in extreme events** - Floods, droughts
- **Changes in water temperature profiles -**Ocean currents; Circulation (polar ice melt and SLR)
- **Changes in CO_2** – Acidification
- **Sea level Rise**- Inundation (Figure 9.1)



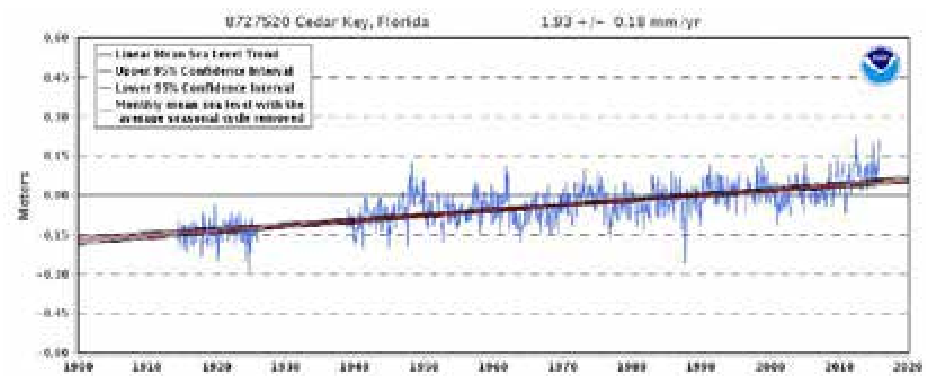


Figure 9.1. Tide gauge data for the Key West (top) and Cedar Key (bottom). Data courtesy of NOAA (http://tidesandcurrents.noaa.gov/sltrends/sltrends.html).

Ecological Consequence: Altered Disturbance Regime

Outcomes can include changes in: surface runoff, sediment transport processes (coast to ocean) and patterns of erosion.

Actions to reduce risk:

- Restore and/or protect coastal vegetation and upland buffers to reduce stormwater runoff, sediment transport, and siltation of nearshore habitats

- ✓ Model Coastal Riparian Buffer Ordinance for Georgia's Local Governments – (http://bit.ly/1Y6W2Cs)
- Manage surface water runoff in order to minimize impacts on sensitive SAV, mangrove, and diverse reef communities (short and long-term considerations)
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Address foreshore habitat conservation and adaptation in coastal county comprehensive planning activities
- Work with communities and landowners to choose vegetation, living shorelines, oyster reef restoration, or hybrid approaches in favor of traditional hard armoring
  - ✓ NOAA Living Shoreline Guidance – (http://1.usa.gov/1M9m2eU)
  - ✓ http://floridalivingshorelines.com/
  - ✓ Natural and Structural Measures for Shoreline Stabilization – (http://1.usa.gov/1VVcZRh)
  - ✓ http://livingshorelinesforum.org/resources - includes FL specific resources

CASE STUDY

CORAL BAY WATERSHED, ST. JOHN, USVI

The watershed management plan was created through an integral collaboration of non-government and government organizations with an overarching goal to improve water quality and ecological health of Coral Bay. The original plan was completed in 2008, implementation of recommended actions is ongoing and has included many roadway drainage projects to decrease sediment loadings into the sensitive nearshore environment which supports mangroves, coral reefs and sea grasses. Additional work has been done or is underway to address trash and marine debris issues. Numerous outreach community initiatives and targeted turbidity sampling after rain have been undertaken by the Coral Bay Community Council.

Research/Monitoring:

- Continue and expand disturbance monitoring activities with the goal of establishing early warning systems and management responses to address impacts on SAV, mangrove and reef communities
- Research flooding and sedimentation trends
- Research differences in natural vs. human influenced sedimentation and pollution on SAV, mangrove, fringing reefs and other near-shore habitats
- Monitor, map and research shifts in communities; identify sensitive and resilient species
- Evaluate and research the removal of sediment from sensitive habitats

- Assess impact of beach renourishment activities and develop adaptive management plans to minimize effects
- Research "zone of impact" for specific habitats prone to disturbance from specific coastal counties/communities
- Research existing coastal county plans for natural resources adaptation inclusion
- Install Surface Elevation Tables in sensitive areas to improve future SLAMM efforts and monitor ability of critical habitats to maintain elevation with sea level rise

Outreach (internal and external):

- Work with communities to reduce stormwater runoff negatively impacted natural habitats
  - ✓ Montgomery County Rainscapes - encourages reducing stormwater runoff from private, institutional and commercial properties through technical and financial assistance (http://bit.ly/1Y5UjND)
  - ✓ Retrofit Existing Stormwater Infrastructure – the Chesapeake Stormwater Network has compiled a long list of stormwater retrofitting resources
  - ✓ Incorporating Low Impact Development into Municipal Stormwater Programs – (http://1.usa.gov/1Qohr7c)
  - ✓ Low Impact Development- Urban Design Tools - (http://bit.ly/1VTCBvw)
- Work with counties, local municipalities and regional planning councils to incorporate natural resources adaptation strategies in comprehensive plans and hazard planning efforts, reviewing draft plans as personnel time allows
  - Provide example plans that incorporate natural resources adaptation strategies
  - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
  - ✓ Incorporating Sea Level Change Scenarios at the Local Level- (http://1.usa.gov/1L6F6dz)
- Educate planners on importance of coastal habitat preservation (including serving as hazard buffers), climate change and incorporation into long range planning efforts
  - TNC Conservation Gateway – climate risk and resilience resources (http://bit.ly/21w2Cme)

Ecological Consequence: Hydrologic Factors

Outcomes can include changes in: hydrology, flood frequency/extent, groundwater (saltwater intrusion), streamflow, water levels, hydroperiod, drought/flood cycles, water temperature, water chemistry, pollutants, nutrient loading, sedimentation (turbidity), circulation patterns, wave energy, soil chemistry

Actions to reduce risk:

> IN ADDITION TO PROTECTION OF UPSLOPE HABITATS, OTHER MANAGEMENT ACTIONS WILL BE NECESSARY TO MITIGATE THE EFFECTS OF SEA LEVEL RISE ON COASTAL WETLAND SYSTEMS. POSSIBLE MEASURES INCLUDE THE RESTORATION AND ENHANCEMENT OF OYSTER REEFS AS A WAY TO REDUCE WAVE-GENERATED EROSION AND ENHANCE ACCRETION OF THE SEDIMENTS REQUIRED TO BUILD SALT MARSH AT THE SALT MARSH-TIDAL SALT TRANSITION ZONE.
>
> Greselbracht *et al*. 2011

- Restore and/or protect riparian buffers to reduce runoff
  - ✓ Model Coastal Riparian Buffer Ordinance for Georgia's Local Governments – (http://bit.ly/1Y6W2Cs)
- Modification of stormwater outfalls that negatively affect nearshore habitats, and/or install BMP's upstream of sensitive habitats
  - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/
- Encourage best management practices to reduce sources of land-based pollutant and nutrient loads impacting species and habitats
  - ✓ Pinellas County – fertilizer ordinance limits sale and use of fertilizer with nitrogen or phosphorus from June 1 – September 30 to protect aquatic resources (http://bit.ly/1ppur3L)
- Promote management practices that discourage the application of pesticides in the rainy season

Research/Monitoring:

- Monitor toxic levels of pollutants
- Monitor salt wedge intrusion in rivers
- Monitor surface water flow
- Monitor groundwater flow and water quality
  - ✓ FL USGS Water Science Center – currently maintains over 100 groundwater monitoring stations across the state (http://on.doi.gov/1Qr2q4B)

Outreach (internal and external):

- Engage hunting and angling communities to support minimum river and stream flows
- Actively engage with communities to minimize urban encroachment
  - ✓ Model Coastal Riparian Buffer Ordinance for Georgia's Local Governments – (http://bit.ly/1Y6W2Cs)
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)

- ✓ [OpenNSPECT](http://1.usa.gov/21Kpgg7) – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Enhance outreach regarding impacts of fertilizer on water quality
  - ✓ Urban Fertilizer Management - Chesapeake Stormwater Network has compiled fertilizer related resources (http://bit.ly/1OUJyXz)
  - ✓ Leaves, nutrient pollution and homeowner outreach in Wisconsin - http://bit.ly/1RsfnZL
  - ✓ Managing Fertilizer for Lawn Use – (http://bit.ly/1QWjra4)
- Enhance outreach efforts to correlate water quality and habitat health to improve public stewardship and support actions to improve water quality

Ecological Consequence: Altered habitats

Outcomes can include changes in: ecological services, habitat extent, habitat quality and condition, spatial/temporal functions, migration patterns of fish, relative species abundances, spatial distribution, reef smothering (sedimentation, macroalgae), salinity, habitat fragmentation, pest/disease prevalence, degraded SAV and reef communities, species composition, community structure and composition, soil chemistry

Actions to reduce risk:

- Develop coordinated foreshore habitat management plans that establish a connected network of protected areas across the entire Florida shoreline
- Use SLAMM outputs to identify and preserve priority migratory pathways for salt marsh habitats, remove barriers when feasible
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
- Establish protections for transitional habitats that will provide for range shifts and serve as potential climate refugia
- Restore nearshore habitats
- Work with volunteers to control invasive species

Research/Monitoring:

- Analyze fisheries surveys for shifting populations
- Research succession in terms of different communities using these habitats
- Continue and expand disturbance monitoring activities with the goal of establishing early warning systems and management responses to address impacts on nearshore coastal habitats
- Monitor salt wedge intrusion in rivers

- Monitor, map and research shifts in communities; identify sensitive and resilient species
    - Long-term, statewide monitoring using consistent methodology
    - ✓ Sentinels of climate change: coastal indicators of wildlife and ecosystem change in Long Island Sound (http://bit.ly/1M39dD8)
- Monitor community movements (e.g. *Vallisneria americana* beds moving with salinity shifts)
- Assess existing restoration programs and identify opportunities for expanding multispecies cultures
- Research expanding live rock techniques to larger scale
- Encourage periodic bioblitz events to capture comprehensive inventories, repeat periodically (5 to 10 years)

Outreach (internal and external):

- Educate on disposal options of fishing gear if a fishery is no longer viable due to population shifts
- Engage hunting and angling communities to support watershed planning and wetland conservation programs
    - ✓ Coastal Florida Adopt-A-Wetland Training Manual - http://bit.ly/1QtT7lP
- Work with stakeholders to identify educational opportunities
    - ✓ Sea Level Rise Adaptation Strategy Role-Play Game - http://bit.ly/21a43Xk
- Engage volunteers for reef restoration and protection efforts
- Encourage oyster shell recycling efforts
    - ✓ Oyster recovery partnership shell recycling list (http://oysterrecovery.org/florida/)

Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: phenology, bleaching events, biotic interactions, direct mortality due to algal outbreaks, pest/disease prevalence, metabolic/physiologic processes, growth and reproduction, mortality events, species ranges/extent of occurrence, recruitment patterns, migration pattern, trophic interactions, trophic dynamics, nutrient distributions (spatial and temporal), and migratory patterns

Actions to reduce risk:

- Re-evaluate fishery management and water quality standards where doing so could increase recruitment
- Re-direct or limit boating or other recreational and commercial pressures at sensitive sites where intense use could further reduce habitat cover
- Recover impacted shoreline habitats with species adapted to changing conditions

- Work with local municipalities and counties to target water quality improvement projects directly impacting priority recruitment areas
    - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
    - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
    - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
    - ✓ Interactive Stormwater BMP Tool- http://impervious.werf.org/

Research/Monitoring:

- Monitor disease prevalence and occurrence (spatially and temporally)
- Monitor settlement rates
- Continue reef monitoring efforts
- Monitor phenology

Outreach (internal and external):

- Work with local fishing, boating and diving industries to promote minimum impact through habitat use activities
- Education of recreational users on the importance of phenology factors and how they relate to regulations/closures
- Educate and work with fisheries participants to recognize and report irregularities in phenology indicators

9.2.7 SHORELINE – BACKSHORE

Coarse Filter Description: Above Median High Water line (Extent of Privately owned lands), essentially terrestrial

Habitat Categories Included: Beach/Surf Zone, Coastal Strand

Primary Climatic Shifts:

- **Sea Level Rise**- Inundation

Ecological Consequence: Altered Coastal Processes

Outcomes can include changes in: coastal accretion and sedimentation, altered erosion, spatial distribution and extent of habitat, habitat degradation, habitat fragmentation, sediment transport, species ranges/extent of occurrence, migration patterns, trophic interactions, metabolic/physiologic processes

Actions to reduce risk:

- Coordinate with County staff to incorporate SLR adaptation strategies into comprehensive plans and post-storm redevelopment activities (e.g. restricting development and other land uses that alter coastal processes)
  - ✓ Climate Adaptation for Coastal Communities Training- trains participants to recognize, identify, examine, evaluate and apply adaptation strategies at the local level – (http://1.usa.gov/1Qv28rn)
  - ✓ Incorporating Sea Level Change Scenarios at the Local Level- (http://1.usa.gov/1L6F6dz)
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)
  - ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Manage coastal vegetation to improve habitat for species that require early successional (e.g., open beach) habitat
- Consider reduction of other human activities (e.g., mechanical beach cleaning, armoring) affecting sand loss and/or species disturbance that pose a threat to beach communities
  - ✓ National Audubon Society- social marketing campaign: beach-nesting birds - http://bit.ly/1QnBdzTv
- Restore and/or protect coastal vegetation to reduce the impact of increased disturbance events (intense storms, increased erosion) and encourage aeolian sand capture
  - ✓ FL DEP Coastal Vegetation and Dune Protection Publications - http://bit.ly/1oRPDyC
  - ✓ Palm Beach County- Guidelines for Beach and Dune Management- http://bit.ly/1Y5d2sF
  - ✓ FL DEP Building Back the Sand Dunes - http://bit.ly/1WWYudy
- Identify inland areas under private ownership that may be connected to coastal terrestrial habitats that could receive protection through Florida forever and similar funding mechanisms (to enable habitat inland migration and improve connectivity)
- Restrict development and other land uses that alter disturbance processes in sensitive areas
  - ✓ Habitat priority planner – free, easy to use tool aids in decision making regarding conservation, restoration and planning efforts (http://1.usa.gov/21K4Bso)
  - ✓ NatureServe Vista – allows land planners to assess scenarios (http://bit.ly/1TvSIC8)

- ✓ OpenNSPECT – investigates potential water quality impacts from development (http://1.usa.gov/21Kpgg7)
- Work with communities and landowners to choose vegetation, living shorelines, oyster reef restoration, or hybrid approaches in favor of traditional hard armoring
    - ✓ NOAA Living Shoreline Guidance – (http://1.usa.gov/1M9m2eU)
    - ✓ http://floridalivingshorelines.com/
    - ✓ Natural and Structural Measures for Shoreline Stabilization – (http://1.usa.gov/1VVcZRh)
    - ✓ http://livingshorelinesforum.org/resources - includes FL specific resources
- Identify potential refugia, corridors, and relocation sites

Research/Monitoring:

- Research relocating threatened/endangered species to appropriate sites newly created by climate change trends
- Monitor phenology cues and conduct adaptive management practices if possible
- Research offshore sand sources which allow short-term accretion of beach resources

Outreach (internal and external):

- Provide examples of comprehensive planning efforts that incorporate future consideration of climate change impact to natural resources
- Educate planners on importance of a healthy resilient beach/dune system to protect against coastal hazards
    - ✓ TNC Conservation Gateway – climate risk and resilience resources (http://bit.ly/21w2Cme)
- Educate on benefits of structural walkways over a dune rather than pedestrian pathways through dunes- dunes with holes don't offer the same level of protection
    - ✓ FL DEP Beach and Dune Walkover Guidelines - http://bit.ly/1L6uFqo

Ecological Consequence: Altered Population Health & Survival

Outcomes can include changes in: growth and reproduction, mortality events, species ranges/extent of occurrence, recruitment patterns, migration patterns, trophic interactions, trophic dynamics

Research/Monitoring:

- Research relocating threatened/endangered species to appropriate sites newly created by climate change trends, identifying critical sediment traits (e.g. moisture, grain size) is consistent

Outreach (internal and external):

- Promote "keeping cats indoors" to protect beach nesting activities

9.2.8 OFFSHORE

Filter Description: The offshore adaptation category consists of deep waters generally beyond the influence of wave action (with the possible exception of hurricane induced waves), the mixed zone of thermocline, and the euphotic zone to shelf seafloor. However these waters are within the EEZ.

Habitat Categories Included: Open Ocean

Ecological Consequence: Hydrologic Factors

Outcomes can include changes in: water temperature, water chemistry, pollutants, nutrient loading, circulation patterns, wave energy

Research/Monitoring:

- Monitoring
  - ✓ Ocean Climate Indicators: a monitoring inventory and plan for tracking climate change in the North-central California Coast and Ocean region - http://1.usa.gov/1nijCyB

CASE STUDIES

NORTH-CENTRAL CALIFORNIA COAST AND OCEAN REGION, CALIFORNIA

The Gulf of Farallones National Marine Sanctuary and more than 50 partners developed monitoring strategy for climate change indicators specific to the region. Twelve ocean climate indicators were selected, many of which were already being monitored. The plan outlines recommendations, objectives, metrics, priority levels, funding needs and implementation timelines.- http://1.usa.gov/1nijCyB

GULF OF MAINE RESEARCH INSTITUTE

In 2012, due to unusually warm water in the Gulf of Maine, Lobsters migrated inshore weeks earlier than usual. Processers weren't ready, prices dropped amidst the early high landings. The Gulf of Maine Research Institute developed a lobster forecast based on water temperatures from the NERACOOS buoy array to better predict lobster landings by week.

Mills *et al*. 2013

OCEANTIPPINGPOINTS.ORG

The Ocean Tipping Points project brings together experts from the natural and social scientists, law and policy experts, and managers. There are case studies and research summaries related to the impacts in the marine realm.

9.2.9 UPLAND FOREST

Filter Description: The broad upland forest filter includes all other upland forest types not included in the previous subsets. Forest with overstory of varying associations of conifers and hardwood trees, shrubs and forbs; type dependent upon soils, topography

Habitats Included: Pineland, Sandhill, Tropical Hardwood Hammock, Natural Pineland, Scrubby Flatwoods, Sandhill, Hardwood Hammock

Ecological Consequence: Altered habitats

Outcomes can include changes to: community composition, dominant species, salinity, habitat extent, habitat quality, habitat condition, spatial/temporal functions, fish migration patterns, relative species abundances, spatial distribution, habitat fragmentation, abundance of game species, habitat degradation, habitat fragmentation

Actions to reduce risk:

- Plant with a mix of species that can survive in a diverse range of future climate conditions
- Practice prescribed fire management to maintain fuel loads and natural conditions
- Cultivate multiple age classes of tree and understory species to protect stands from pests or diseases that may be more virulent to specific life stages or specific species, by spreading risk among many species there is a decreased chance the entire ecosystem will be susceptible
  - ✓ Forest Service Adaptation Resources - http://www.nrs.fs.fed.us/pubs/40543

Research/Monitoring:

- Monitor disease occurrences

CASE STUDY

NORTHWOODS, MINNESOTA

Future conditions in Minnesota's Northwoods are expected to be warmer and drier, which may be favorable to a different suite of tree species than the current boreal forest composition. Maintaining a functioning forest is a priority, so re-planting efforts focus on new mixes of native tree species that are adapted to a wider range of climatic conditions that have been modeled to be appropriate for anticipated future conditions.

ADAPTATION WORKBOOK, NORTHERN INSTITUTE OF APPLIED CLIMATE SCIENCE

Created to assist with inclusion of climate change impacts on forest ecosystems, to develop management and conservation activities to prepare for changing conditions. - http://adaptationworkbook.org/

10 ADDITIONAL RESOURCES FOR CLIMATE CHANGE ADAPTATION

There are a variety of other resources that can aid in the development of climate adaptation strategies. These include tools, case studies, and advisory documents that have been developed by federal and state agencies, NGO's, academic institutions and partnerships. While this is by no means and exhaustive list, it does provide a good starting point for researching strategy development methods and approaches and builds on the information already contained in this guide.

10.1 KEY CLIMATE ADAPTATION RESOURCES:

Please consult the resources outlined below to determine the methods that best apply to your own system and to find case studies and examples that are most relevant to the development of climate change adaptation strategies for the species and ecosystems you are responsible for managing.

10.1.1 METHODS AND STRATEGY GUIDES

NATIONAL FISH, WILDLIFE, AND PLANTS CLIMATE ADAPTATION STRATEGY

National Fish, Wildlife, and Plants Climate Adaptation Steering Committee and Joint Implementation Working Group. 2012 and 2014. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington D.C. wildlifeadaptationstrategy.gov

http://www.wildlifeadaptationstrategy.gov/

Background: This nationwide strategy is the product of an interagency steering committee, consisting of members at both the state and federal levels. The overall strategy as described by the steering committee was designed to "inspire and enable natural resource managers and other decision-makers to take action to anticipate and adapt to a changing climate." The committee's first strategy document, released in 2012, serves as a call to action and outlines seven steps, or goals, to safeguard the nation's natural resources from climate change. Two years after this document was released, a joint implementation working group delivered a progress report termed "Taking Action" that provided plentiful examples of how these goals were being addressed across the nation.

Key Findings:

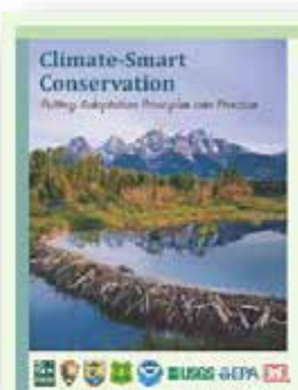
The goals outlined in these documents were as follows:

1. Conserve habitat to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate.

2. Manage species and habitats to protect ecosystem functions and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.
3. Enhance capacity for effective management in a changing climate.
4. Support adaptive management in a changing climate through integrated observation and monitoring and use of decision support tools.
5. Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.
6. Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate.
7. Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

According to the progress report document, these goals have begun to be addressed across the country, and are visible in a wide array of case studies. The example projects included in this progress report are not exhaustive and are simply meant to serve as examples that demonstrate the diversity of ways climate change can be addressed across agencies and ecosystems. Please consult this document for detailed examples.

Significance: Together these broad strategy documents provide a vision of nationwide climate change adaptation. They are a helpful resource to help ensure that any state or federal agency is not failing to consider the climate adaptation needs or strategy relevant to the entire country. These documents provide an excellent starting point for examining broad approaches to climate adaptation and provide key successes that serve as example for how to best to begin employing appropriate climate adaptation strategies.



CLIMATE SMART CONSERVATION: PUTTING ADAPTATION INTO PRACTICE

Stein, B.A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. National Wildlife Federation, Washington D.C.

http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation.aspx

Background: The Climate-Smart Conservation Guide is a product of an expert workgroup organized by the National Wildlife Federation. This workgroup included experts from a variety of federal and state government agencies as well as several NGOs. This guide offers strategies for carrying out conservation in a rapidly changing climate.

Key Findings: The guide first defines climate-smart conservation as, “the intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities.”

The guide also examines four key themes of climate-smart conservation:

- act with intentionality,
- manage for change, not just persistence,
- reconsider goals, not just strategies,
- and integrate adaptation into existing work.

The goal of this guide is to aid policy makers and practitioners in recognizing, designing, and employing good climate-smart conservation strategies and goals. In short, climate-smart conservation can be described as an approach that:

- links actions to climate impacts,
- embraces forward-looking goals,
- considers the broader landscape context,
- adopts strategies robust to uncertainty,
- employs agile and informed management,
- minimized its carbon footprint,
- accounts for climate influence on its success,
- safeguards people and nature,
- and avoids maladaptation.

Finally, this guide provides a step by step outline of the general activities necessary for designing and enacting climate-smart conservation (Figure 10.1):

1. Define planning purpose and scope.
2. Assess climate impacts and vulnerabilities.
3. Review/revise conservation goals and objectives.
4. Identify possible adaptation options.
5. Evaluate and select adaptation actions.
6. Implement priority adaptation actions.
7. Track action effectiveness and ecological responses.

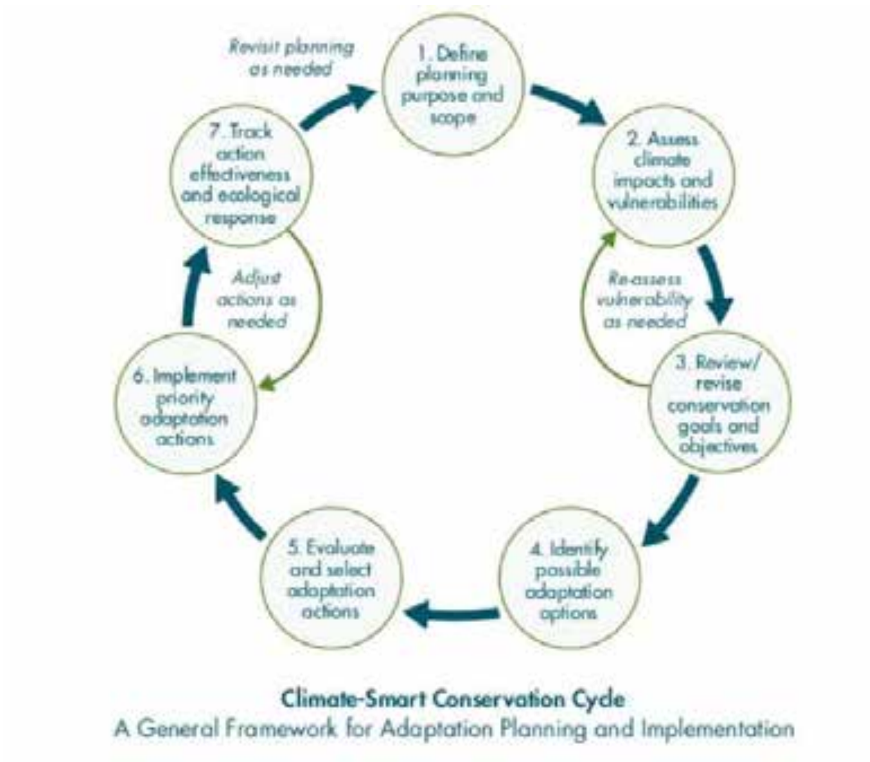


Figure 10.1. Reproduction of the Climate-Smart Conservation Cycle Flowchart.

Significance: This report is an excellent in-depth guide for employing climate adaptation goals and strategies. It provides what is perhaps the most thorough and detailed approach for doing climate smart conservation and adaptation. In short, this guide is a one stop shop for climate adaptation knowledge and implementation ideas and methods.

SCANNING THE CONSERVATION HORIZON: A GUIDE TO CLIMATE CHANGE VULNERABILITY ASSESSMENT.

Glick, P. B.A. Stein, and N.A. Edelson, editors. 2011. National Wildlife Federation, Washington D.C.

http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Assessing-Vulnerability.aspx

Background: Scanning the Conservation Horizon is a broad document put together by the National Wildlife Federation and is intended to help fish and wildlife researchers and managers as well as other conservation practitioners recognize how vulnerability assessments can help them manage natural resources in an era of rapid climate change. The document offers guidance on developing and conducting vulnerability assessments in support of conservation and management missions and is a helpful tool when developing climate change adaptation strategies.

Key Findings:

The guide outlines its three primary objectives as follows:

1. Provide an overview of the general principles of climate change vulnerability as it relates to species, habitats, and ecosystems

2. Describe the various approaches available for assessing the components of vulnerability and address key issues and considerations related to these tools and practices

3. Highlight examples of climate change vulnerability assessment in practice among government agencies, academic institutions, and other stakeholders.

In the executive summary, the guide outlines the key steps for assessing vulnerability climate change and provides an excellent summary graphic enumerating them. That graphic has been reproduced below.

Key Steps for Assessing Vulnerability to Climate Change

Determine objectives and scope

- Identify audience, user requirements, and needed products
- Engage key internal and external stakeholders
- Establish and agree on goals and objectives
- Identify suitable assessment targets
- Determine appropriate spatial and temporal scales
- Select assessment approach based on targets, user needs, and available resources

Gather relevant data and expertise

- Review existing literature on assessment targets and climate impacts
- Reach out to subject experts on target species or systems
- Obtain or develop climatic projections, focusing on ecologically relevant variables and suitable spatial and temporal scales
- Obtain or develop ecological response projections

Assess components of vulnerability

- Evaluate climate sensitivity of assessment targets
- Determine likely exposure of targets to climatic/ecological change
- Consider adaptive capacity of targets that can moderate potential impact
- Estimate overall vulnerability of targets
- Document level of confidence or uncertainty in assessments

Apply assessment in adaptation planning

- Explore why specific targets are vulnerable to inform possible adaptation responses
- Consider how targets might fare under various management and climatic scenarios
- Share assessment results with stakeholders and decision-makers
- Use results to advance development of adaptation strategies and plans

The main text of the document provides more precise guidance touching on a variety of topics. These topics include the principle components of vulnerability, which are bulleted here:

- Sensitivity - refers to the innate characteristics of a species or system and considers tolerance to changes in such things as temperature, precipitation, fire regimes, or other key processes

- Exposure - refers to the extrinsic factors, focusing on the character, magnitude, and rate of change the species or system is likely to experience

- Adaptive Capacity - address the ability of a species or system to accommodate or cope with climate change impacts with minimal disruption.

The guide outlines that vulnerability assessments serve two key functions: to identify *which* species or systems are likely to be most strongly affected by projected changes, and to help to understand *why* these resources are likely to be vulnerable, including the interaction between climate shifts and existing stressors. Once vulnerability assessments have been conducted and policy makers and actors have this information, they can move forward with the best adaptation strategies.

The guide also states that adaptation efforts generally fall under one or more of the following approaches:

(1) building resistance to climate-related stressors as a way of maintaining high-priority species or systems;

(2) enhancing resilience in order to provide species and systems with a better chance for accommodating and weathering changes; and

(3) anticipating and facilitating ecological transitions that reflect the changing environmental conditions.

A great deal of this methodological information can be seen in the figure below, outlining the broad framework for assessing climate change vulnerability and subsequently developing climate change adaptation strategies. The general framework is represented in Figure 10.2.

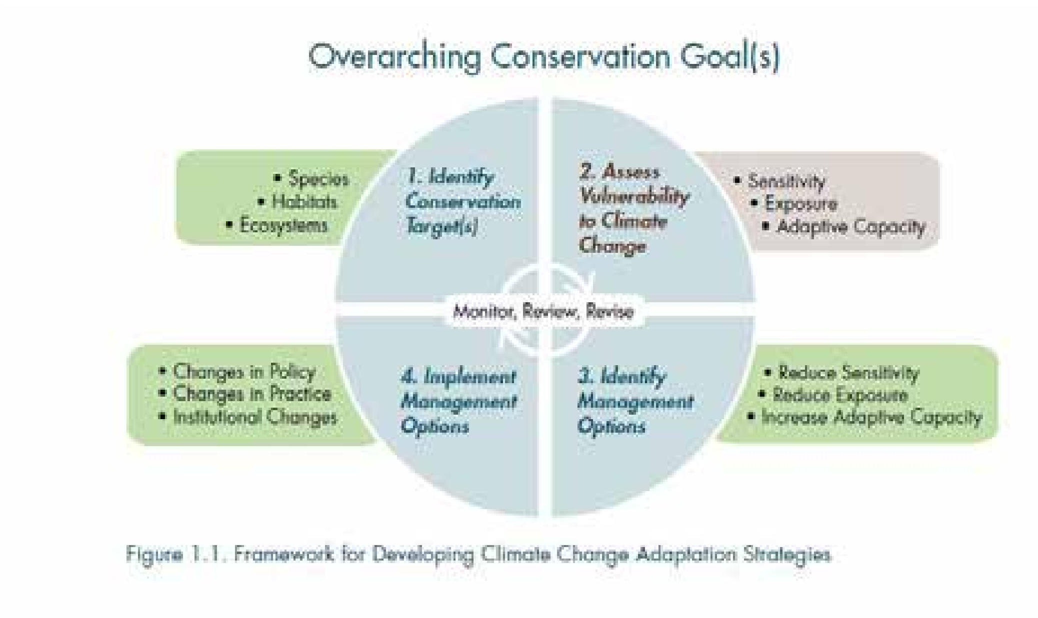


Figure 10.2. Reproduction of flowchart of framework for climate change adaptation strategy development.

<u>Significance</u>: In short, while there is no single, correct approach to conducting vulnerability assessments, this document enumerates the most important factors for consideration. This document helps explain the basic concepts behind vulnerability assessments and provides guidance to managers and conservationists in conducting those assessments for the ultimate purpose of adaptively managing for climate change.

10.1.2 VULNERABILITY ASSESSMENT RESOURCES

INTEGRATING CLIMATE CHANGE VULNERABILITY ASSESSMENTS INTO ADAPTATION PLANNING

Dubois, N., A. Caldas, J. Boshoven, and A. Delach. 2011. [Final Report]. Defenders of Wildlife, Washington D.C.

http://www.defenders.org/climate-change/preparing-climate-change

Background: Another assessment that emphasizes the importance of integrating climate change vulnerability assessments into adaptation planning is a work put out by Defenders of Wildlife to advise FWC lead conservation planning in Florida. This report begins by mentioning the current FWC efforts to plan for new threats that are emerging as a result of climate change. The key purpose of this assessment was to evaluate NatureServe as a Climate Change Vulnerability Index. Specifically, the goals were to determine what ways the tool might be modified to better denote the vulnerability of wildlife and their habitats to climate change and identify ways to use these tools to develop climate adaptation strategies.

Key Findings: Following discussions with relevant species experts, test assessments were conducted on a diverse set of 21 species. These assessments helped identify factors that contribute to climate change vulnerability and estimate the relationships those factors have with each other and the target species and habitats. After these assessments, facilitated sessions with various experts and managers demonstrated to participants a process by which similar vulnerability assessments can be incorporated into climate adaptation planning, specifically by broadening existing plans such as the SWAP.

Based on assessments and discussions, the document outlined key lessons learned when conducting vulnerability assessments. They are as follows:

- A vulnerability assessment should provide a framework for assessing vulnerability to climate change by unpacking vulnerability into its constituent parts.
- Recognize that a priori assumptions about which species will be most vulnerable may not be accurate.
- Consider the appropriate unit of analysis prior to conducting the assessment.
- Understand the limitations of any particular approach.
- Recognize that factors may be interpreted or scored differently by individual experts.
- Differentiate between uncertainties associated with the different components of vulnerability.
- Interpret outputs appropriately.
- Consider involving multiple experts and stakeholders.

Significance: This case study assessment importantly outlines these lessons in detail and has various recommendations for working climate change vulnerability into existing management plans. For more specific information as to the points emphasized or examples using case study species, please consult the assessment itself.

A VULNERABILITY ASSESSMENT OF 300 SPECIES IN FLORIDA: THREATS FROM SEA LEVEL RISE, LAND USE, AND CLIMATE CHANGE

Reece, J.S., R.F. Noss, J. Oetting, T. Hoctor, M. Volk. 2013. PLoS ONE 8(11): e80658. Doi: 10.1371/journal.pone.0080658

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0080658

Background: In this study, the authors applied a new tool, the Standardized Index of Vulnerability and Value Assessments or SIVVA, to assess the conservation priority of 300 species of plants and animals in Florida given projections of climate change, human land-use patterns, and SLR by the year 2100. They prioritized species under five different systems of value, ranging from a primary emphasis on vulnerability or threats to an emphasis on metrics of conservation value such as phylogenetic distinctiveness.

Key Findings: The overall results of this study reveal notable consistency in the prioritization of species across different conservation value systems. Species identified as a high priority included the Miami blue butterfly (*Cyclargus thomasi bethunebakeri*), Key tree cactus (*Pilosocereus robinii*), Florida duskywing butterfly (*Ephyriades brunnea floridensis*), and Key deer (*Odocoileus virginianus clavium*).

The approach used in this vulnerability assessment is an expert opinion-based survey that was developed to address shortcomings in other, previous vulnerability assessments. In this model, 30 criteria are distributed across four modules: vulnerability, lack of adaptive capacity, conservation value, and information availability. For each of the species assessed, experts who either study or manage them were involved in the opinion-based survey process. While this survey tool is described in detail in previous works, the authors did provide a link to an example SIVVA evaluation spreadsheet (http://noss.cos.ucf.edu/publications/sivva).

Using this method, the authors were able to narrow down an extensive list of species to the top 40 most threatened by SLR (seen in the reproduced Table 10.1), many of which were advised to be the target of new conservation and adaptation efforts. These species are enumerated in Table 10.1. For specific results from this study, please consult the original report.

*Table 10.1. Reproduced table of SIVVA results for top 40 species most threatened by SLR. These forty species consistently ranked as having the highest combined vulnerability to threats (VU), lack of adaptive capacity (LAC), conservation value (CV), and information availability (IA).***

Taxon	Species	VU	LAC	CV	IA	1	2	3	4	5
Invertebrate	*Cyclargus thomasi bethunebakeri*	0.94	0.93	0.49	0.63	3	2	1	9	6
Plant	*Pilosocereus robinii*	0.91	0.89	0.55	0.51	5	3	3	4	13
Invertebrate	*Ephyriades brunnea floridensis*	0.95	0.97	0.67	0.22	1	1	5	1	23
Mammal	*Odocoileus virginianus clavium*	0.86	0.69	0.61	0.73	31	9	2	5	2
Reptile	*Malaclemys terrapin rhizophorarum*	0.86	0.81	0.48	0.64	12	8	7	19	12
Invertebrate	*Heraclides aristodemus ponceanus*	0.89	0.78	0.47	0.53	9	10	13	26	22
Plant	*Opuntia corallicola*	0.74	0.92	0.55	0.53	27	16	11	12	15
Reptile	*Caretta caretta*	0.75	0.72	0.63	0.74	61	20	4	6	1
Invertebrate	*Cochlodinella poeyana*	0.94	0.92	0.55	0.17	4	4	22	11	56
Invertebrate	*Chlorostrymon maesites*	0.89	0.83	0.64	0.17	7	7	34	8	49
Plant	*Chamaecrista lineata keyensis*	0.82	0.89	0.46	0.47	15	15	17	30	29
Invertebrate	*Liguus fasciatus*	0.80	0.83	0.57	0.39	24	18	20	16	30
Invertebrate	*Orthalicus reses nesodryas*	0.91	0.85	0.57	0.19	6	6	33	14	52
Invertebrate	*Branchus floridanus*	0.89	0.79	0.50	0.35	8	12	29	28	42
Bird	*Ammodramus savannarum floridanus*	0.72	0.90	0.51	0.54	40	31	14	20	18
Mammal	*Puma concolor coryi*	0.68	0.77	0.70	0.67	80	34	6	2	3
Bird	*Grus americana*	0.65	0.86	0.66	0.57	65	38	10	3	9
Bird	*Charadrius alexandrinus nivosus*	0.88	0.64	0.47	0.66	28	23	16	43	16
Mammal	*Sylvilagus palustris hefneri*	0.90	0.54	0.51	0.72	43	24	15	35	10
Mammal	*Peromyscus gossypinus allapaticola*	0.72	0.81	0.53	0.69	58	35	9	18	8
Plant	*Chamaesyce deltoidea serpyllum*	0.82	0.90	0.45	0.39	11	17	25	38	43
Bird	*Aphelocoma coerulescens*	0.75	0.64	0.62	0.76	73	40	8	10	4
Bird	*Rostrhamus sociabilis plumbeus*	0.81	0.55	0.71	0.55	64	36	18	7	11
Mammal	*Microtus pennsylvanicus dukecampbelli*	0.80	0.83	0.50	0.42	25	26	28	31	33
Invertebrate	*Hojeda inaguensis*	0.91	1.00	0.46	0.17	2	5	32	22	86
Invertebrate	*Aphaostracon asthenes*	0.66	1.00	0.59	0.31	45	41	24	13	35
Plant	*Harrisia aboriginum*	0.80	0.92	0.50	0.28	16	22	39	29	55
Plant	*Eupatorium frustratum*	0.75	0.87	0.53	0.39	37	37	31	23	34
Invertebrate	*Polyphylla woodruffi*	0.83	0.90	0.46	0.31	10	19	40	41	59
Mammal	*Peromyscus polionotus trissyllepsis*	0.82	0.51	0.52	0.83	71	55	12	39	5
Invertebrate	*Euphyes pilatka klotsi*	0.91	0.71	0.50	0.31	13	21	50	42	60
Reptile	*Eretmochelys imbricata*	0.81	0.65	0.48	0.65	55	46	21	48	17
Mammal	*Neotoma floridana smalli*	0.73	0.81	0.53	0.47	54	51	27	27	28
Reptile	*Nerodia clarkii taeniata*	0.86	0.76	0.47	0.38	18	27	42	50	50
Plant	*Harrisia simpsonii*	0.79	0.90	0.50	0.28	20	32	44	34	62
Reptile	*Kinosternon baurii (FL Keys)*	0.86	0.79	0.48	0.31	17	28	49	45	63
Bird	*Picoides borealis*	0.71	0.73	0.51	0.67	69	69	19	37	14
Invertebrate	*Cyclargus ammon*	0.86	0.63	0.60	0.28	42	44	62	25	53
Reptile	*Dermochelys coriacea*	0.80	0.65	0.57	0.43	59	64	48	32	32
Invertebrate	*Eunica tatila tatilista*	0.76	0.79	0.58	0.25	46	54	56	24	61

*** Five weightings schemes are presented, corresponding to 1: stepwise (see methods), 2: 45/25/20/10 percentage weighted averaging of scores for VU, LAC, CV, and IA, respectively, 3: 25/25/25/25 weighting, 4: 20/20/50/10 weighting, and 5: 15/15/35/35 weighting. Species are sorted by the average rank across all five weighting schemes, ranging from 1st to 86th rank (where 1 indicates the highest conservation priority). Red denotes species ranked in the top quartile of this range, orange in the second quartile, yellow in the third, and green in the fourth. The number within each colored square is the relative rank of that species under that weighting scheme. Note that* *some species consistently fall within the high priority (top) quartile, while others vary depending on what type of information is emphasized in a given ranking scheme.*

Significance: This study illustrates the power of this newfound SIVVA approach since, as the authors emphasize, this method provides a way to prioritize conservation that is both quantitative and flexible and does not involve the same qualitative value judgements as other methods. Using this or a similar method would allow targeted conservation efforts to be prioritized and subsequently justified in a simple, transparent way. Thus, this work introduces a convincing vulnerability assessment method that could be used to influence the development of conservation and adaptation strategies for the species in Florida.

CLIMATE CHANGE VULNERABILITY ASSESSMENT FOR NATURAL RESOURCES MANAGEMENT: TOOLBOX OF METHODS WITH CASE STUDIES.

Johnson, K.A. 2014. Version 2.0. U.S. Fish and Wildlife Service. Arlington, Virginia

http://www.fws.gov/home/climatechange/pdf/Guide-to-Vulnerability-Assessment%20Methods-Version-2-0.pdf

Background: This serves as a compilation of climate change vulnerability assessment methodologies and case studies. The methodologies include those for species, habitats, places, ecosystems, ecosystem services, watersheds and water resources. This document was developed with intent to be a living document and updated with new vulnerability assessment methodologies.

METHODOLOGY FOR ASSESSING THE VULNERABILITY OF MARINE FISH AND SHELLFISH SPECIES TO A CHANGING CLIMATE

http://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/TM%20OSF3.pdf

Morrison, W.E., M. W. Nelson, J. F. Howard, E. J. Teeters, J. A. Hare, R. B. Griffis, J.D. Scott, and M.A. Alexander. 2015. Methodology for Assessing the Vulnerability of Marine Fish and Shellfish Species to a Changing Climate. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-OSF-3, 48 p.

Background: Climate change and multidecadal variability have been implicated in the shifting distributions, abundances, and phenology of fish and shellfish species in many marine ecosystems. This methodology uses a vulnerability assessment framework, which is applicable across multiple species and provides a relative rank of vulnerability to climate change and variability, as well as information about why a species may or may not be vulnerable. The results can help fishery managers and researchers identify highly vulnerable species and more effectively target research and assessment resources on species of highest concern.

SAVS: A SYSTEM FOR ASSESSING THE VULNERABILITY OF SPECIES

http://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/

Background: An online questionnaire developed for determining the vulnerability of terrestrial vertebrates, assessing habitat, physiology, phenology and biotic interactions.

NATURESERVE CLIMATE CHANGE VULNERABILITY INDEX (CCVI)

http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index

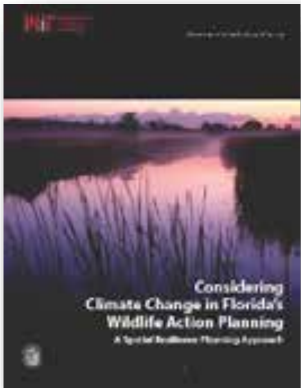
Background: CCVI is a spreadsheet assessment method for estimating a plant or animal species' relative vulnerability to climate change. It combines readily accessible information on the natural history, distribution, and management with downscaled climate predictions from tools. After completion the results can be added to a national database to enable results to be accessible to the public.

CCVATCH

http://www.ccvatch.com/

The CCVATCH is a spreadsheet-based tool to be used by those developing conservation, management, and restoration plans and policies for coastal habitats. This tool will integrate local data, knowledge and current research with climate change predictions to help identify habitats that are likely to be affected by climate change, and the ways in which they will be affected, in order to make more informed decisions about habitat management and restoration.

10.1.3 MODELING AND SCENARIO BUILDING



CONSIDERING CLIMATE CHANGE IN FLORIDA'S WILDLIFE ACTION PLANNING – A SPATIAL RESILIENCE PLANNING APPROACH.

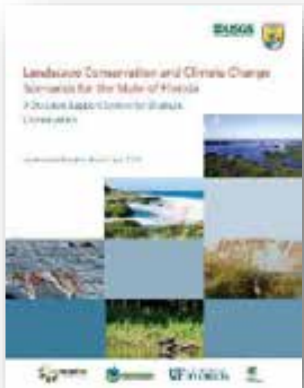
Flaxman M., and J.C. Vargas-Moreno. 2011. Cambridge MA. Research Report FWC-2011. Department of Urban Studies and Planning, Massachusetts Institute of Technology

http://myfwc.com/media/1770248/consideringclimatechange-wildlifeactionplan.pdf

Background: This study was a pilot of a new methodological approach to incorporating climate change into wildlife action planning, termed "spatial resilience planning" or SRP. This is an extension of more general spatial scenario approaches, organized specifically for the case of climate change wildlife adaptation planning. The project evaluated 5 "alternative futures" developed by a prior research venture conducted jointly by MIT, the U.S. Geological Survey, and the U.S. Fish and Wildlife Service.

Key Findings: The scenarios varied across four dimensions: climate change, human population change, land & water planning policies, and availability of public resources. Each alternative future took the form of a potential land use map, simulating climate and land cover change 50 years into the future at three time steps (2010, 2040 & 2060). Some scenarios reflected only minor differences from existing conditions while others simulated very substantial changes. A set of species was selected to test the approach. These included the American Crocodile (*Crocodylus acutus*), Key Deer (*Odocoileus virginianus clavium*), Least Tern (*Sternula antillarum*), Atlantic Salt Marsh Snake (*Nerodia clarkii taeniata*), Short-Tailed Hawk (*Buteo brachyurus*), and Florida Panther (*Puma concolor coryi*). The most vulnerable of these were the American Crocodile and Key Deer and the least vulnerable were the Florida Panther and Short-Tailed Hawk. The other species fell somewhere in between.

Significance: This new approach demonstrated that when the data are available, spatial resilience planning provides far more useful information for management actions than do traditional wildlife climate action planning methods. Thus, this report can be used to guide those who seek to apply these method approaches to other species and ecosystems, when actionable information regarding climate change is desired.



LANDSCAPE CONSERVATION AND CLIMATE CHANGE SCENARIOS FOR THE STATE OF FLORIDA – A DECISION SUPPORT SYSTEM FOR STRATEGIC CONSERVATION *

Vargas, J.C., Flaxman, and B. Fradkin. 2014. Summary for Decision Makers. GeoAdaptive LLC, Boston, MA and Geodesign Technologies Inc., San Francisco CA.

http://peninsularfloridalcc.org/page/climate-change-scenarios

Background: This project, developed in 2012 by GeoAdaptive and Geodesign Technologies for the Peninsular Florida Landscape Conservation Cooperative (PFLCC), was designed to simulate differing future scenarios based on conservation and development policies. The results of this report identify three "alternative futures" for Florida by the year 2060. Put simply, the three futures diverge by an incrementally more aggressive conservation strategy (more conservation and sustainable development). These variables lead to three disparate future for Florida with scenario one illustrating a business as usual prediction, scenario 2 predicting moderate amounts of conservation, and scenario 3 predicting broad statewide conservation.

Key Findings:

This project used a particular, 5-step methodology to develop these scenarios. The graphic included below outlines the key scenario development steps (Figure 10.3):

1. Identify driving forces.
2. Identify key trends.
3. Identify critical uncertainties.
4. Simulate plausible scenarios.
5. Discuss implications and paths.

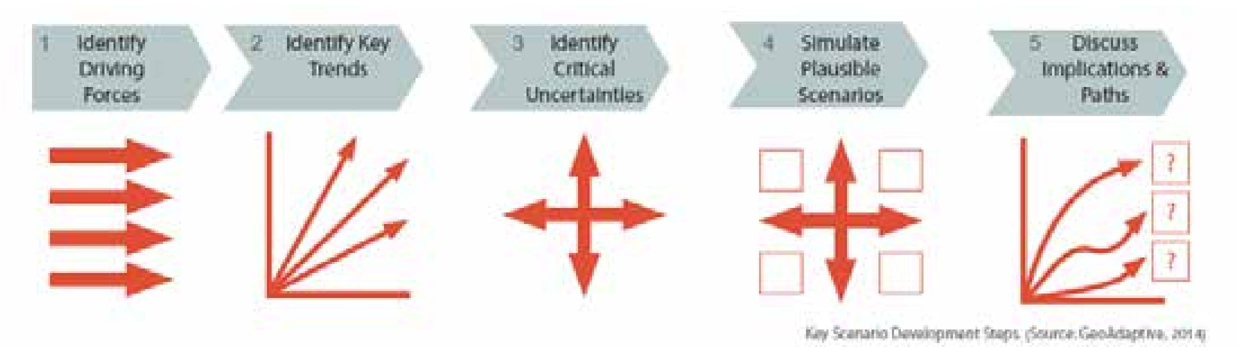


Figure 10.3. Reproduced flow/graphic chart illustrating climate change scenario development.

Using this general method, Geoadaptive and Geodesign created the three alternative futures for the state of Florida. The specific differences among the key driving forces in these models result in the three alternative futures. These differences among the three scenarios are outlined below in the reproduced figure and table describing the scenario architecture (Figure 10.3).

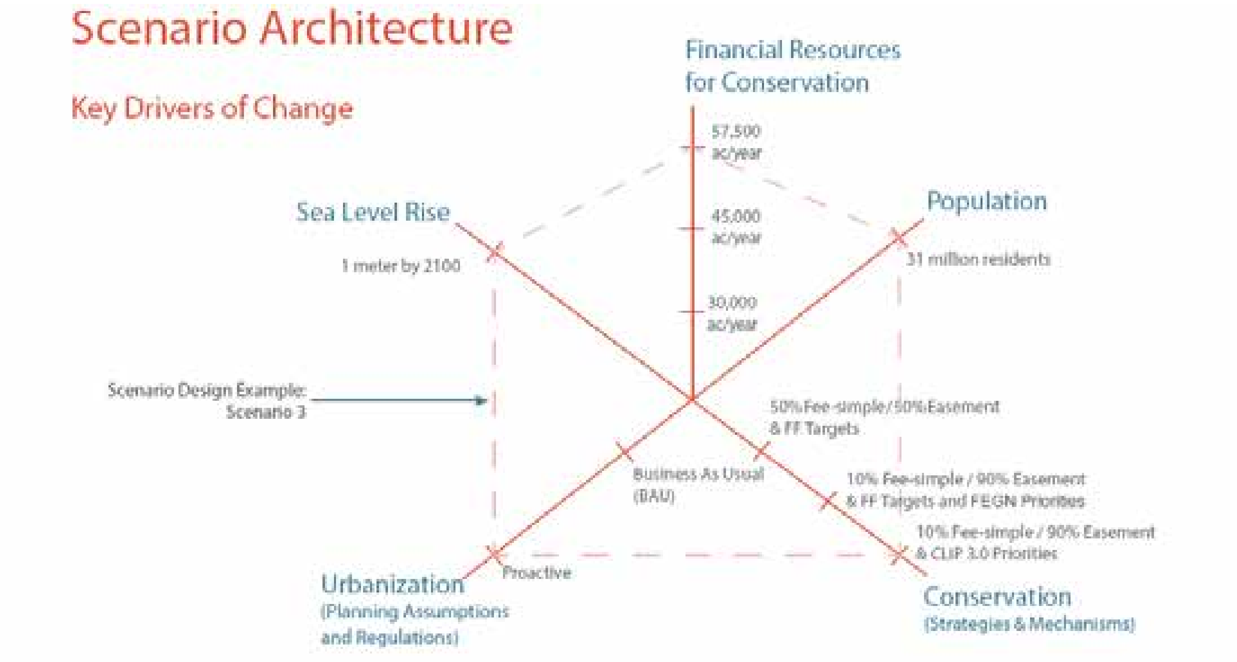


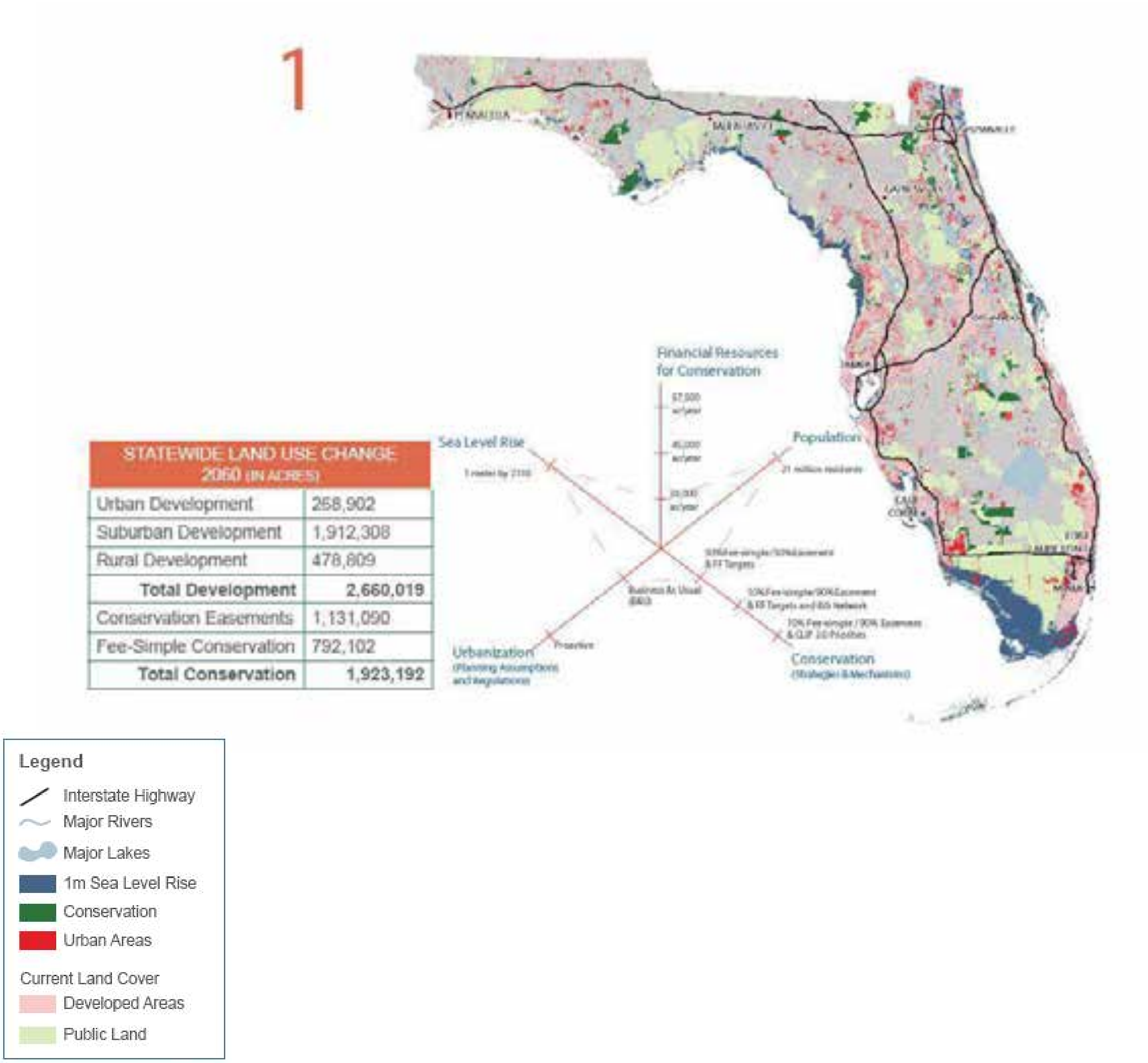
Table: Key Driving Forces

	SCENARIO 1	SCENARIO 2	SCENARIO 3
Acquisition Rate for Conservation	30,000 acres/year	45,000 acres/year	57,500 acres/year
Conservation Strategy + prioritization	50% Fee Simple 50% Easement + Florida Forever (FF) Targets	10% Fee Simple 90% Easement + Florida Forever (FF) Targets & Ecological Greenways Network (FEGN) Priorities	10% Fee Simple 90% Easement + CLIP 3.0 (Highest priority)
Minimum Lot Size for Conservation	none	none	5 acres - Fee Simple 100 acres-Easements
Population	Trend Population 31 million by 2060	Trend Population 31 million by 2060	Trend Population 31 million by 2060
Urbanization (Planning Strategy)	Business As Usual Low density greenfield development Existing distribution of density	Proactive Green infrastructure + Redevelopment + Densification	Proactive Green infrastructure + Redevelopment + Densification
Sea Level Rise	1 meter by 2100 (IPCC AR5 8500 projection)	1 meter by 2100 (IPCC AR5 8500 projection)	1 meter by 2100 (IPCC AR5 8500 projection)
	Development & conservation acquisition allowed in inundation areas	Development & conservation acquisition allowed in inundation areas	Development & conservation acquisition NOT allowed in inundation areas

- 3 acquisition rates identified to achieve conservation priorities set forth by each scenario, defined by the number of acres of conservation land per year.
- 2 primary conservation strategies which identify the breakdown of acquisition strategies between fee-simple purchases and conservation easements. The prioritization of conservation purchases was based on existing programs such as Florida Forever, Florida Ecological Greenways Network and CLIP (Version 3.0).
- The minimum size of the lots was not considered for two scenarios, however it was limited to 5 acres (Fee-simple purchases) and 100 acres (easement acquisitions.
- The projected 2060 population of 31 million remains constant throughout all scenarios.
- 2 primary planning strategies are explored, the first follows existing distribution of housing densities and is given priority over conservation needs, while the second strategy focuses on redevelopment and redensification and shifts priority to conservation needs.
- Sea level projection of 1 m remains constant throughout all scenarios.
- The allocation of development is either allowed in areas affected by sea level rise or not, depending on the scenario.

Figure 10.4. Reproduced figure and table describing the three scenario architectures used in this report.

As already mentioned, this modeling approach lead to development of three disparate futures for the state of Florida. These scenarios are further represented by the three maps reproduced below (Figure 10.5):



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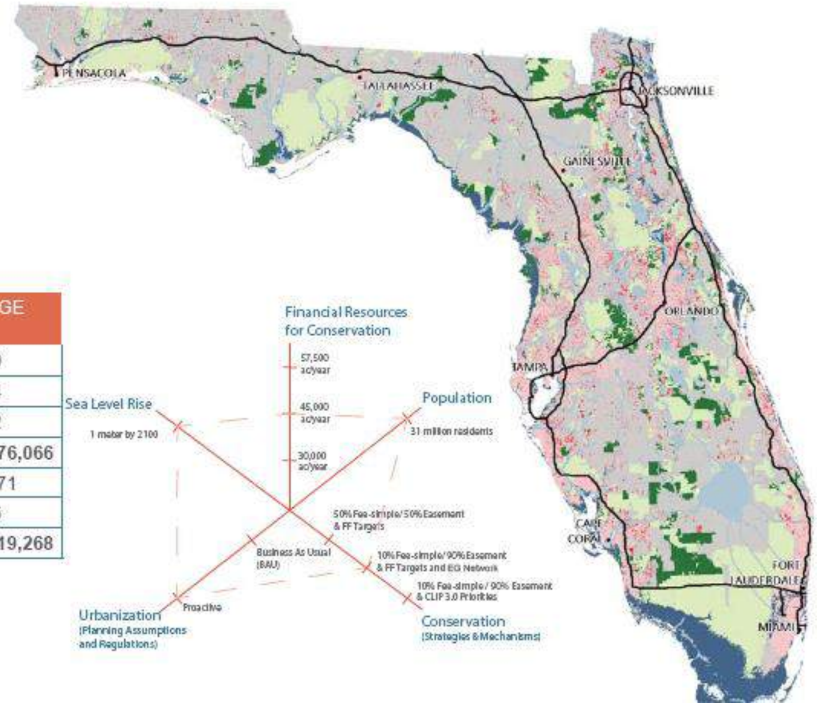
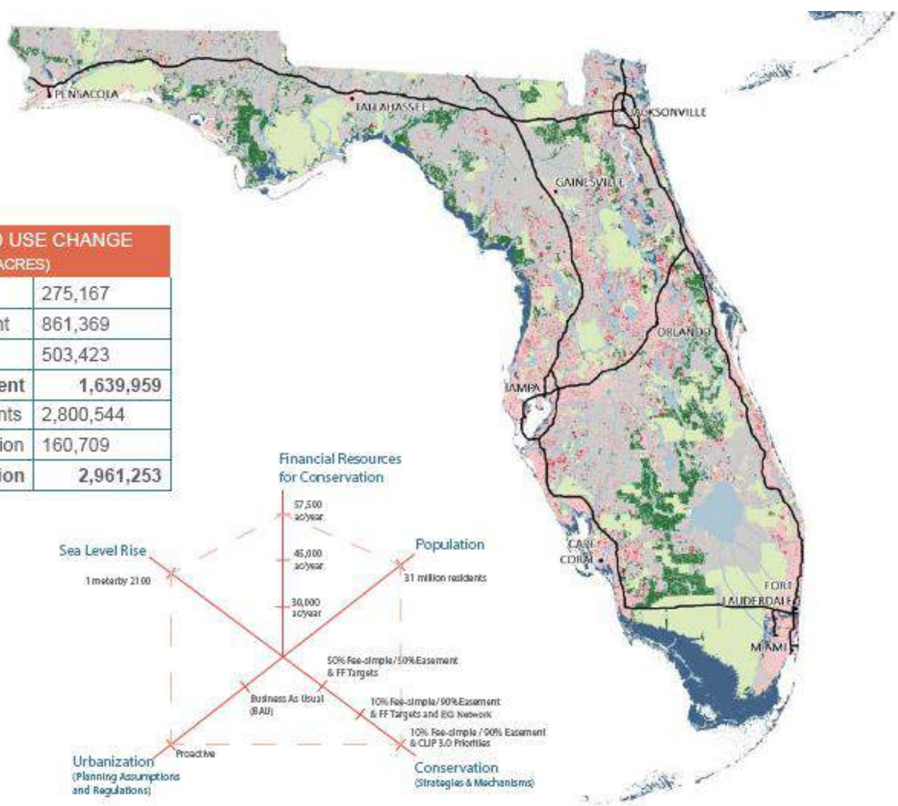


STATEWIDE LAND USE CHANGE 2060 (IN ACRES)	
Urban Development	332,279
Suburban Development	921,544
Rural Development	522,242
Total Development	**1,776,066**
Conservation Easements	1,938,871
Fee-Simple Conservation	280,396
Total Conservation	**2,219,268**

3



STATEWIDE LAND USE CHANGE 2060 (IN ACRES)	
Urban Development	275,167
Suburban Development	861,369
Rural Development	503,423
Total Development	**1,639,959**
Conservation Easements	2,800,544
Fee-Simple Conservation	160,709
Total Conservation	**2,961,253**

Figure 10.5. Reproduced maps visualizing the patterns that result from each scenario.

In addition, this report described more specific results in several focal zones of regional extents named: Apalcahee, East Central, and Southwest. For the specific results for these zones and more detailed statewide results, please consult the report. In short, the results of this project show that scenario modeling can be very useful in determining how best to manage for climate change and how best to promote adaptation.

Significance: The scenario based modeling technique used in this project provides a replicable and robust approach to considering alternative futures and conservation strategies, especially in response to predicted development and climate change. This work also highlights the different conservation strategies that can be employed to accomplish similar conservation goals, at least in terms of location. This document is an example of a successful attempt to synthesize and visualize many of the threats predicted to face Florida in the coming decades and how differing conservation strategies would address them.

KEYSMAP – KEYS MARINE ADAPTATION PLANNING

Vargas, J.C., M. Flaxman, and C. Chu. 2013. KeysMAP: Keys Marine Adaptation Planning. GeoAdaptive. Final Report

http://geoadaptive.com/experience/current-projects/keysmap/

Background: The KeysMAP project piloted an approach to marine climate adaptation planning based on scenario simulation and several rounds of expert review. This project further develops a method, spatial scenario simulation, proven successful in terrestrial ecosystem planning, but has not yet been adopted in marine planning contexts. This approach once again develops a set of “alternative futures” and examines their effects on natural resources. It also couples these expected outcomes against a number of adaptation strategies to plan for future conditions then tests the effectiveness of a set of potential management actions across this range of conditions. The scenarios are tied to IPCC scenarios, and they also encompass a discrete set of potential management strategies.

Key Findings: This project considered three indicator species and associated coastal and marine habitats: Goliath Grouper, Spiny Lobster and Loggerhead Sea Turtle. Of these, Spiny Lobster is important both commercially and recreationally. The Goliath Grouper and Loggerhead are both protected species, albeit occupying different ecological niches. Habitats considered included Coral Reefs, Mangrove Forests, and Sandy Beaches. Spatial scenarios were simulated based on three models. Regionally-downscaled sea surface temperature model outputs provided by the NOAA’s Southeast Fisheries Science Center were mapped with special attention to critical thresholds for species and habitats of concern. The consequences of SLR on coastal ecosystems and changes to habitats were simulated using the Sea Level Affecting Marshes Model (SLAMM) model.

Significance: This report provides yet another example scenario building and modeling can advise climate change adaptation planning. However, this project demonstrates that scenario building is also applicable and useful in marine settings and provides a methodological approach that can be applied to future modeling and scenario planning for marine systems in Florida and elsewhere.

SEA LEVEL AFFECTING MARSHES MODEL (SLAMM)

Warren Pinnacle Consulting, Inc. Environmental Modeling. Waitsfield, VT 05673

http://warrenpinnacle.com/prof/SLAMM/

Background: The Sea Level Affecting Marshes Model (SLAMM) is a useful model that relies on digital elevation data to simulate the long-term impact of seal level rise on tidal zones. Tidal marshes are exceptionally susceptible to climate change, especially SLR. Reductions or expansions in tidal marsh in response to sea-level rise can be modeled using the SLAMM 6. This model accounts for the dominant processes involved in wetland conversion and shoreline modifications during long-term SLR (Park *et* al. 1989).

SLAMM simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term SLR. This includes the five primary processes that affect wetlands: inundation, erosion, over wash, saturation, and accretion. A complex decision tree incorporating geometric and qualitative relationships is used to represent transfers among coastal classes. Each site is divided into cells of equal area; each cell has an elevation, slope, and aspect.

Key Findings:

Since SLAMM is a broader model set and approach, the listing below has been included to provide a more detailed review of how SLAMM has been used in Florida. A brief synopsis and key findings are outlined for each study or application mentioned below.

Evaluation of Regional SLAMM Results to Establish a Consistent Framework of Data and Models

Warren Pinnacle Consulting, Inc. 2014. Evaluation of Regional SLAMM Results to Establish a Consistent Framework of Data and Models. Final Report for the Gulf Coast Prairie LCC SLAMM Gap Analysis Project.

http://warrenpinnacle.com/prof/SLAMM/GCPLCC/WPC_GCPLCC_Final_Report.pdf

In 2014, the Gulf Coast Prairie Land Conservation Cooperative funded this analysis of the US Gulf of Mexico Coast.in order to establish a consistent framework of data and models. The main objectives of this project were to generate a seamless set of land cover projections for the Gulf of Mexico coast using SLAMM and conduct a focal species analysis using SLAMM results.

The results from this study indicate losses due to SLR in the majority of land covers analyzed, though in a few (e.g. marshes) gains occur. These gains assume that marshes will move upslope if they can across the coastal areas. Nevertheless, some underrepresented and important habitats do face severe reductions in the face of continued SLR along these coast line. These changes are expected to impact some of the focal species targeted by this modeling study. While this model does contain a great deal of uncertainty, it provides a first step toward creating a seamless gulf-wide model aimed at predicting how important elements of the gulf-coast will change in the face of SLR and climate change.

Application of SLAMM 4.1 to Nine Sites in Florida

Clough, J. 2006. Application of SLAMM 4.1 to Nine Sites in Florida. Warren Pinnacle Consulting, Inc. Warren, VT. Final Report prepared for National Wildlife Federation.

http://warrenpinnacle.com/prof/SLAMM/NWF_SLAMM_FLORIDA_2-16-2006.doc.

The SLAMM 4.1 model was applied to nine sites within Florida, comprising over 1.7 million hectares. Sites evaluated included Pensacola, Apalachicola, Tampa Bay, Charlotte Harbor, Ten Thousand Islands, Florida Bay, Biscayne Bay, Saint Lucie, and Indian River Lagoon. This work provides detailed for these nine important sites in Florida and was one of the first applications of SLAMM to Florida's natural resources. Thus, this work provided an important starting point to build from for later studies in Florida and later versions and applications of SLAMM.

Understanding Future Sea Level Rise Impacts on Coastal Wetlands in the Apalachicola Bay Region of Florida's Gulf Coast

Freeman, K., L. Geselbracht, D. Gordon, E. Kelly, and L. Racevskis. 2012. Understanding Future Sea Level Rise Impacts on Coastal Wetlands in the Apalachicola Bay Region of Florida's Gulf Coast. DEP Agreement No. CM112.

https://www.conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/Apalachicola%20Bay%20SLAMM%20Analysis%20Final%20Report%202-9-12.pdf

This project conducted a multi-part analysis that modeled SLR impacts on coastal marsh systems, described potentially vulnerable infrastructure and cultural resources, assessed potential impacts on vulnerable species, and characterized public attitudes and trade-offs surrounding simulated changes in ecosystem services. In addition, a group of natural resource, natural areas management, planning and water resource experts to developed locally relevant strategies that should be implemented to help natural and human communities adapt to the anticipated SLR impacts.

The findings of this work suggest that saltmarsh, brackish marsh, tidal marsh and tidal flat expand in this area mostly at the expense of forested wetland and inland freshwater marsh. Developed lands were also negatively affected, at least where they were not believed to be protected from SLR (via seawalls and other structures). This work also determined that many cultural resources would be affected in the region along with many imperiled aquatic and terrestrial species. In short, this work provides a good overview of the vulnerability of this area to the threat of SLR.

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The next three studies are part of a larger effort that the Gulf of Mexico Alliance Habitat Conservation and Restoration Team is undertaking with the Florida and Texas chapters of TNC to understand the Gulf-wide vulnerability of coastal natural communities to SLR and thus to identify appropriate conservation and restoration strategies and actions. Changes in tidal marsh area and habitat type in response to sea-level rise were modeled using the Sea Level Affecting Marshes Model (SLAMM 6) that accounts for the dominant processes involved in wetland conversion and shoreline modifications during long-term SLR.

Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Great White Heron NWR

Warren Pinnacle Consulting, Inc. 2011. Final Report prepared for Gulf of Mexico Alliance.

http://warrenpinnacle.com/prof/SLAMM/GOMA/SLAMM_GWH_Final_6-6.pdf

This work predicted that Great White Heron National Wildlife Refuge will severely impacted by a rise in sea levels of just .69 meters. In fact, more than half of refuge land is projected to be lost in every scenario run. More specifically, inundation effects are severe and pronounced for nearly every land cover category in the refuge. Only in minimum to moderate SLR scenarios did some classes experience expansion (e.g. mangrove). In the face of SLR, this refuge may be a complete loss in moderate to severe SLR scenarios.

Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Ten Thousand Islands NWR

Warren Pinnacle Consulting, Inc. 2011. Final Report prepared for Gulf of Mexico Alliance.

http://warrenpinnacle.com/prof/SLAMM/GOMA/SLAMM_10K_Islands_June28_2011.pdf

This study experienced a significant amount of uncertainty and demonstrates that there are some locations or settings in which the SLAMM approach does not work well in its current form. Thus, this report is most useful for helping to determine when SLAMM may not work well and what to do if the results do not come out as anticipated. Nevertheless this study also showed that there is a break-point for SLR and that when the seas rise above 1 to 1.5 meters inundation effects become so severe that wetland migration does not seem to occur in this system. Thus, for this refuge SLR may result in significant losses.

Application of the Sea-Level Affecting Marshes Model (SLAMM 6) St Andrew and Choctawhatchee Bays

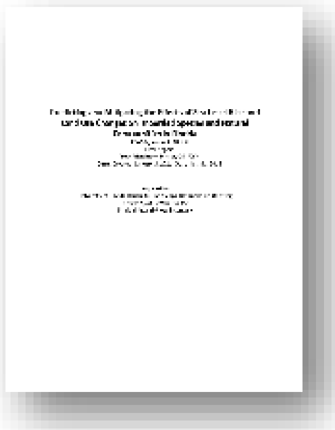
Warren Pinnacle Consulting, Inc. 2011. Final Report prepared for The Nature Conservancy.

http://warrenpinnacle.com/prof/SLAMM/TNC/SLAMM_SAC_Florida_Final.pdf

This study found this region of Florida is predicted to be less impacted by SLR than the settings of the previously mentioned case studies, at least in terms of percentage. Some land cover classes are predicted to experience gains although most of the area affected by SLR is projected to experience losses according to this application of SLAMM. Once again, this study demonstrates the general trend that as SLR becomes more pronounced the loss of important wetland areas become disproportionately severe. This is mostly due to the fact that the accretion needed for wetland migration cannot keep up with more rapid and severe SLR.

Significance:

These numerous applications of SLAMM demonstrate how useful the approach and modeling method can be when conducting vulnerability analysis in the face of SLR. Thus, SLAMM is a tool on the forefront of climate change adaptation and mitigation. Each of the aforementioned resources could provide an excellent framework for applying SLAMM approaches to future SLR vulnerability assessments. In short, SLAMM should not be overlooked as a potential resource or methodology.



PREDICTING AND MITIGATING THE EFFECTS OF SEA LEVEL RISE AND LAND USE CHANGES ON IMPERILED SPECIES AND NATURAL COMMUNITIES IN FLORIDA

Center for Landscape Conservation Planning and Florida Natural Areas Inventory. 2014. Predicting and Mitigating the Effects of Sea Level Rise and Land Use Changes on Imperiled Species and Natural Communities in Florida. FWC Agreement 10289. Final Report submitted to Florida Fish and Wildlife Conservation Commission.

http://conservation.dcp.ufl.edu/Project-Downloads.html.

Background: The goal of this project was to create a detailed assessment of the combined impacts of SLR and land-use changes on imperiled species and habitats throughout the state, which have been used to develop spatially explicit, science-based adaptive strategy recommendations to assist policy decisions. This project, also termed the SIVVA Report, is a starting point for future assessments of the impacts of SLR and adaptation options, and will form an essential foundation for future research that builds on the results and methodology of this project. This document was derived from the same efforts and work as was a publication previously mentioned in this resources section, “A Vulnerability Assessment of 300 Species in Florida: threats from Sea Level Rise, Land Use, and Climate Change.”

Key Findings: The method outlined for this work is generally divided into two phases: data collection and development and impact assessment. The data collection and development portion included an expert and literature review, a Standardized Index of Vulnerability and Value Assessments (SIVVA) analysis, and the collection of SLR and land-use change data. The impact assessment portion used various SLR projections, Sea Level Affecting Marshes Model (SLAMM) run outputs, future land-use projections, and recently updated imperiled species and natural community datasets. Using these datasets along with elaborate impact assessment tactics (see report for detailed information), this study developed impact assessment results for key natural communities and focal species, as well as, overall ecological connectivity. The report even identifies hotspots of land use and SLR impacts. Wide ranging recommendations were also made from these results, including: increasing urban density, ceased construction in certain areas, and the further protection of important natural and agricultural lands.

The key output from this work, however, was the identification of the potential adaptation options available for species (and communities) vulnerable to climate and land use change. These options are enumerated below:

1. Protect and manage existing habitat for as long as possible, including natural buffers to SLR and storm surge.
2. Protect and manage projected future (recipient) habitat.
3. Protect and manage existing corridors to projected future (recipient) habitat.
4. Restore/create corridors to recipient habitat (including wildlife crossings/ecopassages)
5. Provide assisted colonization (managed relocation) to recipient habitat.
6. Provide ex situ conservation in zoos, botanical gardens, seed and gene banks.

In addition, the report exhaustively discusses other potential adaptation options and general strategies for maximizing community health and landscape connectivity. Please consult the report for more detailed information.

Significance: This report is quite similar to those previously described except that it explicitly focuses on SLR as a key threat and provides a much greater level of detail as to the actual adaptation strategies to use in the state of Florida. This work, like those previously mentioned, assesses the vulnerability of species and communities to climate change and ways to mitigate those vulnerabilities. However, it provides as rigorous examination of SLR, how it combines with other potential threats, and how these combinations impact Florida. This work is an excellent guide of how to incorporate SLR into vulnerability assessments and adaptation strategies. In fact, this report provides an excellent example of a detailed and thorough vulnerability assessment and combines that assessment with a rigorous methodological approach to climate change adaptation that has been used to develop an extensive set of adaptation and mitigation options.

10.2 AN ANNOTATED BIBLIOGRAPHY:

Use this annotated bibliography to find other reports and guidance on conservation and proper management. While the documents included below are not as directly relevant to climate change adaptation, they are important resources that may provide useful background information or prove helpful in developing adaptation strategies.

10.2.1 OTHER RELEVANT RESOURCES:

1) Resilient Sites for Terrestrial Conservation in the Southeast Region

Anderson, M.G., A. Barnett, M. Clark, C. Ferree, A. Olivero Sheldon, and J. Prince. 2014. The Nature Conservancy, Eastern Conservation Science. 127 pp.

https://easterndivision.s3.amazonaws.com/Terrestrial/Resilient_Sites_for_Terrestrial_Conservation_In_the_Southeast_Region.pdf

This report is targeted at developing methods to identify a climate-resilient conservation portfolio for the Southeastern United States. The methods developed in this report can be used to identify a network of sites that would be resilient to threats such as climate change and representative of the important geophysical characteristics of the southeast. These sites would also maximize landscape diversity and local connectedness. The conservation of this identified network would allow regional adaptation to climate change while also maintaining ecosystem functions and biological diversity.

The method used in this report consisted of a four step process: the mapping and classification of all distinct "geophysical settings" in the region, the identification of all sites that have an increased level of resilience (high landscape diversity and local connectedness), the examination of geographical patterns on the landscape to identify possible networks of sites, and finally, the selection of a network of sites that represent all of the geophysical settings within the seven ecoregions in the southeast. The metrics identified and used in this process represent either a site's physical complexity (landform variety, elevation range, and wetland diversity) or permeability (local connectedness and regional flow patterns) (both of which are important to resiliency).

The report identifies a network of resilient sites that should be targeted for conservation in Florida (either continued or new) and the rest of the southeast. It provides detailed sub-region maps that reveal the location and configuration of this network of sites throughout Florida. This report also demonstrates the power of a landscape ecology approach to climate resiliency and adaptation. In short, this report can serve as a good check on other conservation prioritization and climate adaptation outputs and can be used to emphasize the importance of certain key areas when attempting to mitigate the threat of climate change.

2) Florida 2060: *A Population Distribution Scenario for the State of Florida.*

Zwick, P.D. and M.H. Carr. 2006. Geoplan Center University of Florida. Final report submitted to 1000 Friends of Florida.

http://www.1000friendsofflorida.org/connecting-people/florida2060/

Florida 2060 is a series of studies that examine how Florida will continue to develop over the next half century, until the year 2060. The outputs from these studies outline how the development in Florida is likely to progress over the coming decades, specifically by 2020, 2040, and finally, 2060. These scenarios assume that Florida does not significantly alter its existing development policies, outlining what is essentially a business as usual scenario. However, because this series of studies does attempt to make some temporal predictions (at the bi-decadal scale), it is possible to use the outputs from this work to prioritize conservation or adaptation efforts. For instance, more immediate mitigation or conservation strategies would likely be required if an area is expected to be developed by 2020 rather than by 2060. Thus, this work can be used to identify which areas are most vulnerable to urban/suburban expansion and can help prioritize which areas should be addressed first or even what strategies may be still relevant or too little too late.

3) Predicting Ecological Changes in the Florida Everglades under a Future Climate Scenario.

N. Aumen, L. Berry, R. Best, A. Edwards, K. Havens, J. Obeysekera, D. Rudnick and M. Scerbo. 2013. Final Report. Sponsored by United States Geological Survey, Florida Sea Grant and the Center for Environmental Studies at Florida Atlantic University.

http://www.ces.fau.edu/climate_change/ecology-february-2013/PECFEFCS_Report.pdf

Predicting Ecological Changes in the Florida Everglades under a Future Climate Scenario is the final report from a series of meetings over the past three years. These meetings examined the current and future potential impact of SLR and other hydrological changes on select regions and processes of the greater Florida Everglades, and on the potential outcomes of implementing the Comprehensive Everglades Restoration Plan (CERP).

Meetings by this an inter-agency steering committee were a continuing effort to facilitate discussions and develop pathways for understanding the consequences of climate change and SLR and building a sound scientific basis for managing changing environments. Results from this exercise will guide targeted research to address critical science uncertainties and improve ecological forecasts, and also update resource managers regarding the current state of our ecological understanding of climate change effects and ability to forecast these effects. In particular, the purpose of this technical meeting is to have experts in Everglades ecosystems predict how key attributes may respond to specific future climate scenarios that include increased temperature, altered rainfall and runoff, higher evapotranspiration, rising sea level, greater climate extremes, and elevated atmospheric CO2; and to identify gaps in scientific information leading to unacceptable levels of uncertainty in ecological predictions, including changes in environmental parameters needed by ecologists to predict how these ecosystems may respond; and finally to consider options for future resource management and scientific needs and capabilities to support management adaptations.

In short, this technical meeting will identify the best available information on climate and its hydrologic effects on south Florida natural ecosystems. Hopefully, this information will initiate discussions of whether our existing scientific knowledge is adequate to predict how the Everglades ecosystems will respond to anticipated climate changes. It will also targeted to provide direction to both researchers and funding agencies to address key scientific informational gaps and provide managers with climate change scenarios to use for restoration planning under an altered climatic regime.

4) Climate Envelope Models in Support of Landscape Conservation

Watling, J.I., L.A. Brandt, A. Benscoter, D. Bucklin, C. Speroterra, F.J. Mazzotti, and S. S. Romanach. 2012. Final Report to USFWS Agreement No. F11AC00028. Fort Lauderdale Research and Education Center, University of Florida, Davie, FL.

http://crocdoc.ifas.ufl.edu/projects/climateenvelopemodeling/publications/Project%20F11AC00028%20Final%20Report.pdf

The objective of this project was to develop modeling methods and products that will allow natural resource managers to examine potential effects of climate change on species' geographic ranges in the context of ecosystem and landscape planning. Climate envelope modeling, a subset of species distribution modeling (SDM), is one type of modeling that can be useful in understanding species and habitat responses to climate change because they identify key links between drivers of change (e.g., climate) and relevant responses. Climate envelope models describe relationships between species' occurrences and bioclimate variables derived from temperature and precipitation data to define a species' climate niche (envelope).

This project consists of four parts: (1) developing climate envelope models and associated prediction maps for 26 federally threatened and endangered terrestrial (T&E) vertebrate species occurring in peninsular Florida; (2) providing a technical guidebook for use and interpretation of climate envelope models; (3) developing visualization and social networking tools that allow natural resource managers and the general public to view our models, and (4) creating a searchable database of species traits for use in developing vulnerability assessments and other biological planning documents. This modeling technique provides a robust way to understand how species may respond to climate change and thus assess a species' vulnerability. This could be a highly useful tool for the development of a climate adaptation guide for certain species or ecosystems.

5) **Use and Interpretation of Climate Envelope Models: A Practical Guide**

Watling, J.I., L.A. Brandt, F.J. Mazzotti, and S.S. Romanach. 2013. University of Florida, 43 pp.

http://crocdoc.ifas.ufl.edu/projects/climateenvelopemodeling/publications/Use%20and%20Interpretation%20of%20Climate%20Envelope%20Models%20-%20A%20Practical%20Guide.pdf

The guidebook is intended to provide a practical overview of climate envelope modeling for conservation professionals and natural resource managers. The material is intended for people with little background or experience in climate envelope modeling who want to better understand and interpret models developed by others and the results generated by such models, or want to do some modeling themselves. This is not an exhaustive review of climate envelope modeling, but rather a brief introduction to some key concepts in the discipline. This work provides a broader background than the previously mentioned climate envelope modeling study which provides a more detailed framework for applying the models to the species and regions of Florida.

6) **Rapid Assessment of Threats to Wildlife Corridors in Southwest Florida**

The Center for Landscape Planning and Florida Natural Areas Inventory. 2011.

http://conservation.dcp.ufl.edu/RA_Report_March%202011.pdf

The Rapid Assessment of Threats to Wildlife Corridors in Southwest Florida, a spatial analysis conducted in late 2010 and early 2011 by the University of Florida Center for Landscape Conservation Planning and the Florida Natural Areas Inventory, compared a representation of potential priority areas for conservation in southwest Florida, including wildlife corridors, with representations of five potentially corridor-inhibiting factors. These factors were current land use, parcel fragmentation, future land use, developments of regional impact and SLR. Each factor was compared individually with the representation of potential priority areas for conservation, yielding five single threat analyses, which were then combined in two different ways to produce a pair of combined threat-synthesis. The individual analyses and especially the syntheses identify potential hazards to wildlife corridors in southwest Florida.

This work, while not comprehensive, provides a useful guide for indicating where threats may impact much needed wildlife corridors. In short, this study could help determine both the best routes in which to establish corridors and what strategies must be taken (by when) to avoid these threats across the wildlife corridor network in Florida.

7) Climate Change Action Plan for the Florida Reef System 2010-2015

Florida Reef Resilience Program, State of Florida, NOAA, The Nature Conservancy, Great Barrier Reef Marine Park Authority. 2010.

http://frrp.org/SLR%20documents/FL%20Reef%20Action%20Plan-WEB.pdf

This Action Plan is the culmination of 5 years of collaborative effort amongst a broad spectrum of coral reef scientists, managers, and user groups with some of the best and most informed individuals in their respective fields. The plan recognizes the need for a holistic approach across the geographic range of Florida's coral habitats given the inevitability of warmer, more acidic, oceans, and rising sea levels. It is grounded in the concept of "resilience", or ability of the ecosystem to resist or bounce back from impacts. Collectively the actions are designed to enhance our coral reef systems ability to combat the stresses associated with climate change thereby giving them the best chance to adapt while continuing to provide their vital services to our society.

This plan is an excellent example of a coordinated set of climate adaptation strategies. Any managers or conservations currently tasked with developing a similar action plan should consider reviewing this brief example for coral reef systems in Florida.

8) Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans.

U.S. Environmental Protection Agency. 2014. Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans. EPA Office of Water, Washington, DC

http://www2.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf

This workbook presents a guide to climate adaptation planning based on EPA's experience with watershed management, the National Estuary Program and the Climate Ready Estuaries program. The Workbook will assist organizations that manage environmental resources to prepare a broad, risk-based adaptation plan. This Workbook helps meet the need for guidance on conducting climate change vulnerability assessments at a watershed scale, provides decision-support tools, helps people plan climate change adaptation strategies, and builds the capacity of local environmental managers.

This detailed resource provides more methodology for developing climate adaptation strategies and adaptation plans. Although this work is less targeted at species or even communities, it is nonetheless a useful resource that provides a different perspective from those other resources listed in this adaptation guide.

9) Developing Climate Change Adaptation Strategies For Florida

Dubois, N., M. Surridge, and A. Delach. 2014. Developing Climate Change Adaptation Strategies for Florida. Defenders of Wildlife. FWC Agreement No. 11412. Final report submitted to Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.

Defenders of Wildlife received a two-year State Wildlife Grant to support the Florida Fish and Wildlife Conservation Commission's (FWC) incorporation of climate change into conservation and management planning. FWC's goal is to develop a set of tools and resources for climate change adaptation planning that can be used across the agency's management programs. Defenders worked with FWC to develop and pilot approaches to support adaptation decision processes as part of FWC's climate change response strategy that can be rolled into agency planning efforts. Using a case study approach, Defenders engaged with agency staff involved in ongoing planning efforts to develop climate change response strategies for priority habitats and/or species and develop the processes for assessing and revising current practices and management actions. Based on the outcomes of these case studies, we developed recommendations for the agency to further the use of planning tools and approaches that can be used to modify current practices and management actions in order to continue to achieve conservation and management goals under a changing climate.

10.2.2 USEFUL TOOLS AND DATA SOURCES:

10) EverVIEW

Conzelmann, C., and Romañach, S.S., 2010, Visualizing NetCDF Files by Using the EverVIEW Data Viewer: U.S. Geological Survey Fact Sheet 2010–3046.

http://www.jem.gov/

Ecological models are needed to facilitate evaluation and assessment of alternative approaches to restore Greater Everglades ecosystems. However, the provision of useful and accessible models is a challenge because there is often a disconnect between model developers and model users. Joint Ecosystem Modeling (JEM) was established to meet this challenge, with the goal of getting ecological models into the hands of users. JEM is a partnership among federal and state agencies, universities and other organizations which is currently funded by the USGS Priority Ecosystem Science program, the Everglades National Park, and the Peninsular Florida Landscape Conservation Cooperative.

The development of this product, EverVIEW Data Viewer, is occurring to meet these needs. This data viewer software is aimed at allowing the end user to view and understand ecological model runs. For more information, consult JEM.

11) NOAA Digital Coast – Sea Level Rise Viewer

http://coast.noaa.gov/digitalcoast/tools/slr

This tool simulates various SLR scenarios (form one to six feet above the average highest tides) and the corresponding areas that would be impacted by flooding. Additional information about marsh impacts, nuisance flood frequency and social and economic data is also provided. This is an excellent tool that goes beyond average SLR which may or may not be the most useful metric of sea level and climate change. Taking into account the maximum affected flooding area is quite useful when determine which areas are most vulnerable to SLR.

12) Climate Explorer

http://toolkit.climate.gov/climate-explorer/

Climate Explorer is a research application built to support the U.S. Climate Resilience Toolkit. The tool offers interactive visualizations for exploring maps and data related to the toolkit's Taking Action case studies. Map layers in the tool represent geographic information available through climate.data.gov. Each layer's source and metadata can be accessed through its information icon. Climate Explorer graphs display 1981 – 2010 U.S. Climate Normal values for temperature and precipitation, overlain with daily observations from the Global Historical Climatology Network-Daily (GHCN-D) database. Please note that GHCN-D data have been checked for obvious inaccuracies, but they have not been adjusted to account for the influences of historical changes in instrumentation and observing practices.

This product is designed to visualize a variety of predicted climate stressors and how they are projected to impact people and their "assets." This is a more human-centric approach to climate change vulnerability but it is a useful and versatile tool that is probably quite relevant to conservation and adaptation plans.

13) Development of a Geographic Information System (GIS) Tool for the Preliminary Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure. Sea Level Scenario – Sketch Planning Tool

Thomas, A., R. Watkins, C. Goodison, and R. Pierre-Jean. 2013. Development of a Geographic Information System (GIS) Tool for the Preliminary Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure. Geoplan Center, Department of Urban and Regional Planning, University of Florida. Gainesville, FL.

http://sls.geoplan.ufl.edu/#intro

Researchers from the University of Florida developed a sketch planning tool that can be used to conduct statewide and regional assessments of transportation facilities potentially vulnerable to climate trends. The project focused on the potential vulnerability of transportation infrastructure to the effects of possible future rates of sea level change (SLC) and increasing tidal datums. The Florida Sea Level Scenario Sketch Planning Tool includes (1) a map viewer, (2) the output modeled data layers (inundation surfaces and affected infrastructure), and (3) an ArcGIS calculator for creating custom inundation surfaces.

This viewer, similar to the previously mentioned viewer, was developed in conjunction with human needs, specifically those of the Florida Department of Transportation. Thus, this viewer is targeted at assessing the impact of SLR on existing transportation infrastructure. However, it is one of the best SLR modeling projects to date and provides detailed SLR predictions at a fine temporal scale (decadal). The outputs from this modeling study are highly relevant to Florida's species and natural communities and can be viewed as some of the best SLR predictions Florida has.

14) U.S. Climate Resilience Toolkit

https://toolkit.climate.gov/tools

The website or "toolkit" enumerates a variety of potentially useful climate change tools and resources. This same website hosts the Climate Explorer (Resource #12), the additional spatial tools and data resources may be useful in climate change adaptation projects.

15) Peninsular Florida Landscape Conservation Cooperative Resources Webpage

http://peninsularfloridalcc.org/page/useful-documents

This PFLCC resource page provides links to some of the guidance documents above, project reports and tools relevant to the region.

16) PINEMAP

http://climate.ncsu.edu/pinemap/index.php

This online tool was developed to look at the relationship of loblolly pines and climate, and management components to look at future seedling source and markets. Currently the tool maps summer precipitation, summer temperature and extreme winter temperatures under two future emission scenarios (RCP4.5 and RCP8.5) and historic conditions. The three map ensemble layout allows user to view the lowest, average and highest for the respective chosen climate factor to show the variability between the models. Simply select a point on the map to retrieve the modeled information for a given part of the state. Future enhancements are planned.

17) Multivariate Adaptive Constructed Analogs (MACA) Statistical Downscaling Method

http://maca.northwestknowledge.net/index.php

Statistical downscaled climate data using CMIP5 and allows users to visualize temperature, relative humidity, potential evapotranspiration and precipitation projections under RCP4.5 and RCP8.5 (AR5) seasonally and annual time periods. Data can be downloaded as NetCDF for viewing in ArcGIS.

18) ClimateWizard

Girvetz EH, Zganjar C, Raber GT, Maurer EP, Kareiva P, Lawler JJ. 2009. Applied Climate-Change Analysis: The Climate Wizard Tool. PLoS ONE 4(12): e8320. doi: 10.1371/journal.pone.0008320

http://climatewizard.org/

Enables technical and non-technical audiences alike to visualize climate change information. The first generation of this web-based program allows the user to choose a state or country and both assess how climate has changed over time and to project what future changes are predicted to occur in a given area. The tool is currently uses AR4 climate models and scenarios.

19) NOAA Tide Gauge Sea Level Trends

http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Access sea level rise trend data for the 15 tide gauges around the state.

20) Florida Climate Center

https://climatecenter.fsu.edu/topics/climate-change

While future projections are critical to creating scenarios for vulnerability studies, it can be useful to provide historical reference of climate data. The climate data and visualization options has approximately 100 long term weather stations. Data includes temperature (average, minimum and maximum) and precipitation, and can be displayed annually, monthly or seasonally. Temperature options can also display number of days below 32°F and above 90° or 100°F.

21) USGS Florida Water Science Center

http://fl.water.usgs.gov/

Provides current stream stage, streamflow, water quality and groundwater levels for Florida.

22) EPA Water Quality Data

http://watersgeo.epa.gov/mwm/

This viewer is a simple option see whether there are stations near a site of interest to access data from a map based platform and see impairments. Station data can be downloaded directly from the pop-up dialogue boxes for individual. Type in the desired location in order to select further options. Under the 'Other EPA Water Data' and turn on the 'STORET Water Monitoring Stations' layer. This will allow access to all submitted water quality data for an area of interest.

23) Ocean Observing

http://data.gcoos.org/ (Gulf of Mexico Coastal Ocean Observing System) and http://secoora.org/data (Southeast Coastal Ocean Observing Regional Association)

Regional ocean observing consortiums collate ocean monitoring data into easily accessible data portals from numerous entities. Data can include currents, wind speed, wind direction, sea surface temperature and salinity.

24) Planning for Sea Level Rise in the Matanzas Basin- Planning for Sea Level Rise Toolkit

https://planningmatanzas.files.wordpress.com/2012/06/h2-planning-for-sea-level-rise-toolkit.pdf

This toolkit is an appendix of the Planning for Sea Level Rise in the Matanzas Basin report, and serves as a good quick resource for a number of adaptation activities. The toolkit summarizes the legal authority of actions, likelihood of being challenged in court, appropriate land use, feasibility, efficacy of many adaptation activities ranging from shoreline armoring, living shorelines, dune creation, elevating buildings, transfer of development rights, and more.

25) Forest Service Climate Change Atlas

http://www.fs.fed.us/nrs/atlas/

The Climate Change Atlas documents the current and possible future distribution of 134 tree species and 147 bird species in the Eastern United States and gives detailed information on environmental characteristics defining these distributions.

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12 APPENDICES

12.1 APPENDIX 1 – CLIMATE SCIENCE

The following appendix was the result of a Climate Wizard Custom Analysis (http://www.climatewizard.org/custom). This analysis was conducted for Florida (Girvetz *et al*. 2009). In this analysis the user can select variables to measure (e.g., Percent Precipitation Change, Average Temperature (°C) and Precipitation (mm)), Emissions Scenario from the IPCC Fourth Assessment (e.g., A1B, A2), General Circulation Models (15 GCMs plus ensemble runs), and "season" (e.g., annual, seasonal, monthly). A multitude of Climate Wizard runs were performed by modifying these settings.

According to the Climate Wizard documentation, these data consisted of downscaled 12km translations of contemporary climate projections over the contiguous United States. The original projections were from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. The resolution of these models was 12 kilometers (Geographic, WGS84) and the extent consisted of the entire contiguous United States. The temporal extent consisted of a 1950 - 2099 monthly time-series.

For those interested, the ensemble analyses used in Climate Wizard is explained thoroughly on the FAQ page of their website. This discussion is reproduced below.

Ensemble analyses (Climate Wizard FAQs)

"Climate change analysis becomes more complex for the future than the past because there is not one time-series of climate, but rather many future projections from different GCMs run with a range of CO2 emissions scenarios (IPCC 2007b). It is important not to analyze only one GCM for any given emission scenario, but rather to use ensemble analysis to combine the analyses of multiple GCMs and quantify the range of possibilities for future climates under different emissions scenarios. There are many approaches for doing ensemble analysis ranging from simple averaging approaches to more complex and computationally intensive probability estimation approaches (Dettinger 2006, Araujo and New 2007). Here, we used a fairly simple, yet informative non-parametric quantile-rank approach that maps out the 0 (minimum), 20, 40, 50 (median), 60, 80, and 100th (maximum) percentiles."

"The term *Ensemble Average* located in the General Circulation Model (GCM) pull-down list on the Climate Wizard home page displays the 50th percentile or median prediction of all subsequent GCMs listed. "

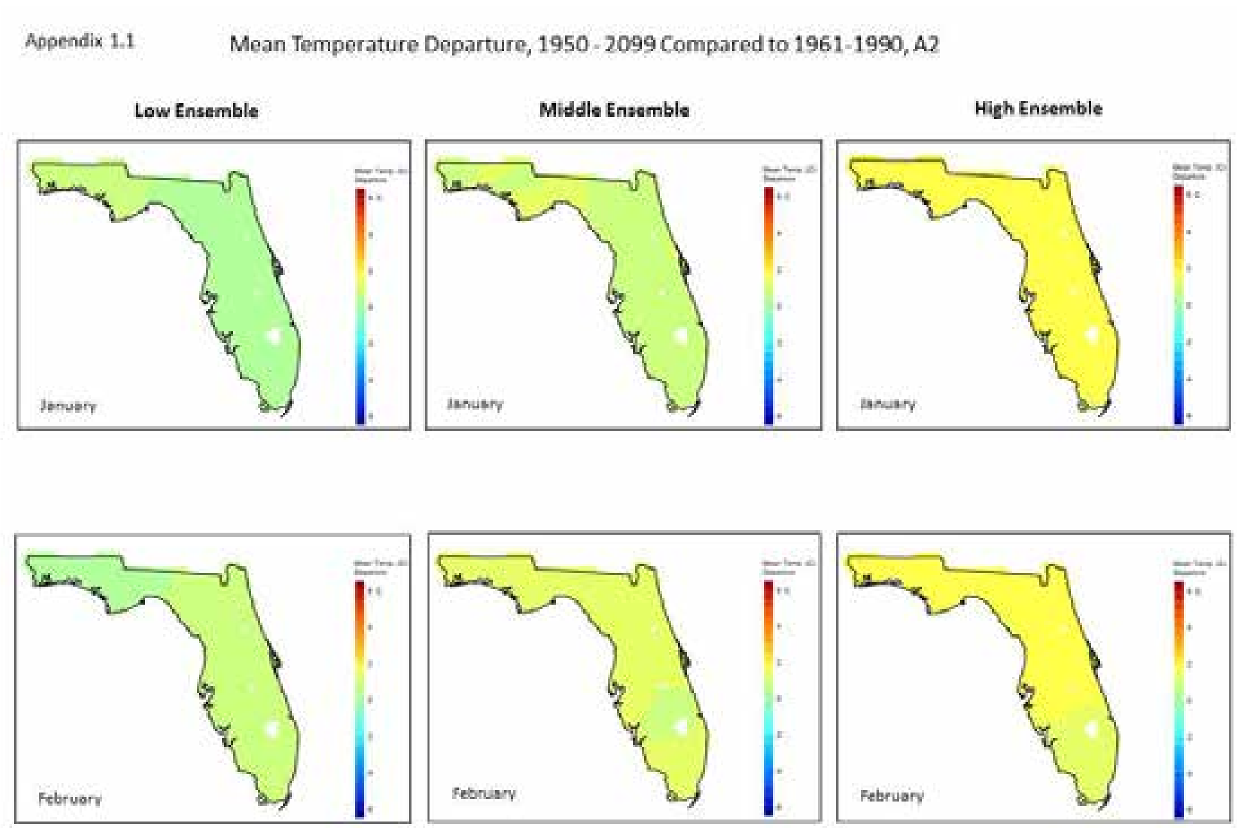
The following subset appendices have map images and graphs of some of the results produced in this analysis.

Maps produced by Climate Wizard © University of Washington and the Nature Conservancy, 2013. Base climate projections downscaled by Maurer *et al*. (2007). We acknowledge the modeling groups, The Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on

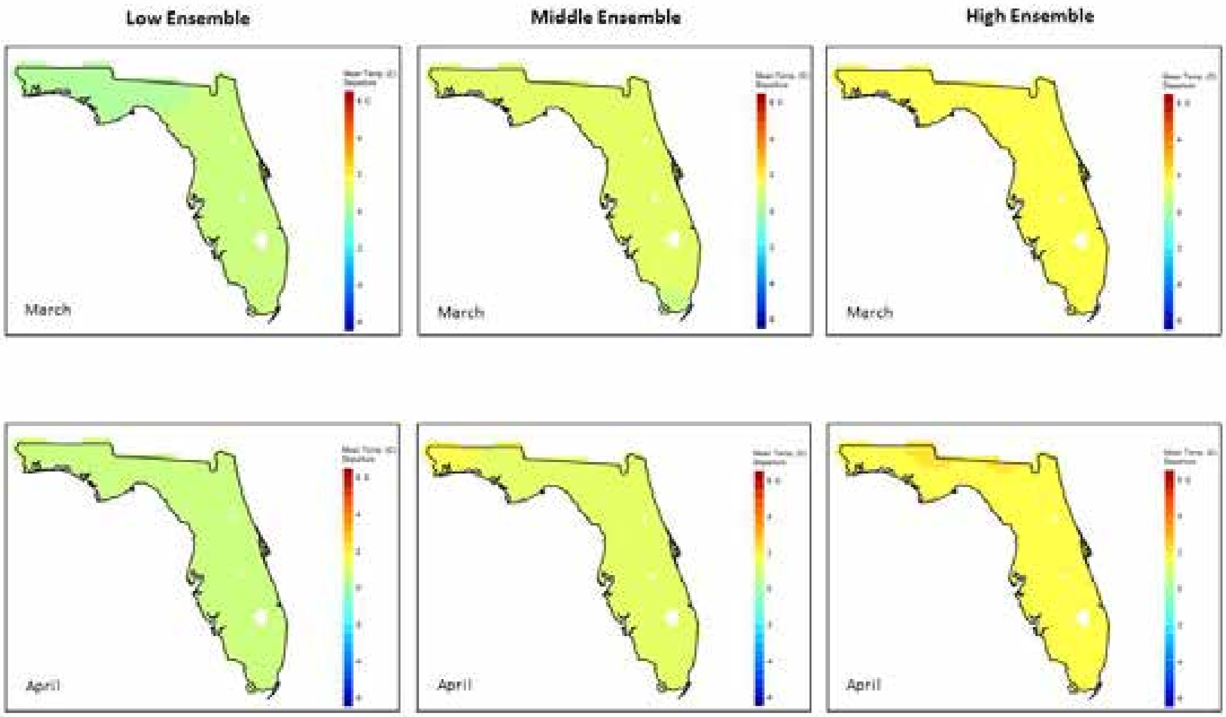
Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.

12.1.1 APPENDIX 1.1

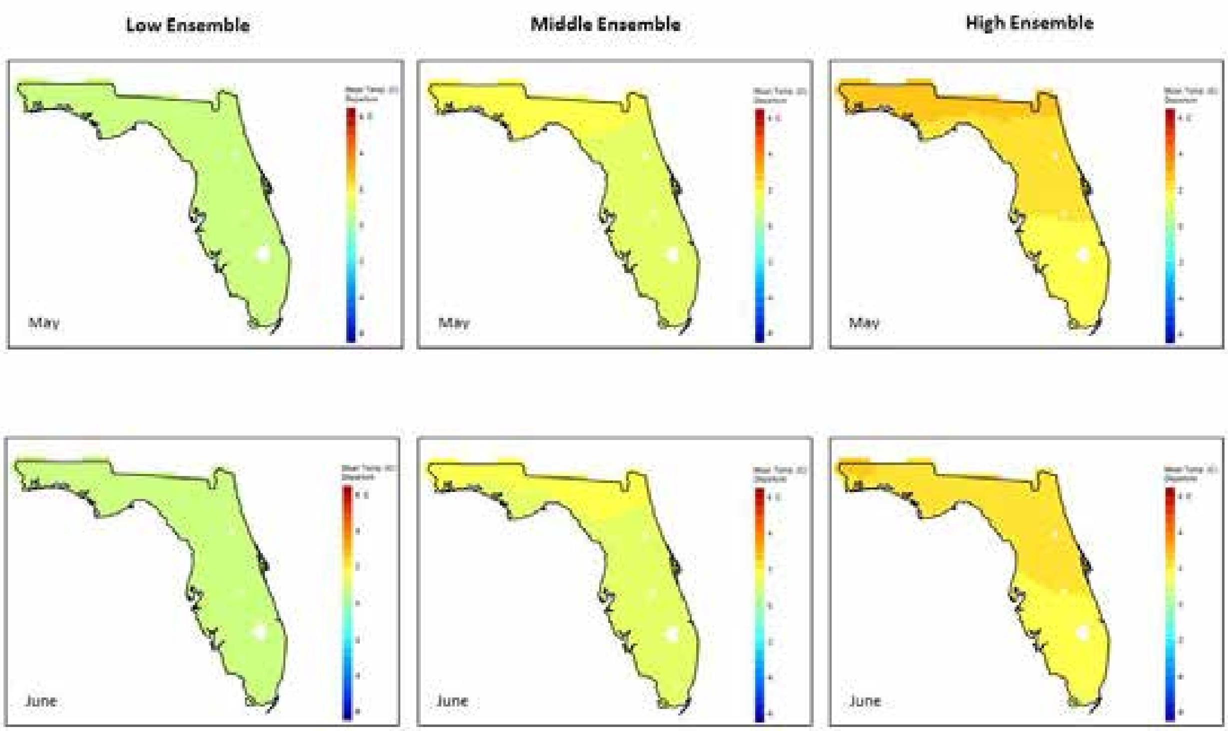
Projected Mean Temperature Change, by Month. 1950 – 2099 is compared to 1961 – 1990, for each month. Based on Emission Scenario A2, and shown separately for 3 Ensembles: Low, Middle and High (This analysis uses all 15 GCMs). It is important not to analyze only one GCM for any given emission scenario, but rather to use ensemble analysis to combine the analyses of multiple GCMs and quantify the range of possibilities for future climates under different emissions scenarios. These figures use a color scale to illustrate changes in average temperature (°C) across months and model scenarios. These graphics allow comparisons of climate projections across the state and seasons (Girvetz *et al*. 2009)**.**



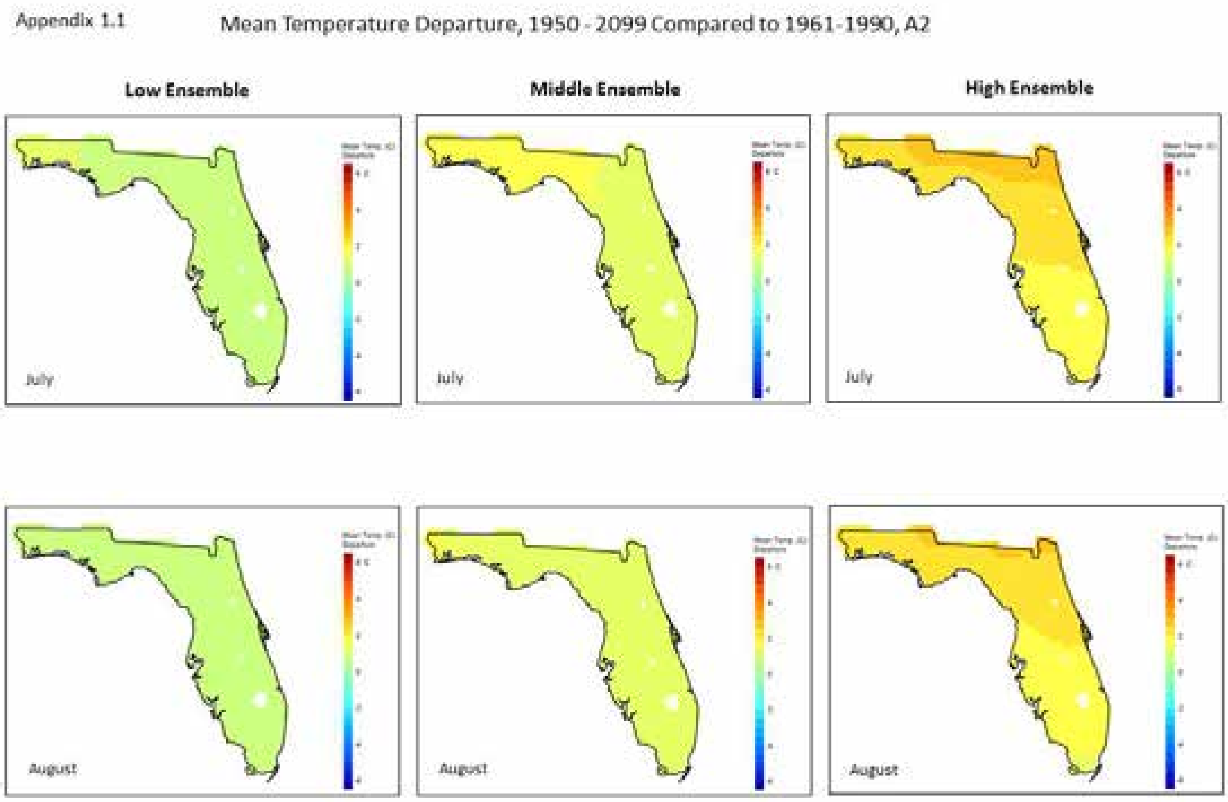
Appendix 1.1 Mean Temperature Departure, 1950 - 2099 Compared to 1961-1990, A2

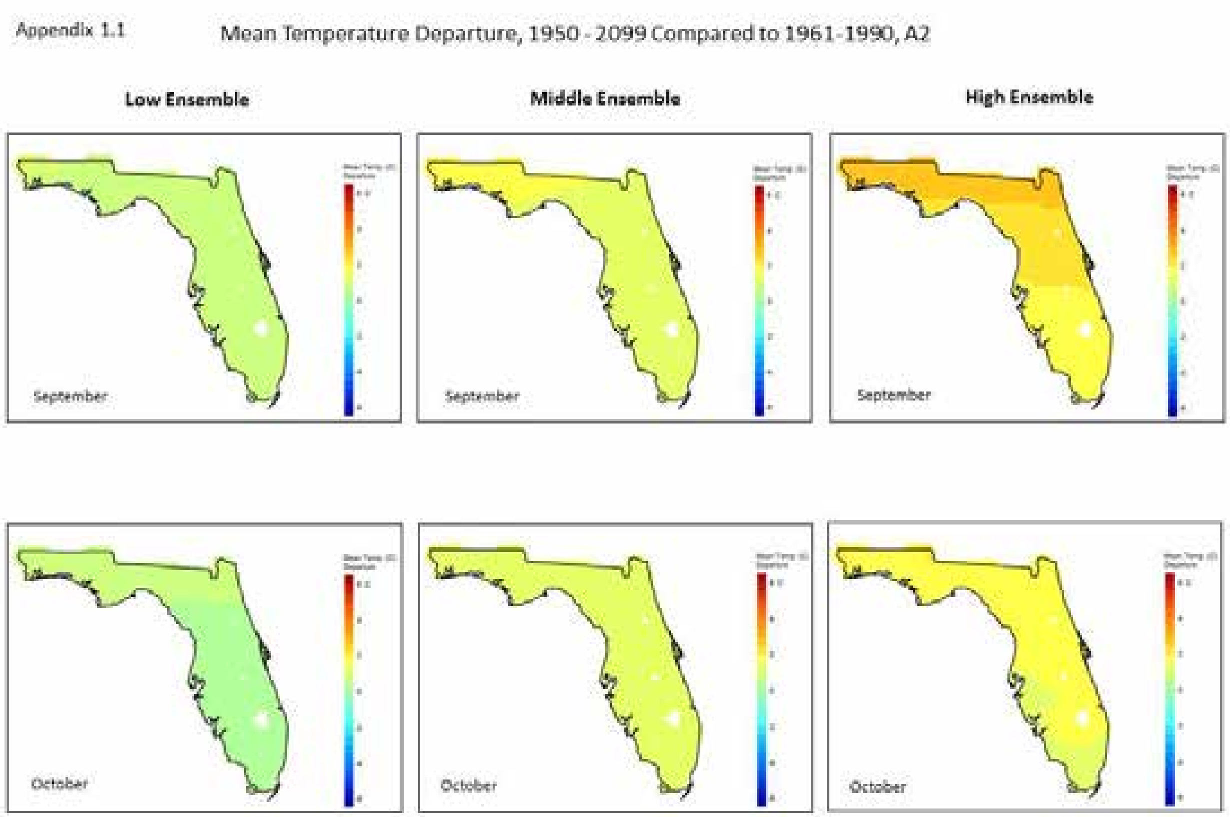


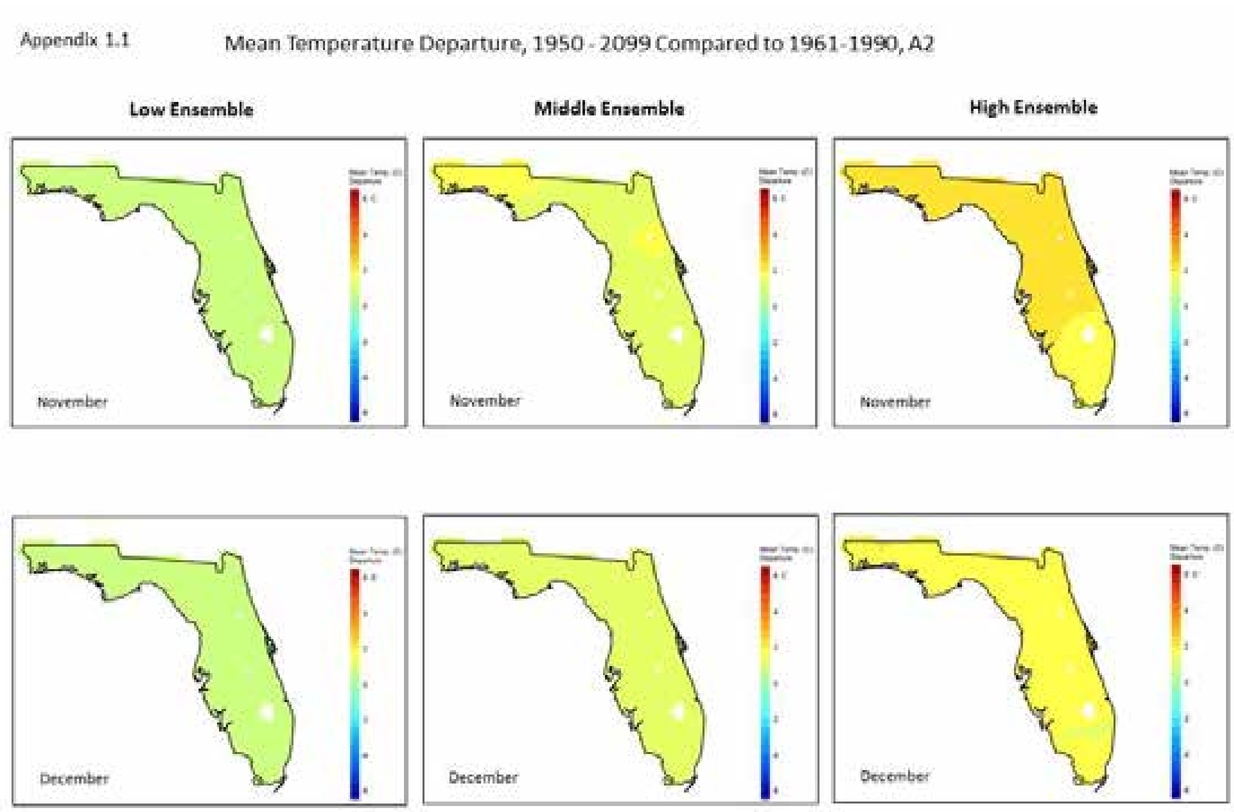
Appendix 1.1 Mean Temperature Departure, 1950 - 2099 Compared to 1961-1990, A2



12 Appendices


Appendix 1.1
Mean Temperature Departure, 1950 - 2099 Compared to 1961-1990, A2
Low Ensemble
Middle Ensemble
High Ensemble
July
July
July
August
August
August

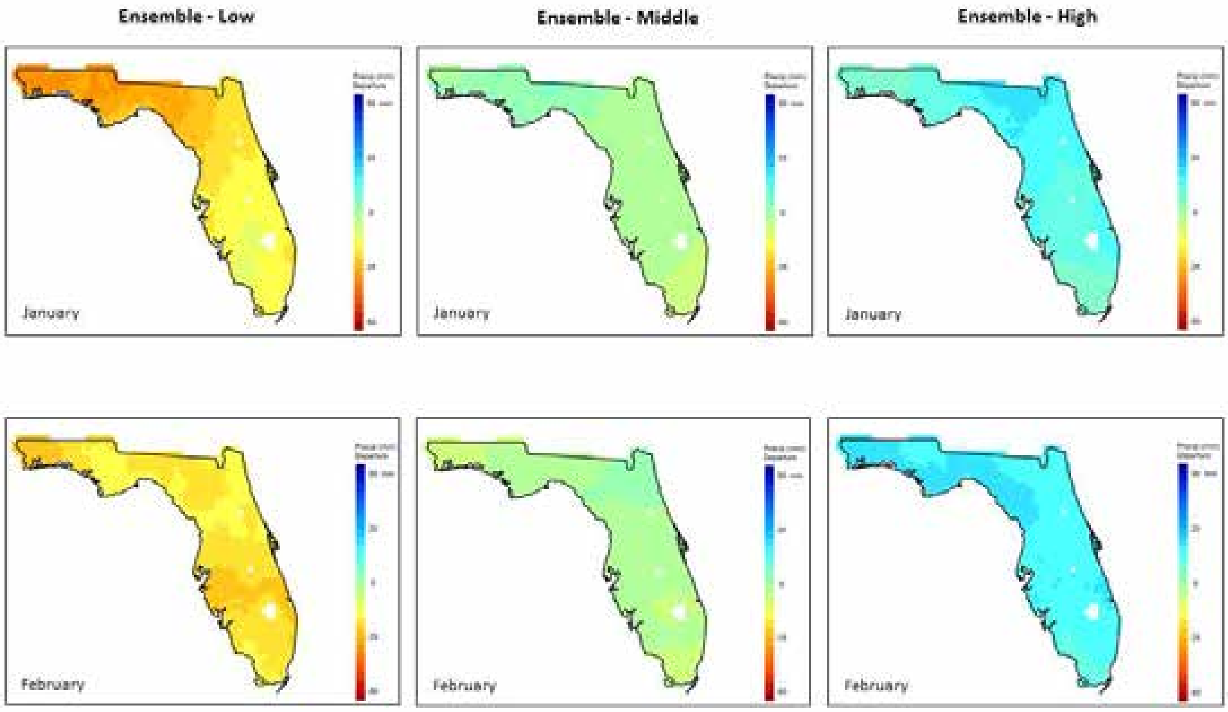

Appendix 1.1
Mean Temperature Departure, 1950 - 2099 Compared to 1961-1990, A2
Low Ensemble
Middle Ensemble
High Ensemble
September
September
September
October
October
October



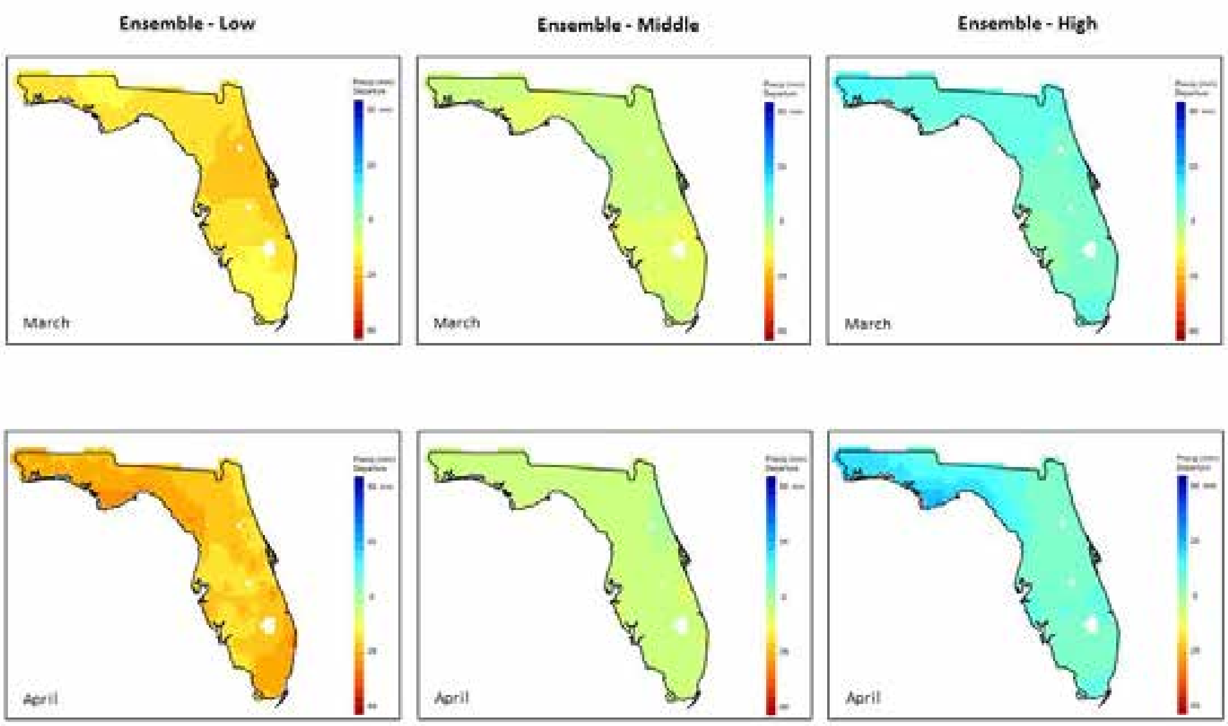
12.1.2 APPENDIX 1.2

Projected Precipitation Change, by Month. 1950 – 2099 is compared to 1961 – 1990, for each month. Based on Emission Scenario A2, and shown separately for 3 Ensembles: Low, Middle and High (This analysis uses all 15 GCMs). These figures use a color scale to illustrate the projected change in average precipitation across months and model scenarios. These graphics can be used to compare how precipitation is projected to change across the state and seasons (Girvetz *et al*. 2009)**.**

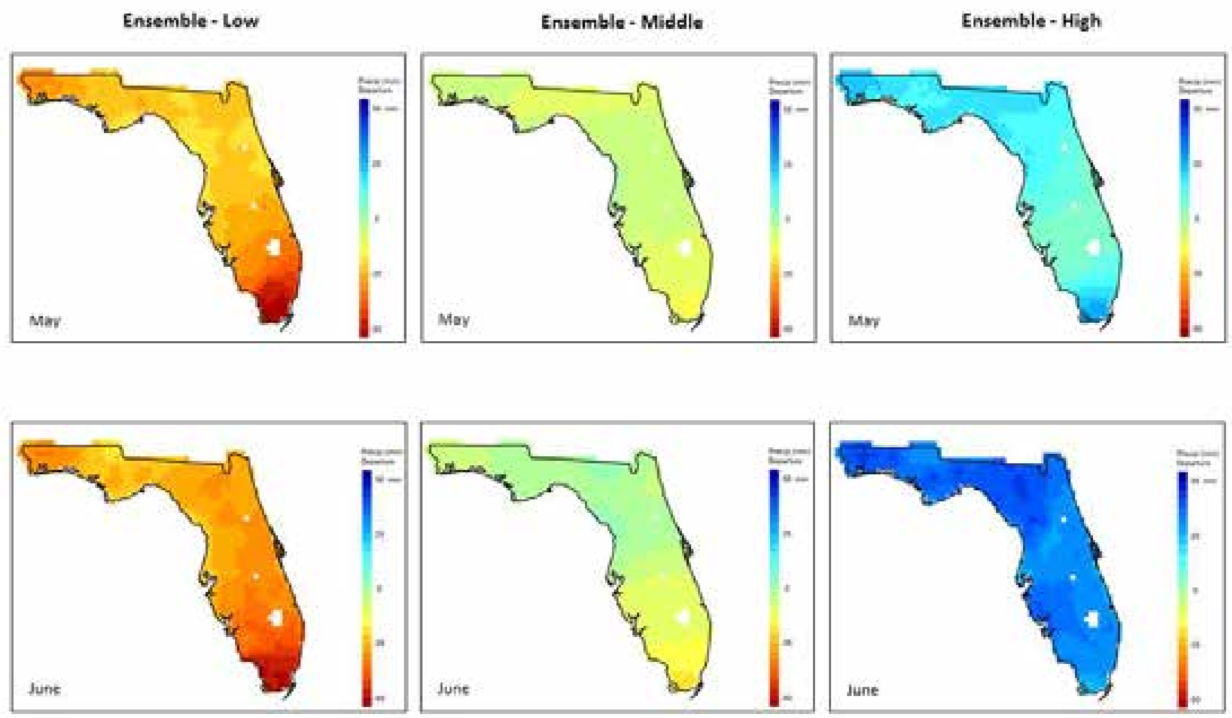
Appendix 1.2 Average Precipitation (mm) Departure 1950 -2099 Compared to 1961 – 1990, A2



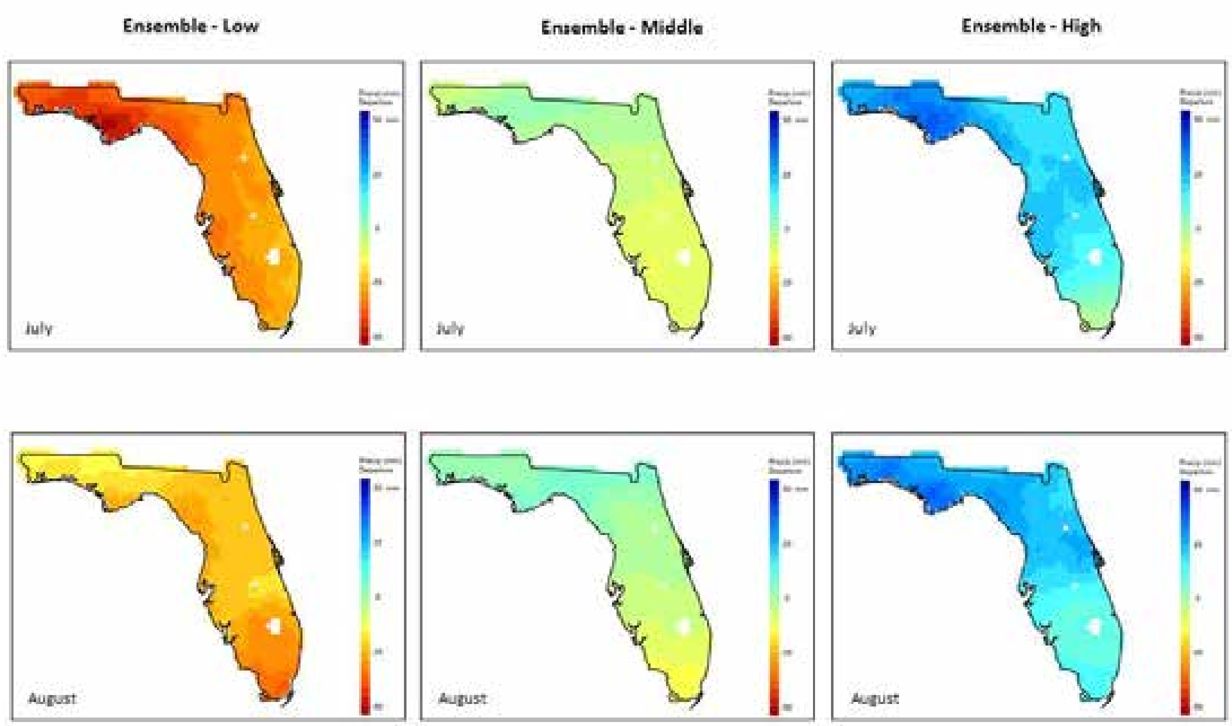
Appendix 1.2 Average Precipitation (mm) Departure 1950 -2099 Compared to 1961 – 1990, A2



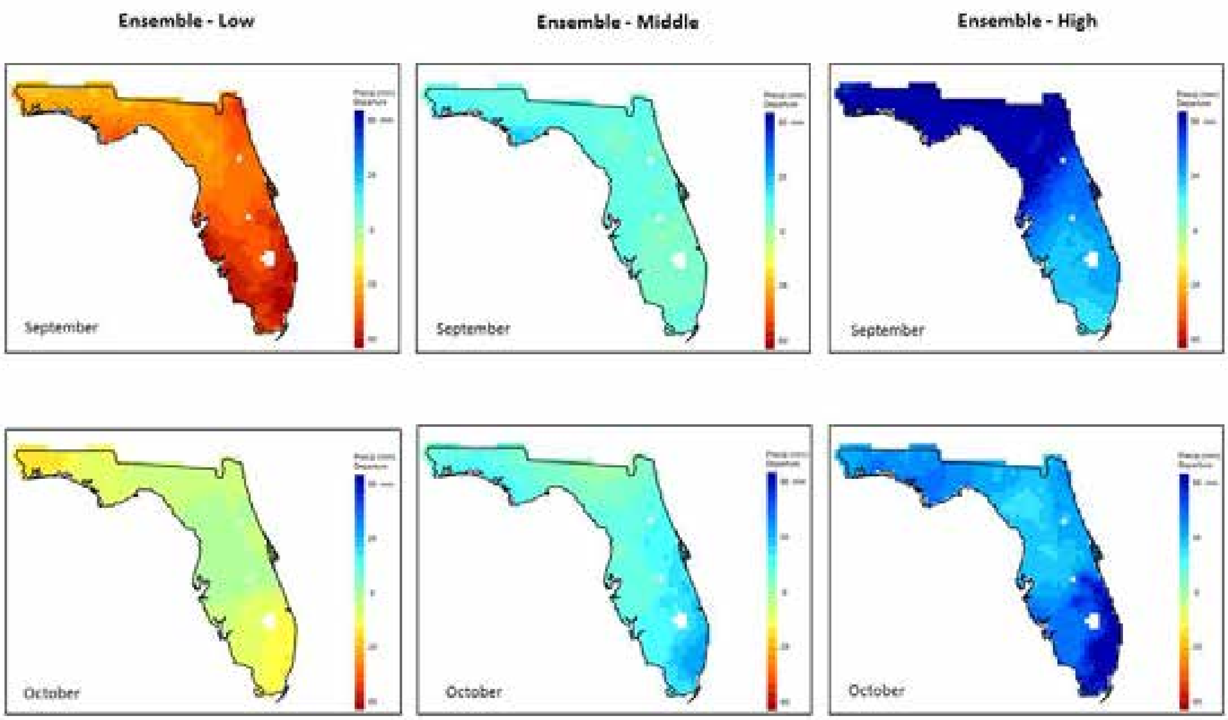
Appendix 1.2 Average Precipitation (mm) Departure 1950 -2099 Compared to 1961 – 1990, A2



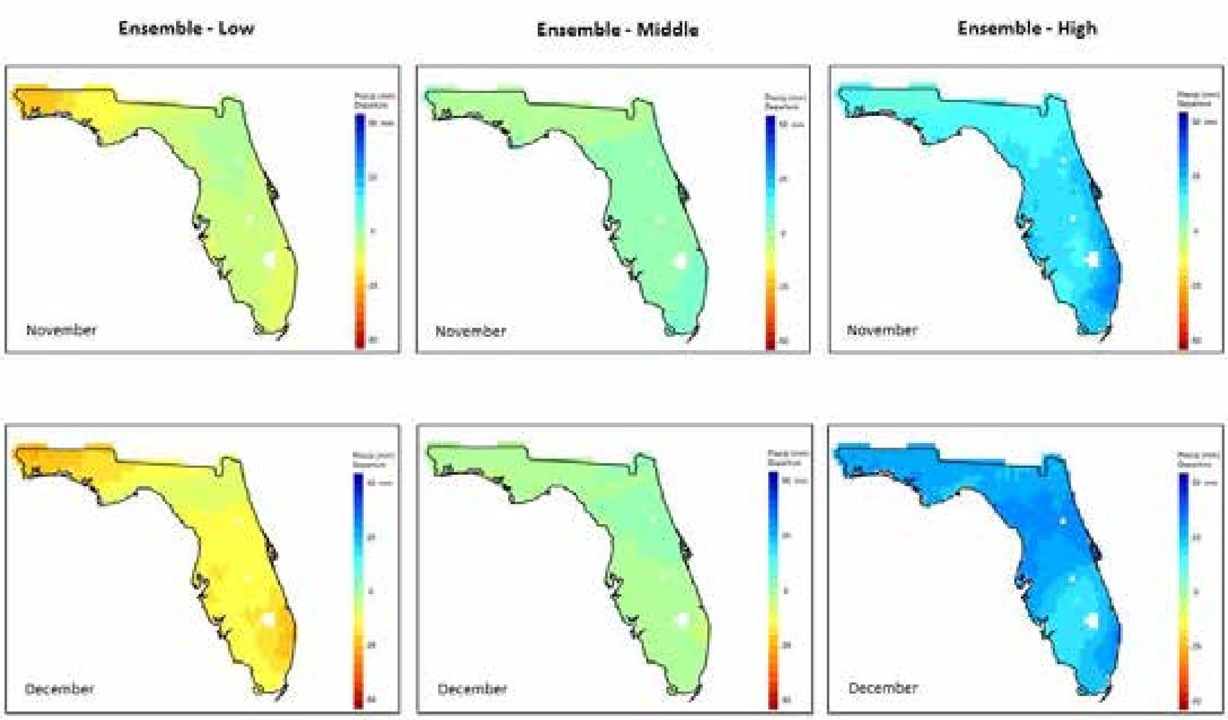
Appendix 1.2 Average Precipitation (mm) Departure 1950 -2099 Compared to 1961 – 1990, A2



Appendix 1.2 Average Precipitation (mm) Departure 1950 -2099 Compared to 1961 – 1990, A2



Appendix 1.2 Average Precipitation (mm) Departure 1950 -2099 Compared to 1961 – 1990, A2



12.1.3 APPENDIX 1.3

Table A1. This table outlines the acronyms for the various climate circulation models outlined in the previous set of regional climate maps and graphs. Use this table as a reference for differentiating which circulation models were used in this Appendix.

General Circulation Models

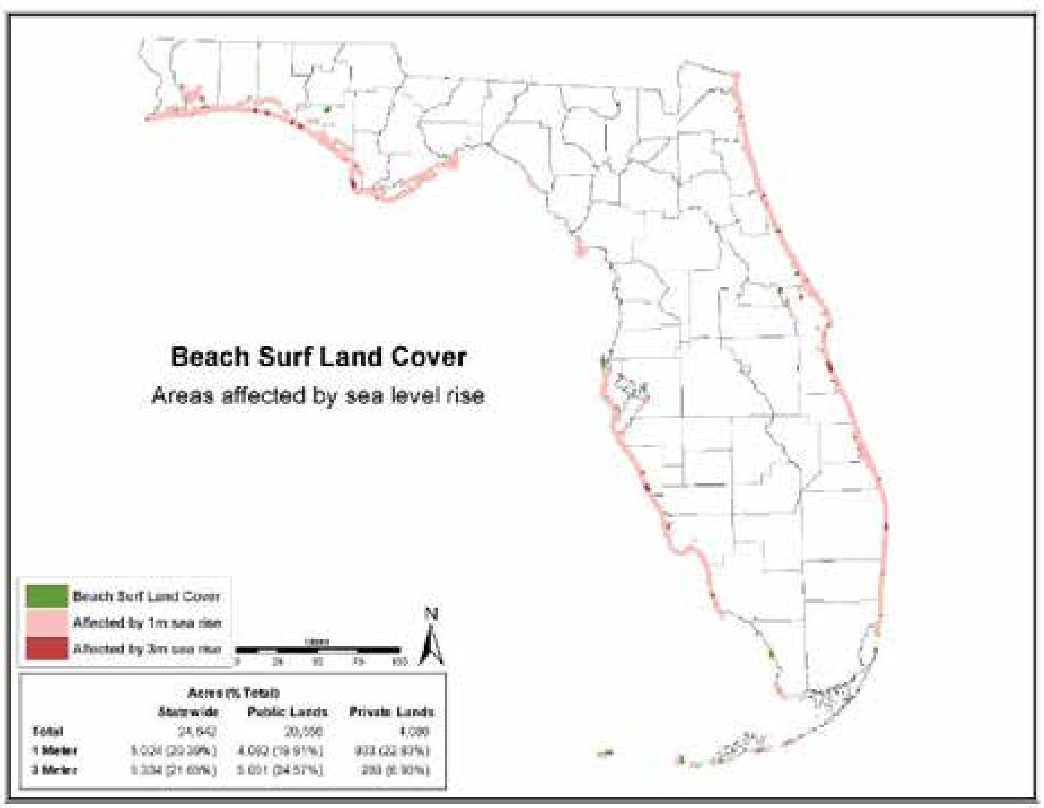
BCCR-BCM2.0	Norway	Bjerknes Centre for Climate Research
CGCM3.1(T47)	Canada	Canadian Centre for Climate Modelling & Analysis
CNRM-CM3	France	Météo-France / Centre National de Recherches Météorologiques
CSIRO-Mk3.0	Australia	CSIRO Atmospheric Research
GFDL-CM2.0	USA	US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory
GFDL-CM2.1	USA	US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory
GISS-ER	USA	NASA / Goddard Institute for Space Studies
INM-CM3.0	Russia	Institute for Numerical Mathematics
IPSL-CM4	France	Institut Pierre Simon Laplace
MIROC3.2 (medres)	Japan	Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)
ECHO-G	Germany / Korea	Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, and Model and Data group.
ECHAM5/MPI-OM	Germany	Max Planck Institute for Meteorology
MRI-CGCM2.3.2	Japan	Meteorological Research Institute
CCSM3	USA	National Center for Atmospheric Research

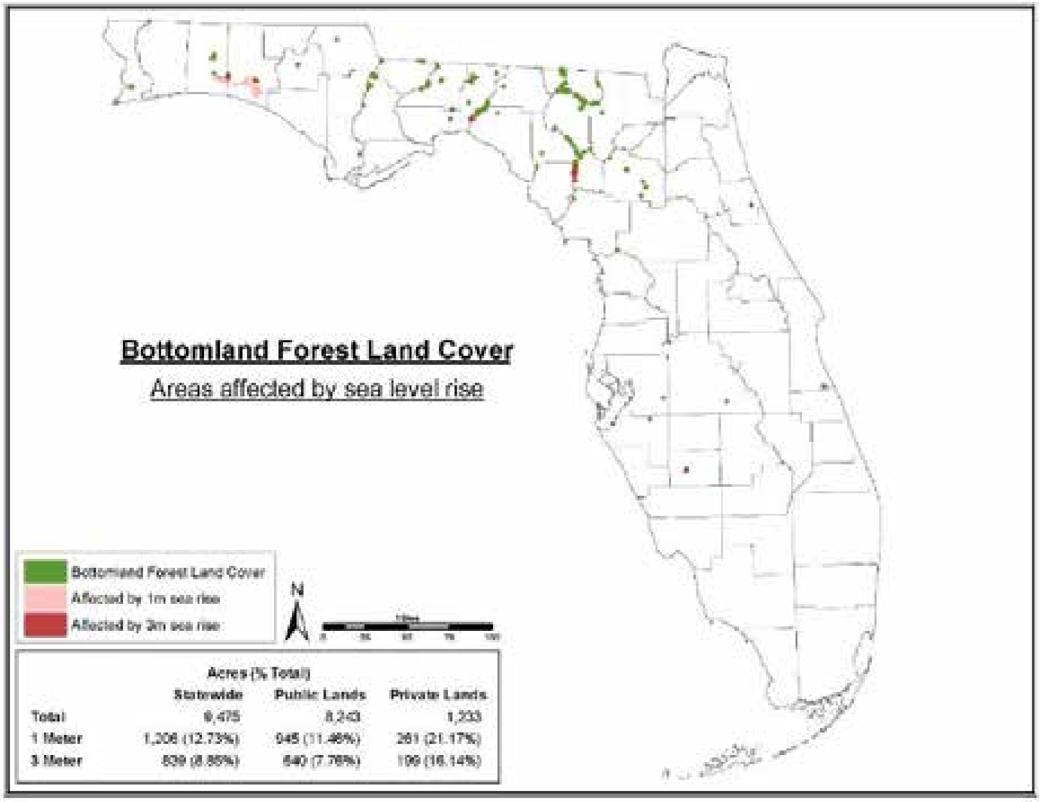
PCM	USA	National Center for Atmospheric Research
UKMO-HadCM3	UK	Hadley Centre for Climate Prediction and Research / Met Office

12.2 APPENDIX 2 - SUPPLEMENTAL COMMUNITY SEA LEVEL RISE IMPACT MAPS

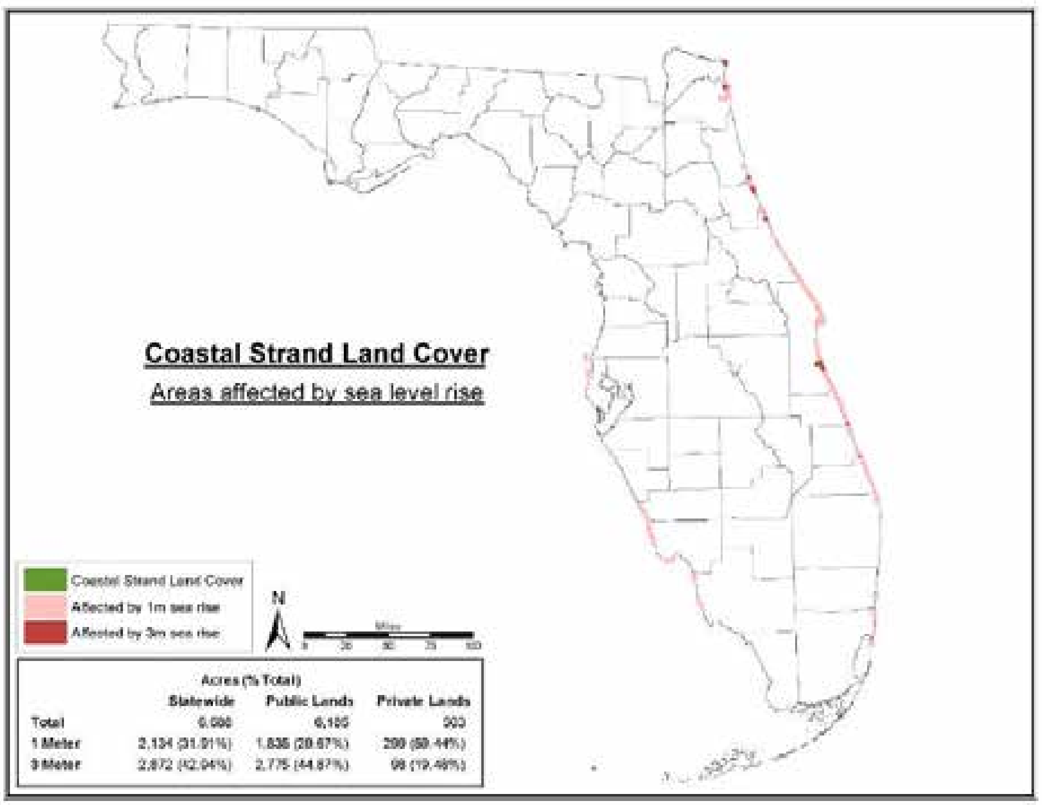
The maps included in this appendix are heavily generalized and were designed to show the approximate portion of habitat projected to be impacted by SLR for some of the habitats and communities outlined earlier in Section 6 of this adaptation guide. These habitat maps utilized buffers of vector land cover data to highlight and emphasize these habitats in Florida. As a result, these maps do not support accurate areal depictions or locations of these habitats and should be used for generalization purposes only. More detailed maps of each habitat type can be found in the text of this adaptation guide, the State Wildlife Action Plan, or FWC's Cooperative Land Cover Map.

Figure A1. This grouping of maps (17) show the buffered intersections of various habitats and communities and different SLR scenarios. Each map also included the same acreage calculations included previously in the text of this guide. These maps can be used to highlight where certain habitats are projected to be impacted across the state.

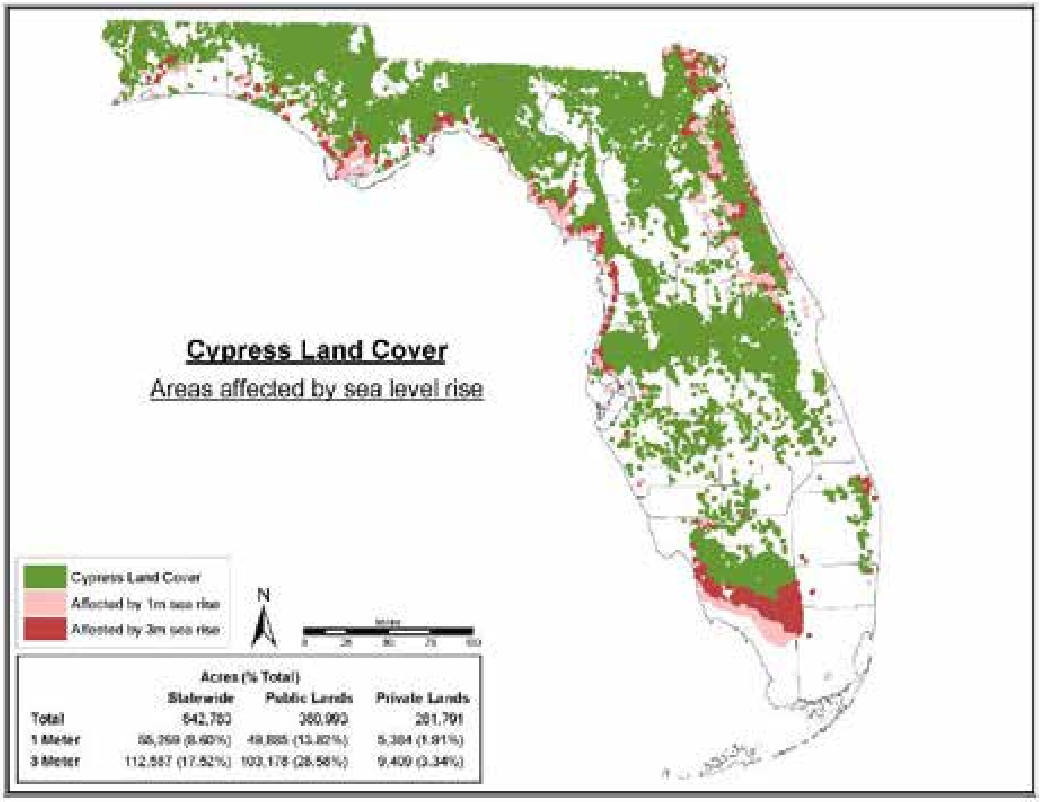




	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	9,475	8,243	1,233
1 Meter	1,206 (12.73%)	945 (11.46%)	261 (21.17%)
3 Meter	839 (8.85%)	640 (7.76%)	199 (16.14%)

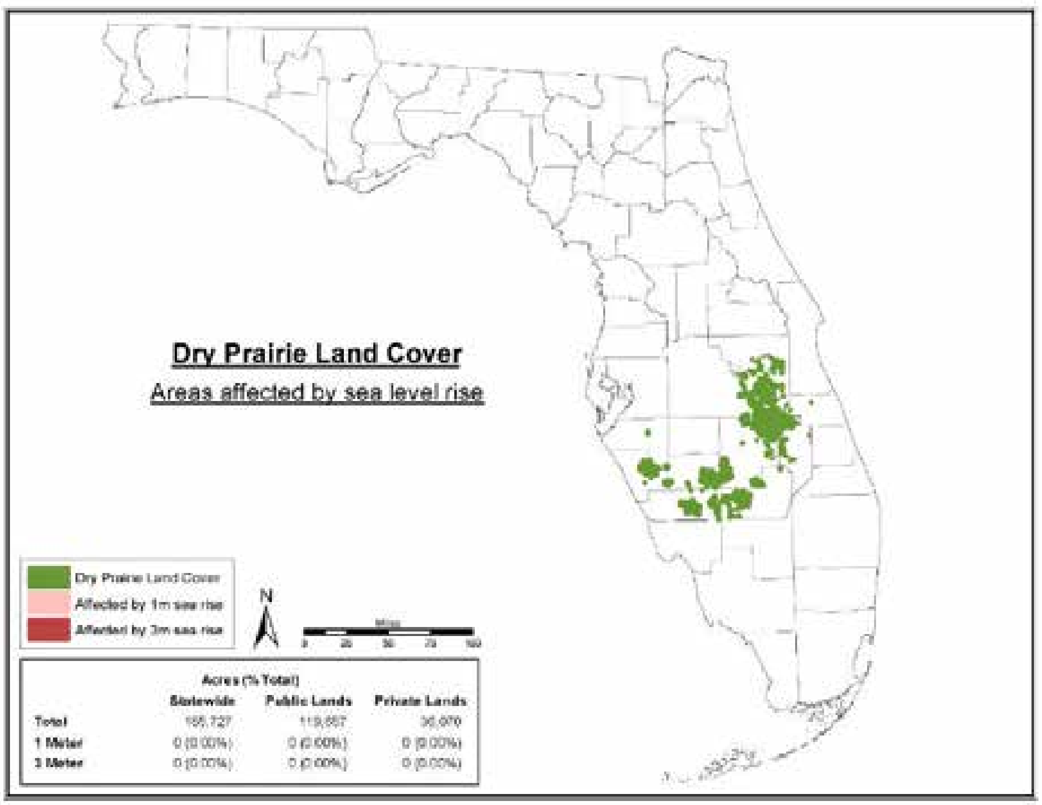


	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	6,688	6,185	503
1 Meter	2,134 (31.91%)	1,835 (29.67%)	299 (59.44%)
3 Meter	2,872 (42.94%)	2,775 (44.87%)	98 (19.48%)



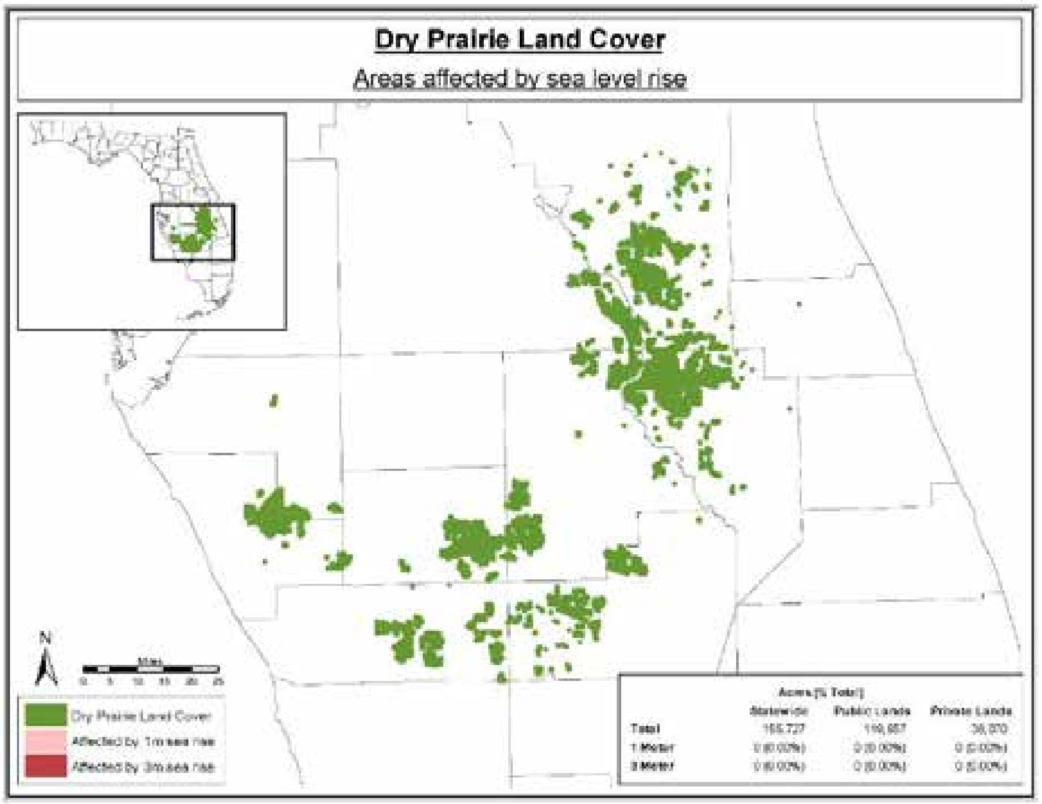
Cypress Land Cover
Areas affected by sea level rise
Cypress Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Miles
0 25 50 75 100
Acres (% Total)

	Statewide	Public Lands	Private Lands
Total	642,780	360,993	281,791
1 Meter	55,259 (8.60%)	49,885 (13.82%)	5,384 (1.91%)
3 Meter	112,587 (17.52%)	103,178 (28.58%)	9,409 (3.34%)

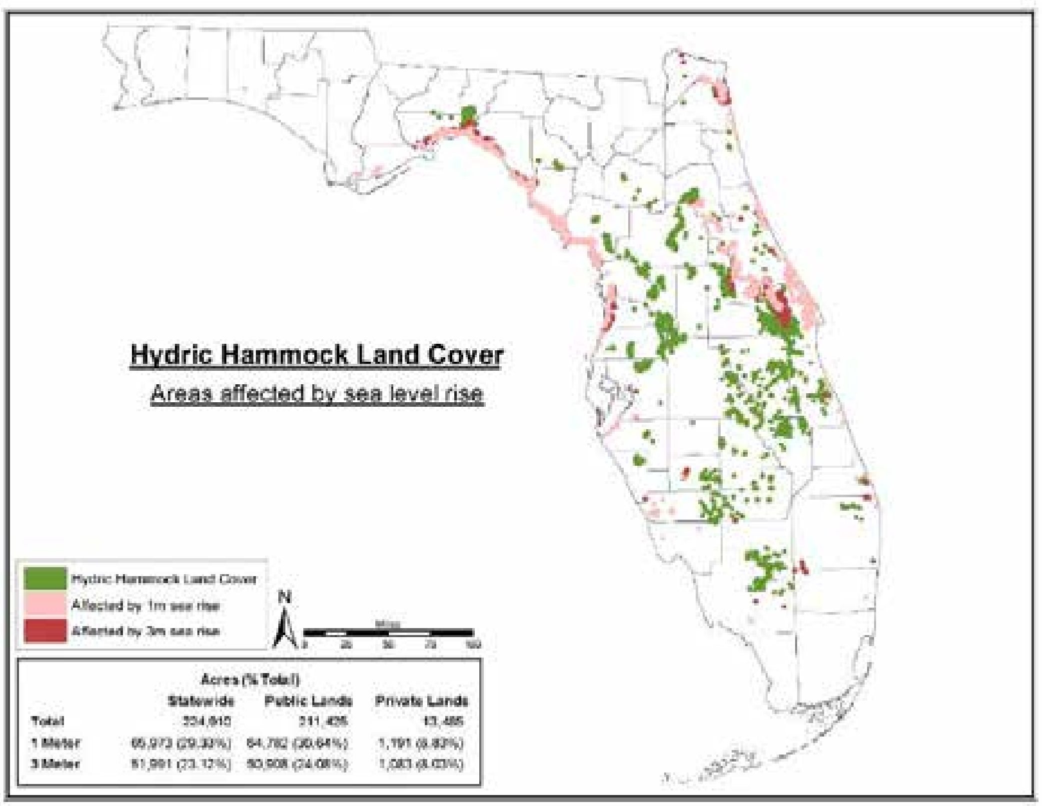


Dry Prairie Land Cover
Areas affected by sea level rise
Dry Prairie Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Miles
0 25 50 75 100
Acres (% Total)

	Statewide	Public Lands	Private Lands
Total	155,727	119,657	36,070
1 Meter	0 (0.00%)	0 (0.00%)	0 (0.00%)
3 Meter	0 (0.00%)	0 (0.00%)	0 (0.00%)

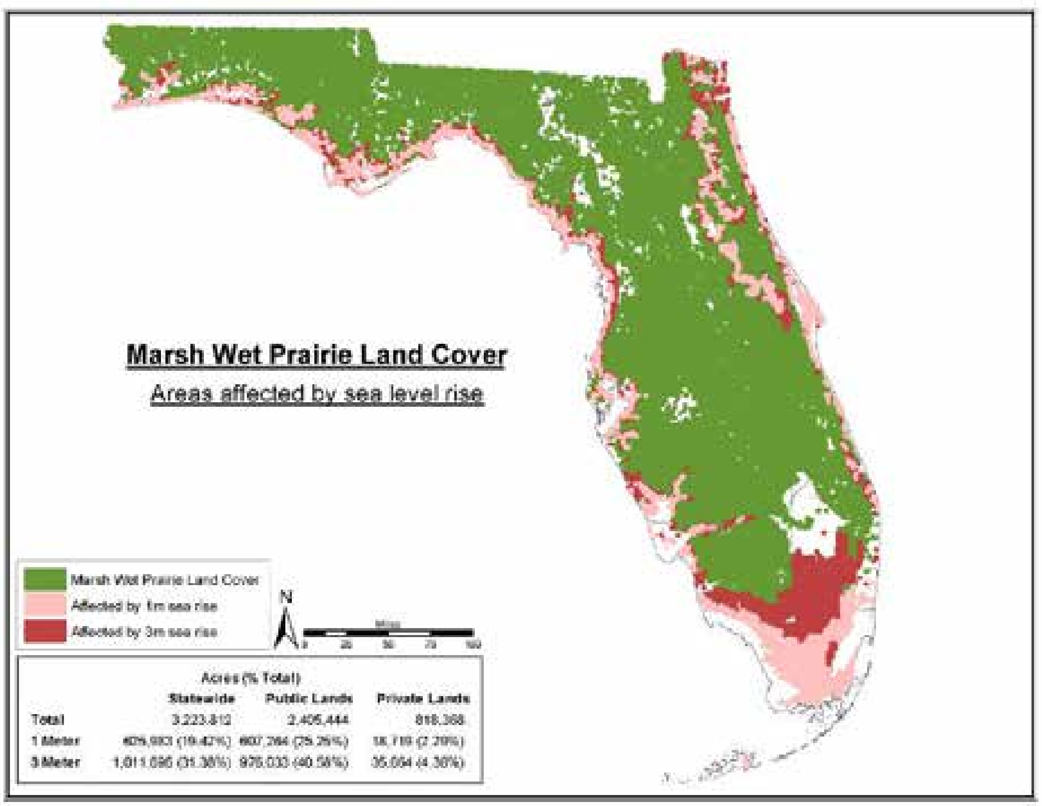


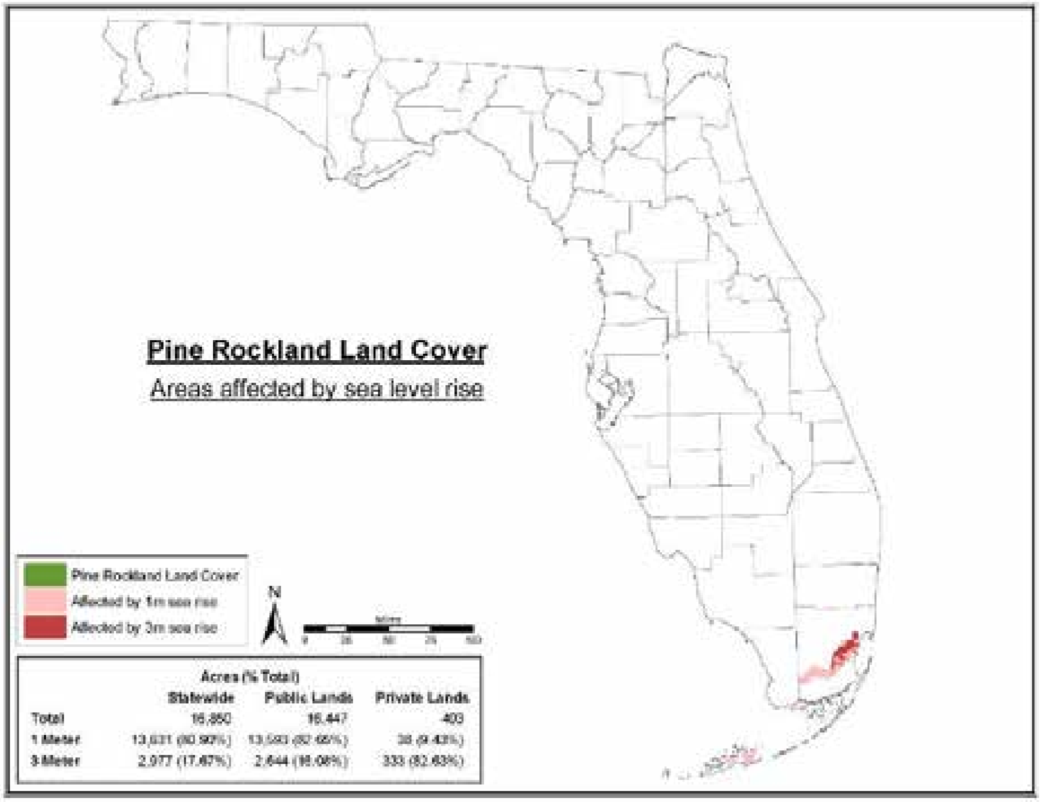
	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	155,727	116,857	38,870
1 Meter	0 (0.00%)	0 (0.00%)	0 (0.00%)
3 Meter	0 (0.00%)	0 (0.00%)	0 (0.00%)

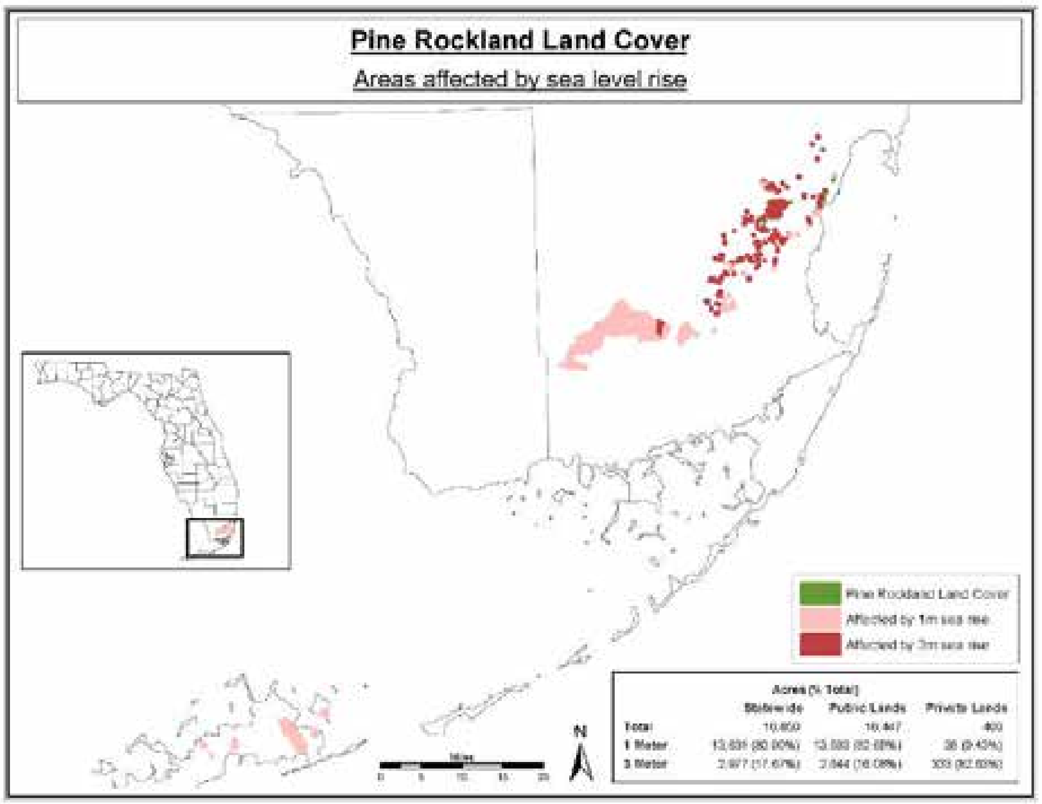


	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	224,910	211,425	13,485
1 Meter	65,973 (29.33%)	64,782 (30.64%)	1,191 (8.83%)
3 Meter	51,991 (23.12%)	50,908 (24.08%)	1,083 (8.03%)

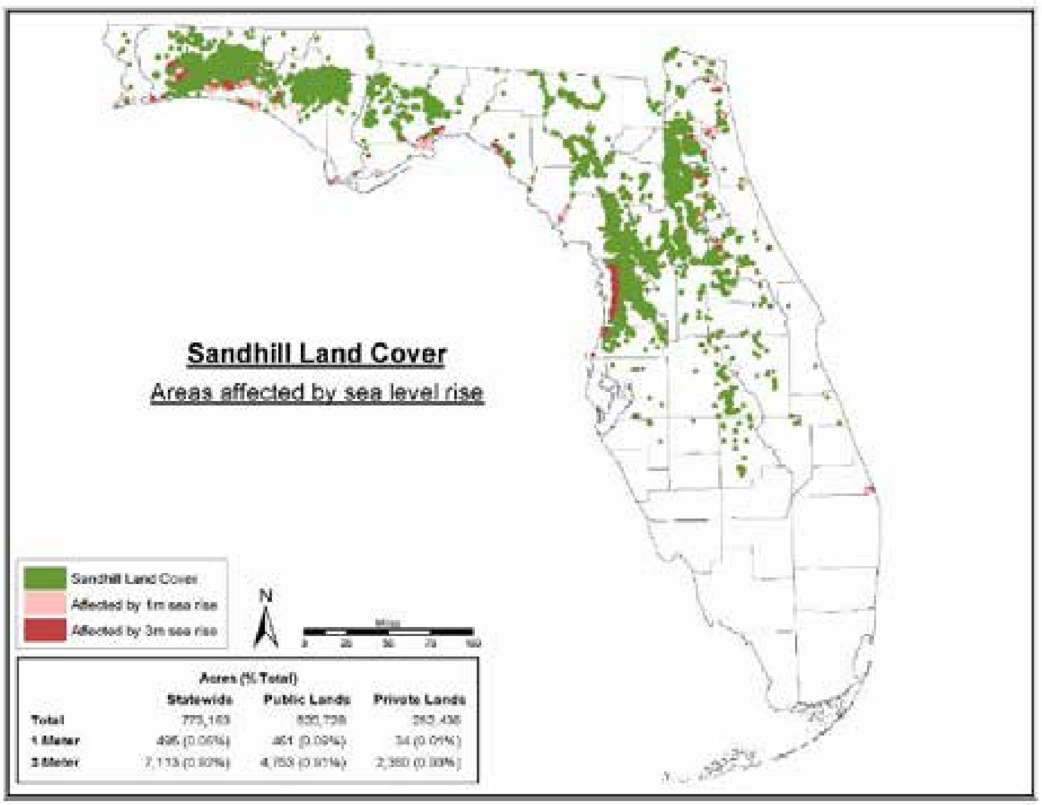

Mangrove Land Cover
Areas affected by sea level rise
Mangrove Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Acres (% Total)
Statewide Public Lands Private Lands
Total 613,137 583,445 29,691
1 Meter
3 Meter 304 (1.02%)

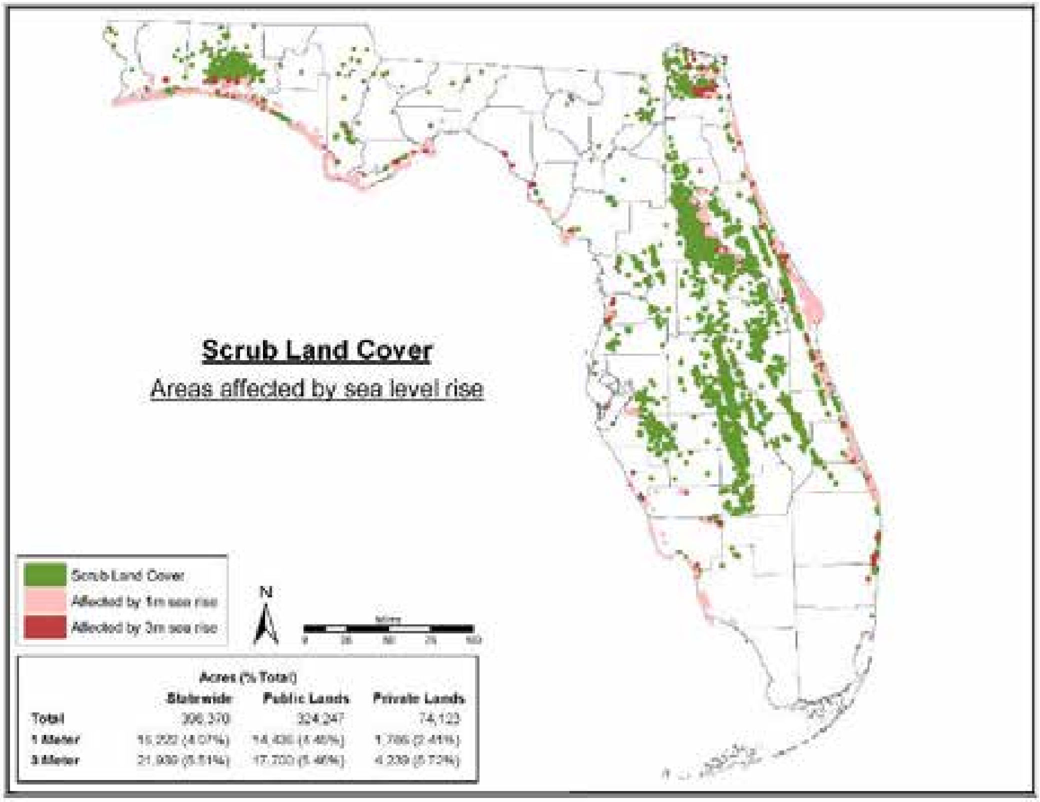

Marsh Wet Prairie Land Cover
Areas affected by sea level rise
Marsh Wet Prairie Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Acres (% Total)
Statewide Public Lands Private Lands
Total 3,223,812 2,405,444 818,368
1 Meter 625,983 (19.42%) 607,264 (25.25%) 18,719 (2.29%)
3 Meter 1,011,096 (31.36%) 976,033 (40.58%) 35,064 (4.30%)


Pine Rockland Land Cover
Areas affected by sea level rise
Pine Rockland Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Miles
Acres (% Total)
Statewide
Public Lands
Private Lands
Total
16,850
16,447
403
1 Meter
38 (9.43%)
3 Meter
2,977 (17.67%)
2,644 (16.08%)
333 (82.63%)

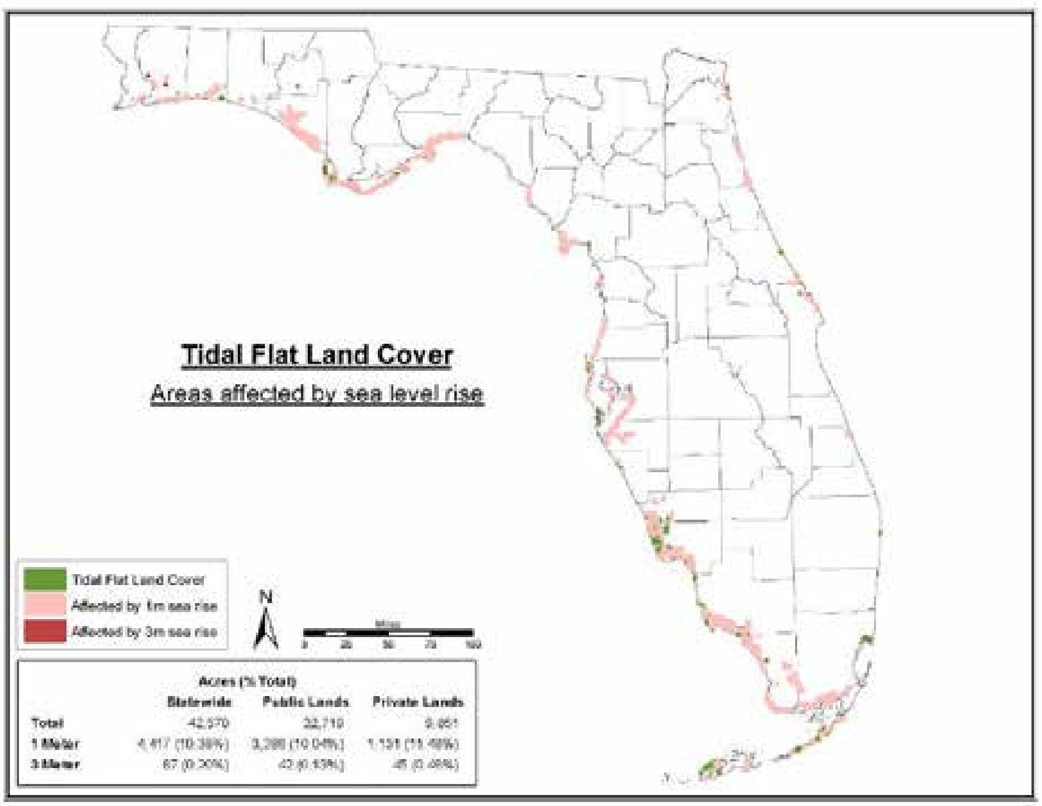

Pine Rockland Land Cover
Areas affected by sea level rise
Pine Rockland Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Miles


Salt Marsh Land Cover
Areas affected by sea level rise
Salt Marsh Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Miles
0 25 50 75 100
Acres (% Total)
Statewide Public Lands Private Lands
Total 377,875 315,462 62,413
1 Meter 315,500 (83.49%) 269,026 (85.28%) 46,474 (74.46%)
3 Meter 16,411 (4.34%) 9,934 (3.15%) 6,476 (10.38%)

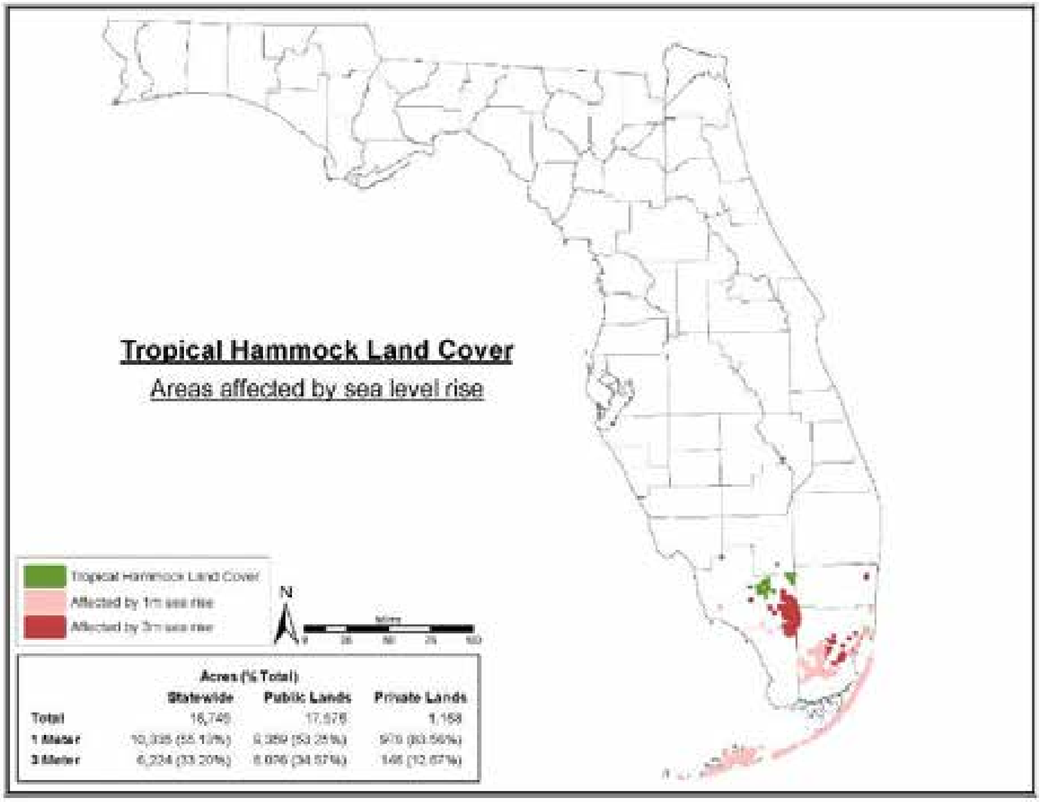

Sandhill Land Cover
Areas affected by sea level rise
Sandhill Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Miles
0 25 50 75 100
Acres (% Total)
Statewide Public Lands Private Lands
Total 775,163 520,738 253,436
1 Meter 495 (0.06%) 461 (0.09%) 34 (0.01%)
3 Meter 7,113 (0.92%) 4,753 (0.91%) 2,360 (0.93%)

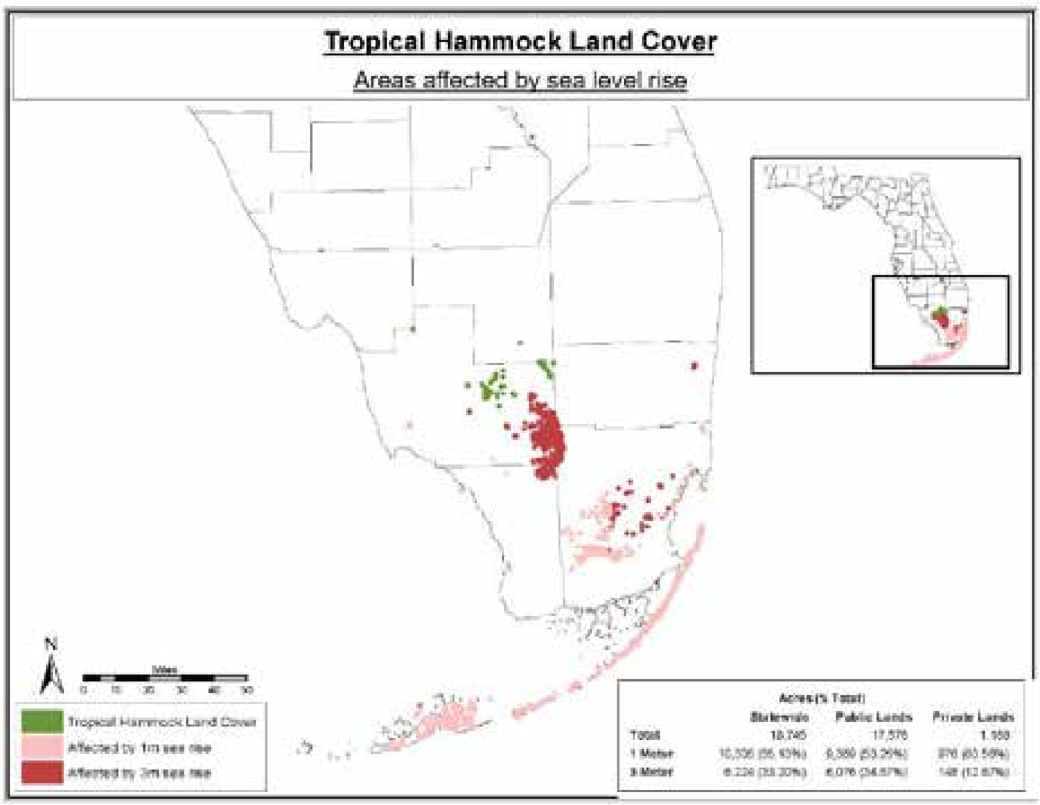


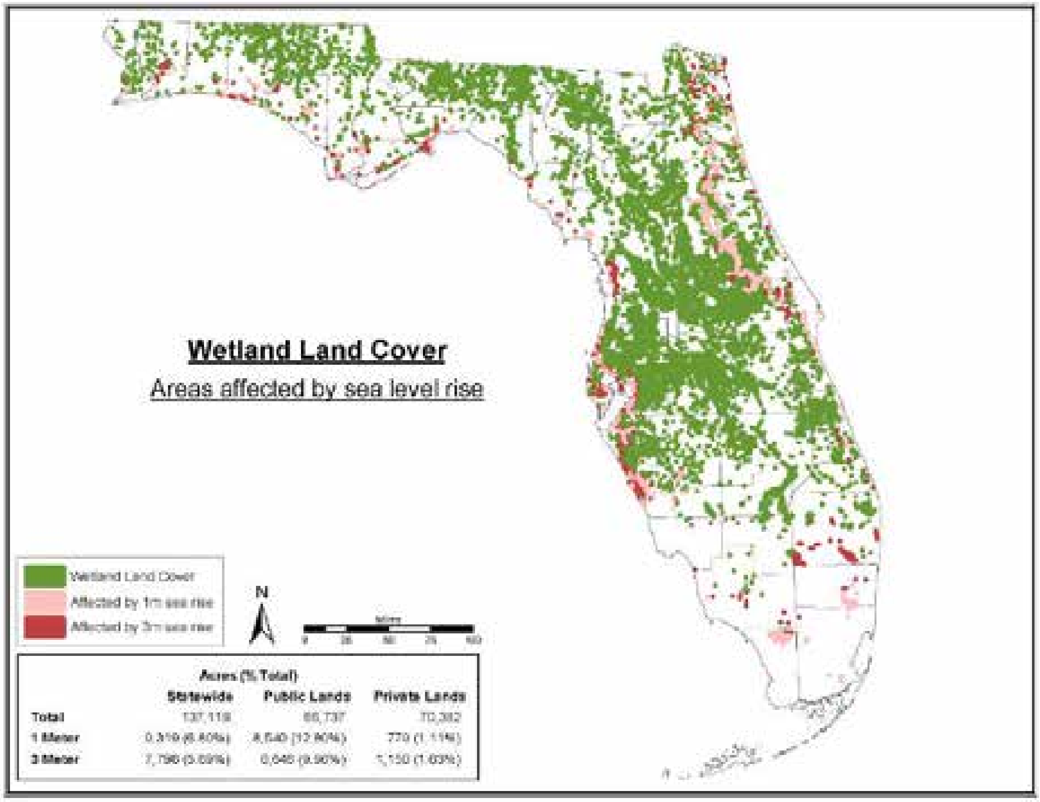
	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	398,370	324,247	74,123
1 Meter	16,222 (4.07%)	14,436 (4.45%)	1,786 (2.41%)
3 Meter	21,939 (5.51%)	17,700 (5.46%)	4,239 (5.72%)



	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	42,570	32,719	9,851
1 Meter	4,417 (10.38%)	3,286 (10.04%)	1,131 (11.48%)
3 Meter	87 (0.20%)	42 (0.13%)	45 (0.46%)


Tropical Hammock Land Cover
Areas affected by sea level rise
Tropical Hammock Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
N
Acres (% Total)
Statewide
Public Lands
Private Lands
Total
1 Meter
3 Meter


Tropical Hammock Land Cover
Areas affected by sea level rise
N
Miles
Tropical Hammock Land Cover
Affected by 1m sea rise
Affected by 3m sea rise
Acres (% Total)
Statewide
Public Lands
Private Lands
Total
1 Meter
3 Meter



	Acres (% Total)		
	Statewide	Public Lands	Private Lands
Total	137,119	66,737	70,382
1 Meter	9,310 (6.80%)	8,540 (12.80%)	770 (1.11%)
3 Meter	7,796 (5.69%)	6,646 (9.96%)	1,150 (1.63%)