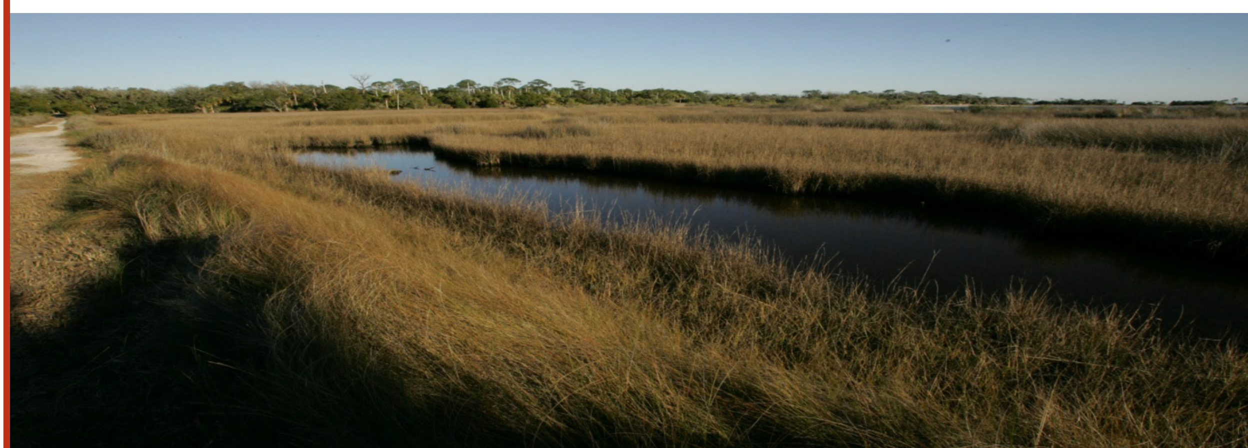
Integrating Climate Change Vulnerability Assessments into Adaptation Planning

A case study using the NatureServe Climate Change Vulnerability Index to inform conservation planning for species in Florida

A Report Prepared for the Florida Fish and Wildlife Conservation Commission



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Defenders of Wildlife is a national, nonprofit, membership organization dedicated to the protection of all native wild animals and plants in their natural communities.

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EXECUTIVE SUMMARY

Most natural resource planning, management and monitoring methodologies in place today are based on an assumption that species distributions and ecological processes will remain relatively stable over time. This fundamental assumption has been challenged, however, in the face of rapid climatic changes that are altering temperature, precipitation, sea level and ocean chemistry processes. Increasingly, wildlife and natural resource agencies are being challenged to address the impacts of climate change on the resources they strive to protect. In the context of wildlife conservation and management, the emerging field of "climate change adaptation" refers to the process of identifying strategies to prepare for or reduce the impacts of climate-related threats and stresses to biological systems.

Climate change adaptation requires an understanding of how climate change may impact a given biological system so that appropriate management strategies can be identified. Vulnerability to climate change refers to the degree to which an ecological community or individual species is likely to experience harm as a result of changes in climate (Schneider et al. 2007). Vulnerability is a function of exposure to climate change – the magnitude, intensity and duration of the climate changes experienced, the sensitivity of the species or community to these changes, and the capacity of the system to adapt (IPCC 2007, Williams et al. 2008). A vulnerability assessment can help to identify which species or systems are likely to be most strongly affected by projected changes in climate and provides a framework for understanding why particular species or systems are likely to be vulnerable (Glick et al. 2011). Such an assessment informs conservation planning by identifying climate-related threats and resulting stresses, which then become part of the decision-making process undertaken to identify and prioritize conservation strategies. When integrated into a conservation planning framework, adaptation does not replace current conservation practices and standards, but expands the applicability of these tools to better address the realities of a changing world.

Integrating Climate Change into Florida's Wildlife Legacy Initiative

In 2005, the Florida Fish and Wildlife Conservation Commission (FWC) released Florida's Wildlife Legacy Initiative (FWC 2005), the state's wildlife action plan or SWAP, which identifies conservation threats impacting species of greatest conservation need (SGCN) and their associated habitats, and actions proposed to mitigate those threats. As FWC moves towards the 2015 revision of the SWAP, they are actively expanding their efforts to address new threats emerging as a result of climate change. Defenders of Wildlife assisted FWC with a pilot exercise using an existing vulnerability assessment tool, the NatureServe Climate Change Vulnerability Index (CCVI) (Young et al. 2010) to identify factors contributing to vulnerability to climate change for a set of species occurring in Florida. The results of this assessment were used in

combination with a scenario-based modeling approach developed by a team from MIT (Flaxman and Vargas-Moreno 2011) to identify potential adaptation strategies as part of an integrated planning framework. This combined approach was implemented through a pair of workshops held in January and April 2011.

In conducting this assessment, we sought to:

- Evaluate the applicability of the NatureServe Climate Change Vulnerability Index as a tool for understanding the impacts of climate change on wildlife in Florida
- Identify ways in which this tool might be adapted and/or modified to better capture factors influencing vulnerability of species and habitats in Florida
- Understand how this tool might inform and be integrated with other approaches to vulnerability assessment
- Identify methods for incorporating these tools into processes for developing effective adaptation strategies

Assessing Vulnerability to Climate Change

We conducted assessments for 21 species that reflected diverse ecological and management attributes of interest: five native birds, four native reptiles, three native amphibians, four native mammals[1], two native invertebrates and three non-native, invasive species. Many of the native species investigated are identified in the SWAP as species of greatest conservation need. The NatureServe Climate Change Vulnerability Index (CCVI) evaluates vulnerability for each species based on projected exposure to climate change within the species' range and various species-specific factors associated with vulnerability to climate change, such as dispersal ability, dietary and habitat flexibility, and breadth of suitable temperature and moisture requirements. Species experts were identified by FWC and invited to participate in the assessment by individually filling out a worksheet module developed by Defenders staff to elicit the information required to assign scores for the indirect exposure and sensitivity factors identified in the CCVI. After completing the worksheet module, species experts participated in a phone call to discuss their responses. Defenders staff parameterized the CCVI analysis based on the information provided by the species experts and the guidance provided by NatureServe.

The CCVI generates an index score that corresponds to one of five categorical ranks ranging from "Extremely Vulnerable" to "Not Vulnerable" (Figure ES-1). These relative ranks can provide information regarding which species are most vulnerable to climate change, however, it is understanding why a particular species is vulnerable that provides the basis for developing appropriate management responses. This information is derived from the analysis of the factors contributing to vulnerability rather than the overall rank. By using a facilitated process with species experts, we were able to use the CCVI as a framework to (1) identify factors contributing to vulnerability, (2) elucidate hypothesized relationships among these factors and the potential impacts on species and their habitats, and (3) differentiate among sources of uncertainty. This structured process provided a foundation for integrating adaptation planning into the existing planning framework used in the Florida SWAP.

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[1] In addition, bonneted bat is included in the species accounts in Appendix A but is not addressed in the main report.

Integrating Vulnerability into an Adaptation Planning Process

After completing the vulnerability assessment, we involved species experts, managers, and other conservation practitioners in a facilitated workshop in which we undertook a conceptual modeling exercise intended to help participants better understand how target species and habitats are affected by existing threats, such as land-use change, while examining how regional changes in climate may interact with or exacerbate existing threats. This facilitated session was intended to provide participants with a framework to understanding how the results of a vulnerability assessment can be incorporated into climate adaptation planning, with a goal of demonstrating a process by which the existing SWAP could be broadened to address climate change drivers and adaptation strategies. We carried out this exercise for six of the assessed species: short-tailed hawk, least tern, Atlantic salt marsh snake, American crocodile, Florida panther, and Key deer.

For each species, workshop participants started with an initial set of potential threats and drivers drawn from the SWAP and brought in the elements identified in the vulnerability assessment. Participants were asked to review and modify these basic components as needed and use them as the starting point to begin building a conceptual model, with particular emphasis on incorporating climate drivers and interactions with other drivers. Participants were asked to rank the top three to five threats, focusing on those threats either directly or indirectly related to climate change, and identify specific management actions that could be taken to mitigate those threats. Each group identified a set of priority strategies based on their conceptual model. As an example, the conceptual model developed for American crocodile is shown in Figure ES-2.

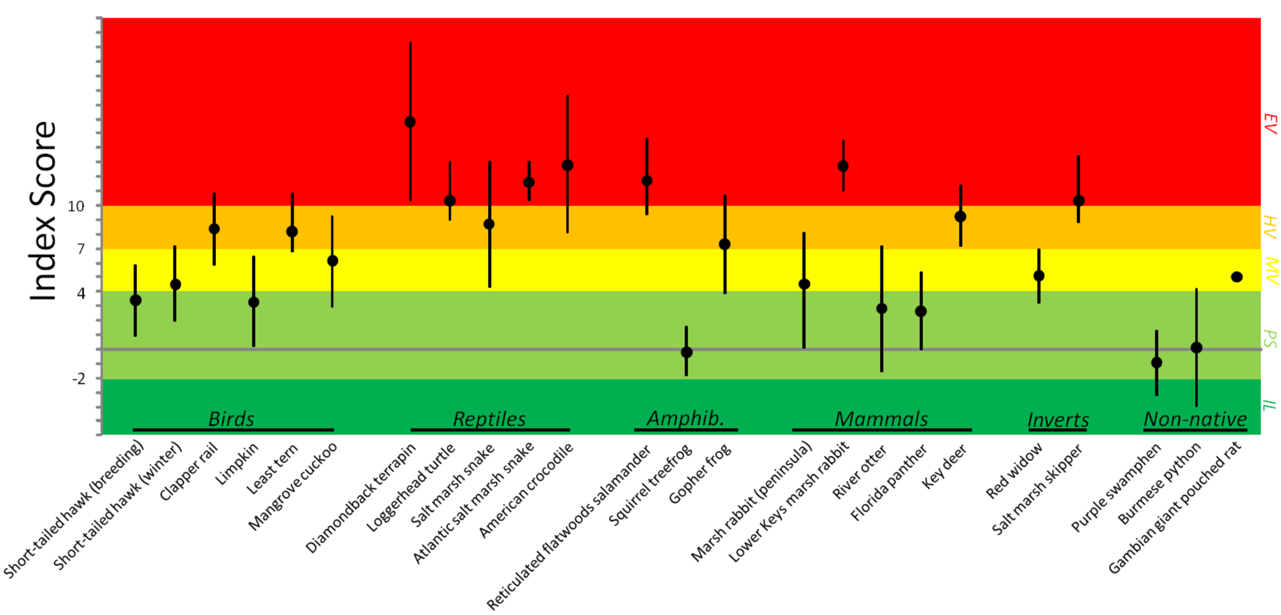

Figure ES-1. CCVI Index scores for the indicated species within their ranges in Florida. The index score (black circle) is shown along with the range of scores produced by the Monte Carlo simulation*. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Not Vulnerable/Presumed Stable" (green), "Not Vulnerable/ Increase Likely" (dark green).

*The Monte Carlo simulations provide an estimate of sensitivity to the range of values associated with the input parameters in cases where more than one score is assigned to one or more factors.

Figure ES-2. Workshop participants developed a conceptual model describing climate-related threats and interactions with other threats affecting American crocodile within its range in Florida. The model was used to identify intervention points where actions could be implemented to improve the condition of the target by ameliorating a particular threat.

Incorporating the Spatial Context

This process was conducted in parallel with a spatially-explicit vulnerability assessment approach developed by a team from the Department of Urban Studies and Planning at the Massachusetts Institute of Technology (Flaxman and Vargas-Moreno 2011). The "Alternative Futures" are a set of future land use scenarios that incorporate climate change (primarily sea level rise), public policy options and financial conditions to model land use changes. By overlaying these scenarios with current habitat models, potential conflicts can be examined, including the location and degree of impact across a species' habitat under future conditions. Participants were able to incorporate the mapping exercises and land use scenarios produced as part of MIT's Alternative Futures approach into their conceptual models. For example, they had a better idea of potential scope of land use changes associated with sea level rise, such as increased demand for interior development, and where those changes were more likely to occur relative to the species' habitat. In addition, the Alternative Futures scenarios provided a spatial context within which participants could translate the adaptation strategies identified through the conceptual modeling process into spatially-explicit actions that could be visualized on the landscape.

Lessons Learned: Important Considerations When Conducting a Vulnerability Assessment

A vulnerability assessment should provide a framework for assessing vulnerability to climate change by unpacking vulnerability into its constituent parts. The CCVI provides one such framework for assessing species' vulnerability. Other causal models of vulnerability could be identified that would address climate-related threats and stresses at additional scales (e.g., habitats or landscapes) or that might capture additional threats and stresses unique to particular geographies or systems.

Recognize that a priori assumptions about which species will be most vulnerable may not be accurate. For example, range-restricted species or rare species did not necessarily rank as more vulnerable than widely distributed or common species. Nor did existing conservation status rankings necessarily correlate with vulnerability to climate change.

Consider the appropriate unit of analysis prior to conducting the assessment. A species-level assessment may not capture differences in exposure and/or sensitivity among subspecies or populations, or where there are differences in exposure and/or sensitivity during different parts of the year or life cycle. For example, mainland populations of marsh rabbit had very different indirect exposure scores than the Lower Keys marsh rabbit and consequently had very different vulnerability ranks.

Understand the limitations of any particular approach. In some cases, there were difficulties capturing complex system dynamics, such as vegetation shifts or responses to seasonal changes in temperature or moisture regimes, in the causal model of vulnerability used in the CCVI. For some species, reviewers identified factors that were not captured in the model or were not well-defined.

Recognize that factors may be interpreted or scored differently by individual experts. Discussing differences among species experts and providing extensive documentation supporting individual scoring decisions is essential to ensuring the repeatability and transparency of any vulnerability assessment.

Differentiate between uncertainties associated with the different components of vulnerability. We found that the CCVI factors associated with the largest amount of uncertainty were those that required a combined evaluation of both sensitivity and exposure. In these cases, the uncertainty was often associated with projecting the magnitude or direction of the exposure factor and its associated impacts rather than the species' sensitivity.

Interpret outputs appropriately. Many vulnerability assessments, including the CCVI, are designed to be used in combination with other assessments of conservation status. For example, the CCVI does not capture factors included in conservation status ranks, such as population size, range size, and or demographic factors. These factors may magnify or interact with species vulnerability to climate change. For place-based tools, such as the CCVI, different management considerations may be required for species that are vulnerable in only a portion of their range versus those that are vulnerable across their entire range.

Consider involving multiple experts and stakeholders. We found benefits to engaging species experts in combined individual-group assessments, although it was a fairly time-intensive approach. Involving multiple experts and allowing them to work through the assessment individually before discussing it as a group elicited multiple viewpoints and additional considerations that may not have been emerged from other elicitation formats.

Adaptation as Part of a Comprehensive Planning Process

Incorporating vulnerability into a comprehensive planning process requires understanding the factors, as well as the strength of interactions between the factors, contributing to vulnerability. A vulnerability assessment informs the conservation planning process by identifying climate-related threats and resulting stresses. Understanding the context within which a vulnerable species or habitat exists, and identifying the relationships among climate threats and other stressors, lays out the context in which to develop goals, strategies and objectives, and lay out key assumptions and uncertainties. Through this process it may become apparent that some existing strategies will become a higher priority or that new strategies may be required to achieve conservation and management goals under climate change. A decision-making process that accounts for the impacts (i.e. threats and stresses) related to climate change on a species or system is what we refer to as "adaptation planning." The case study presented here illustrates a process for integrating the information obtained from a vulnerability assessment into a planning process to identify adaptation strategies and management opportunities for species likely to be vulnerable to the impacts of climate change.

Recommendations and Next Steps

1. **Assess future needs and identify suitable assessment targets.** Vulnerability assessments are flexible and can be tailored to specific situations and purposes. Before deciding on any particular approach, it is important to first identify the decision problem and the applicability of any particular tool to the problem at hand. For example, a species-level approach (such as the CCVI) may not be the most appropriate unit of analysis for land management, and other methods may be needed to address management at different scales.

2. **Integrate multiple approaches for assessing the vulnerability of species to climate change.** Complementary methodologies, including ecophysical modeling, population models and direct observation, are likely to inform our understanding of the potential impacts on species and habitats. Understanding the conceptual linkages connecting climate threats to the stresses affecting a conservation target provides the context within which to evaluate current priorities, strategies and responses, and whether these still make sense under climate change.

3. **Identify the current decision-making process for developing and implementing wildlife management strategies.** Assess whether the current process has the flexibility incorporate climate change response strategies, and if needed define a process for revising current practices and management actions to achieve conservation goals under climate change.

4. **Implement actions and monitor effectiveness as part of a comprehensive planning framework.** Formulate specific "theories of change" regarding the expected results and outcomes for adaptation strategies and monitor the effectiveness of conservation and management activities employed to achieve these results.

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INTRODUCTION

MOST NATURAL RESOURCE PLANNING, MANAGEMENT AND MONITORING METHODOLOGIES IN PLACE TODAY ARE BASED ON AN ASSUMPTION THAT SPECIES DISTRIBUTIONS AND ECOLOGICAL PROCESSES WILL REMAIN RELATIVELY STABLE OVER TIME. HOWEVER, THE RAPID RATE OF CLIMATE CHANGE THAT THE EARTH'S SYSTEMS ARE CURRENTLY EXPERIENCING MEANS THAT MANY OF THESE ASSUMPTIONS NO LONGER HOLD TRUE. INCREASINGLY, WILDLIFE AND NATURAL RESOURCE AGENCIES ARE BEING CHALLENGED TO ADDRESS THE IMPACTS OF CLIMATE CHANGE ON THE VERY RESOURCES THEY STRIVE TO PROTECT.

The current global warming trend has accelerated in recent decades, and continued greenhouse gas emissions commit us to projected global average increases of 2–11.5° F by the end of the century (Karl et al. 2009). Estimates suggest that 20 - 30% of the species currently assessed are at risk of extinction within this century if global mean temperatures exceed increases of 2.7–4.5° F (IPCC 2007a), and certain ecosystems will be affected at temperature increases well below these levels. Already, the timing of biological processes, such as flowering, breeding, hibernation, and migration are changing (McCarty 2001, Walther et al. 2002, Parmesan 2006), altering relationships between species and decoupling critical species interactions. Invasions and outbreaks are becoming more common (e.g., Logan and Powell 2009), and in coastal areas, habitat is being lost to sea level rise (e.g., Stevenson et al. 2002). Some species will adjust to new conditions via ecological or evolutionary adaptation, whereas others will exhibit range shifts as their distributions track changing climatic conditions. And some species unable to respond to changing climates will simply go extinct.

Integrating Climate Change into Florida's Wildlife Legacy Initiative

In 2000, Congress enacted the State Wildlife Grants Program to support state agencies in their efforts to implement cost-effective conservation with the goal of preventing all wildlife from becoming endangered. As part of this program, each state and territory developed a state wildlife action plan (SWAP) to identify priority species and habitats and lay out the actions needed to conserve those resources. In 2005, the Florida Fish and Wildlife Conservation Commission (FWC) released Florida's Wildlife Legacy Initiative (FWC 2005), or SWAP, which identifies conservation threats impacting species of greatest conservation need (SCGN) and their associated habitats and actions proposed to mitigate those threats. As FWC moves towards the 2015 revision of the SWAP, they are actively expanding their efforts to address new threats emerging as a result of climate change.

FWC recognized that vulnerability assessments are a key tool towards integrating climate change into the SWAP and other conservation planning efforts. The primary goal of this project was to develop a better understanding of the available tools and approaches to vulnerability assessment as part of a comprehensive planning process. Defenders of Wildlife assisted FWC with a pilot exercise using the NatureServe Climate Change Vulnerability Index (Young et al. 2010) as part of an assessment of vulnerability to climate change for a selected set of species. The results of this assessment were used in combination with a scenario-based modeling approach developed by a team from MIT (Flaxman and Vargas-Moreno 2011) to identify potential adaptation strategies as part of an integrated planning framework. This combined approach was implemented through a pair of workshops held in January and April 2011.

More specifically, this project sought to:

- Evaluate the applicability of the NatureServe Climate Change Vulnerability Index (CCVI) as a tool for understanding the impacts of climate change on wildlife in Florida
- Identify ways in which this tool might be adapted and/or modified to better capture factors influencing vulnerability of species and habitats in Florida
- Understand how this tool might inform and be integrated with other approaches to vulnerability assessment
- Identify methods to incorporate these tools into processes for developing effective adaptation strategies

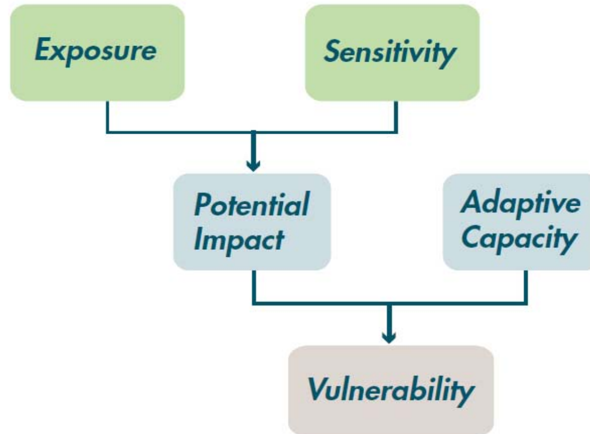


Figure 1. One representation of vulnerability to climate change and the relationship among the three key components (Source: Glick et al. 2011).

Climate Change Vulnerability

In the context of climate change, vulnerability refers to the degree to which an ecological system or individual species is likely to experience harm as a result of changes in climate (Schneider et al. 2007). Vulnerability to climate change is a function of exposure to climate change–the magnitude, intensity and duration of the climate changes experienced, the sensitivity of the species or community to these changes, and the capacity of the system to adapt to these changes (IPCC 2007b, Williams et al. 2008, Glick et al. 2011; Figure 1). Species and ecosystems that are more vulnerable are likely to experience greater impacts from climate change, whereas those that are less vulnerable may be more likely to persist or even benefit from changes in climate.

Some species may be quite sensitive to changes in climate, but will experience little exposure, and thus their realized vulnerability will be low. Other species may experience relatively high exposure but be able to respond to these changes with few impacts. But for many species, biological factors (i.e., sensitivities)–often combined with barriers to dispersal or other landscape features–will limit their ability to adjust to projected changes in climate. It is these species that will be most vulnerable to climate change. As these impacts have become better understood, a new field of climate change adaptation has emerged, encompassing the tools and approaches that will be needed to reduce the vulnerability of ecological systems, including species and habitats, to the impacts of climate change.

Climate models project continued warming across the southeastern United States, with an increasing rate of warming towards the end of the century (Karl et al. 2009). Using downscaled climate data downloaded from Climate Wizard (Zganjar et al. 2009), mid-century projections suggest average annual temperature increases of 3-4° F across the state of Florida (Figure 2). Precipitation projections are more variable, with some models projecting increases and others projecting decreases in annual precipitation. However, even if increases in precipitation occur, these will be offset by increased evaporation and water loss resulting from higher temperatures. Figure 3 shows a map of change in the annual Hamon AET:PET moisture metric as an estimate of projected moisture availability (Young et al. 2010), which shows low to fairly high levels of drying in different regions of the state. While future precipitation trends are often described in terms of changes in annual means, it may be difficult to use this information to assess the impact of climate change on species and ecosystems. Other derived variables, such as hydroperiod, temperature extremes, or changes to disturbance regimes may have more immediate effects.

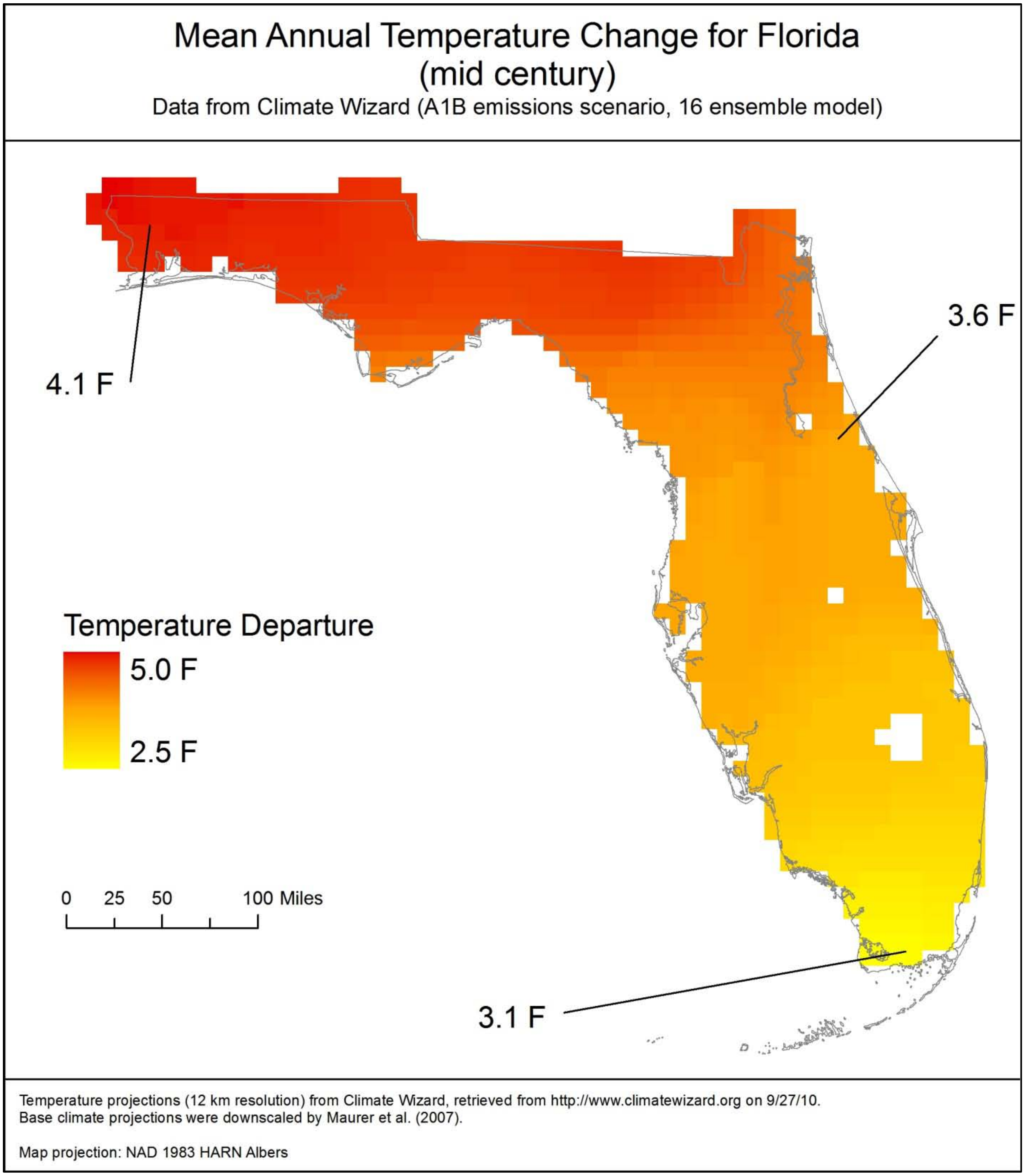


Figure 2. Projected change in mean annual temperature for Florida by mid century. Projections are based on a moderate emissions scenario (A1B) and the ensemble average of 16 GCMs statistically downscaled to 12 km.

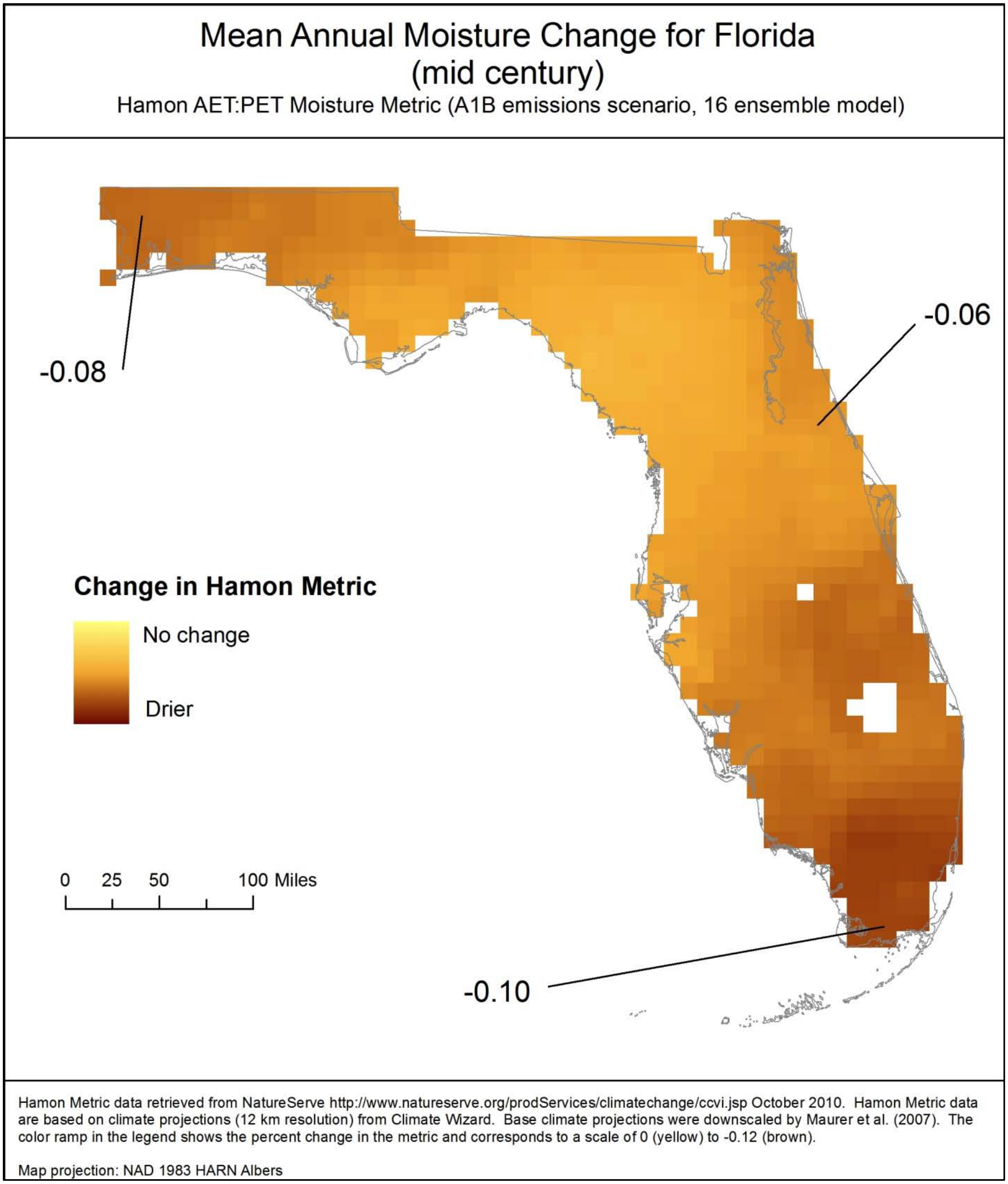


Figure 3. Projected change in mean annual moisture for Florida by mid century. Changes in the Hamon metric are based on projections for a moderate emissions scenario (A1B) and the ensemble average of 16 GCMs statistically downscaled to 12 km.

A vulnerability assessment can help to identify which species or systems are likely to be most strongly affected by projected changes in climate and provides a framework for understanding why particular species or systems are likely to be vulnerable. Determining *which* resources are most vulnerable enables managers to better set priorities for conservation action. Understanding *why* they are vulnerable provides a basis for developing appropriate management responses. However, a vulnerability assessment alone cannot determine where to focus conservation efforts or which management responses should be undertaken (Stein and Glick 2011). A vulnerability assessment informs the conservation planning process by identifying climate related threats and resulting stresses. These threats and stresses then become part of the decision-making process undertaken to identify and prioritize conservation strategies. When the decision-making process accounts for the impacts related to climate change on a species or system, it is often labeled "climate change adaptation."

Climate change adaptation is best understood as a process rather than an outcome. In the context of wildlife conservation and management, adaptation requires an understanding of how climate change may impact a given system (i.e. generate threats and stresses to the system) so that appropriate management strategies can be identified. Many of the analytical and decision-support tools that are being developed to assist conservation practitioners with climate change adaptation are modifications of existing decision-support tools. For example, when incorporated into a conservation planning process, adaptation may involve recognizing new threats, identifying interactions with existing threats (i.e. synergistic threats), re-evaluating existing strategies and even re-evaluating priorities. Some existing strategies will still achieve their desired objectives, whereas others will need to be modified, replaced, or re-invented in order to be effective under climate change. In some cases, novel strategies may be required. Collectively, these "adaptation strategies" reduce a threat that either exists or takes on additional relevance because of climate change. As such, adaptation does not replace current conservation practices and standards, but expands the applicability of these tools to better address the realities of a changing world.

Approaches to Vulnerability Assessment

All vulnerability assessment incorporates some type of ecological response model. The model could be as simple as a conceptual model drawn out in box-and-arrow diagrams or as complex as a geospatial model projecting changes in distribution or vegetation shifts (Hayhoe et al. 2011). These models provide a framework for assessing the sensitivity and potential response of species, habitats, and ecosystems by relating changes in climate to impacts on biological systems. Models can help us understand how a set of drivers interact to influence a system, but they do not predict the future. By definition, all models are simplifications of the real world. It is important to understand the assumptions and limitations of any particular model when assessing the outputs.

Rowland et al. (2011) distinguish between two broad types of vulnerability assessment: those that examine spatially explicit shifts in the geographic range of species with changing climate, and the relatively newer assessment approaches employing evaluative frameworks that generate relative ranks of vulnerability, often across habitats or species. Most evaluative frameworks to vulnerability assessment involve a number of common components (Box 1) and utilize information from multiple sources and approaches. These frameworks often draw on spatially explicit information; however the outputs are not necessarily spatial, although they can be integrated into other spatially explicit frameworks as part of an adaptation planning process.

Vulnerability assessments can vary in the unit of analysis (e.g., species or habitat), scale, investment, and the types of information that can be incorporated. There is no single means to assess vulnerability. The tools and methods used may vary based on the needs, resources, and priorities of the end user. In a recent guide, Glick et al. (2011) highlight a number of case studies using a variety of approaches to vulnerability assessment, and many more examples are currently underway. Below we provide a general overview of how some of these approaches have been implemented and, in many cases, integrated.

Box 1. Assessing Vulnerability to Climate Change (Modified from AFWA 2009)

- STEP 1: Determine the scope of the assessment
  - Set goals/objectives
  - Focus on achievable results, meeting specific information needs
  - Consider analyzing habitat types and a subset of species
  - Decide on an appropriate time frame and spatial scale
  - Identify key products and users
  - Identify limitations and potential partners

- STEP 2: Collect relevant climate and ecological data
  - Use a method that can take advantage of available data
  - Pull in experts
  - Build on existing work

- STEP 3: Describe vulnerability qualitatively and/or quantitatively
  - Build conceptual model of vulnerability
  - Consider not only what is vulnerable, but why and how
  - Highlight opportunities to increase adaptive capacity
  - Determine vulnerability factors
  - Combine climate change vulnerability information with background vulnerability if not addressed in model (e.g. conservation status)
  - Describe uncertainty associated with projections

- STEP 4: Start outlining adaptation priorities and develop strategies
  - Communicate results to stakeholders and partners and ask for feedback
  - Use results to build consensus on strategies
  - Use common vulnerability factors to develop management actions

Expert Panel

Expert panels are a valuable approach in that they draw on a varied and flexible knowledge base with strong stakeholder involvement and often make efficient use of time and resources. However they can vary enormously in approach and outcome, and may lack transparency due to their expert focus. Massachusetts was one of the first states to undertake a vulnerability assessment as part of their efforts to incorporate climate change into the SWAP (Manomet and MADFG 2010). Twenty Massachusetts habitats were selected for evaluation by an expert panel of ecologists and wildlife biologists with professional expertise on the status, distribution, conservation and threats to fish, wildlife and their habitats. Prior to the assessment, all participants in the panel were given training on how the climate in Massachusetts is projected to change, a list of important habitat variables to consider when evaluating climate change impacts, and an appraisal of how climate change is likely to affect habitats and biomes. These components were used to develop a habitat vulnerability scoring system and a scoring system for assessing levels of confidence. By assigning species of greatest conservation need to these habitats the panel was able to obtain a quick overview of vulnerable SGCN. However, being primarily a habitat-based model, this approach may omit sensitivity information that influences vulnerability at the species level.

Computational response models

Computational response models include habitat and occupancy models, vegetation models, physiologically-based models, and ecological models (described in Hayhoe et al. 2011). These approaches include more specific modeling using biophysical data to predict changes in species distribution, vegetation dynamics and/or vegetation or ecological processes, and may differ in how well they capture exposure and sensitivity factors. For example, "climate envelope" models rely on associations between species distributions and climate variables to predict where species distributions will shift under changed climatic conditions. However, they may over or under-estimate the extent of species' distributions when applied to future climate scenarios (Sinclair et al. 2010), particularly in situations in which species distributions are primarily limited by non-climate variables. Physiological models present an opportunity to relate specific sensitivities to climate change variables, but these models are often complex and are only just beginning to be applied to assess the impacts of climate change. The Sea Level Affecting Marshes Model (SLAMM) simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise in order to show how habitat types will change (http:/warrenpinnacle.com/prof/SLAMM/). Earlier versions of this model have been applied to a number of coastal areas, including the Chesapeake Bay (Glick et al. 2008) and to several sites in Florida (Glick and Clough 2006).

Species-level indices

Also referred to as a type of "evaluative framework" (Rowland et al. 2011) or "general characterization models" (Hayhoe et al. 2011), these tools generate relative ranks of vulnerability based on a set of indicators that represent negative or positive responses to climate change. Examples include the NatureServe Climate Change Vulnerability Index (NatureServe 2010), which was used in this assessment, and the U.S. Forest Service System for Assessing Vulnerability of Species (SAVS) to Climate Change (Bagne et al. 2011). Both tools consider the three components of vulnerability: exposure, sensitivity, and adaptive capacity, although they differ in how these components are integrated into the assessment. For example, the CCVI requires downscaled spatial data as an input and calculates a rough estimate of exposure based on projected changes in annual mean temperature and annual mean moisture, whereas SAVS incorporates exposure or expected future conditions into scoring of sensitivity and adaptive capacity. These tools differ in their level of detail in the sensitivity factors, how habitat associations and landscape factors (such as barriers to dispersal) are addressed, and how uncertainty is incorporated into the assessment.

In the Pacific Northwest, the University of Washington is leading a collaborative project that will create a digital database of climate change sensitivities, defined as a measure of the inherent susceptibility to climate change. Unlike the other indices mentioned in this section, this tool ranks species on sensitivity and brings in exposure through a separate component of the assessment, which involves modeling the potential effects of climate change on species' distributions (Case and Lawler 2011).

Integrating Approaches

Of course most assessments of vulnerability to climate change can–and should–include multiple data sources and types of evidence. For example, an expert-based approach may involve assessment of distribution models, species-specific sensitivities, and ecological response models, among others. A tool such as the CCVI essentially provides a framework for assembling relevant information from multiple sources to inform the individual scores assigned to the indicator factors. In the assessment we present here, we have implemented the CCVI as part of a vulnerability assessment to draw on inputs from species experts and their knowledge of the relevant literature.

A number of states and organizations have begun to use the NatureServe Climate Change Vulnerability Index (Box 2) as a first step towards identifying vulnerable species and prioritizing their SGCN, and similar efforts are also emerging from some of the Landscape Conservation Cooperative (LCCs) [2]. The approach to how species were selected for these assessments varies. Some states are running all species through the CCVI, while other states have run a subset as a pilot for a SWAP addendum. The approach for facilitating input on the CCVI criteria also varies. In some cases, assessments rely entirely on experts in the state's Natural Heritage programs, while others involve a wider range of experts from diverse organization and sectors.

[2] LCCs are a network of partnerships facilitated by the Department of Interior that work to ensure the sustainability of America's land, water, wildlife and cultural resources (www.doi.gov/lcc).

Box 2. Examples of other states and organizations that are using the CCVI as part of a species-level vulnerability assessment.

Alaska. The Wildlife Conservation Society is currently conducting a vulnerability assessment for 50 bird species with funding from the Arctic LCC, using expert elicitation with the CCVI based on the approach used in this report.

California. The California Department of Fish and Game is undertaking a vulnerability assessment for sensitive species in California with funding from the California LCC (http://www.californialcc.org). In addition, the California LCC recently funded a proposal from the Institute for Bird Populations to assess vulnerability of 140 bird species that breed in the Sierra Nevada.

Great Plains. The Wildlife Conservation Society conducted a vulnerability assessment for a set of grassland species, focusing primarily on the SGCN listed in the wildlife action plans for the states within the Great Plains LCC. A summary report is available (Zack et al. 2010).

Illinois. The Illinois Department of Natural Resources partnered with the Nature Conservancy to conduct a vulnerability assessment of SGCN as part of the agency's update to the wildlife action plan (Walk et al. 2011).

Nevada. In preparation for amending the Nevada State Wildlife Action Plan, the agency partnered with the Nature Conservancy, Nevada Natural Heritage Program, Lahontan Audubon Society, and the Great Basin Bird Observatory to assess the vulnerability of 263 SGCN. A case study reports results for the first 13 species (Young et al. 2009).

New York. The New York Natural Heritage Program assessed the vulnerability of 119 SGCN, focusing on species that might be susceptible to climate change and would be good indicators of vulnerability of species in similar habitats. A report detailing the findings was recently released (Schlesinger et al. 2011).

Pennsylvania. The Pennsylvania Natural Heritage Program and other partners are working with NatureServe to conduct an assessment of species that have special conservation status in the state. An initial list of animals included in the assessment is available: http://www.naturalheritage.state.pa.us/ccvi.htm.

West Virginia. The West Virginia Division of Natural Resources released a report (Byers and Norris 2011) assessing 185 species, focusing on vulnerable and imperiled SGCN as well as a small number of more common species.

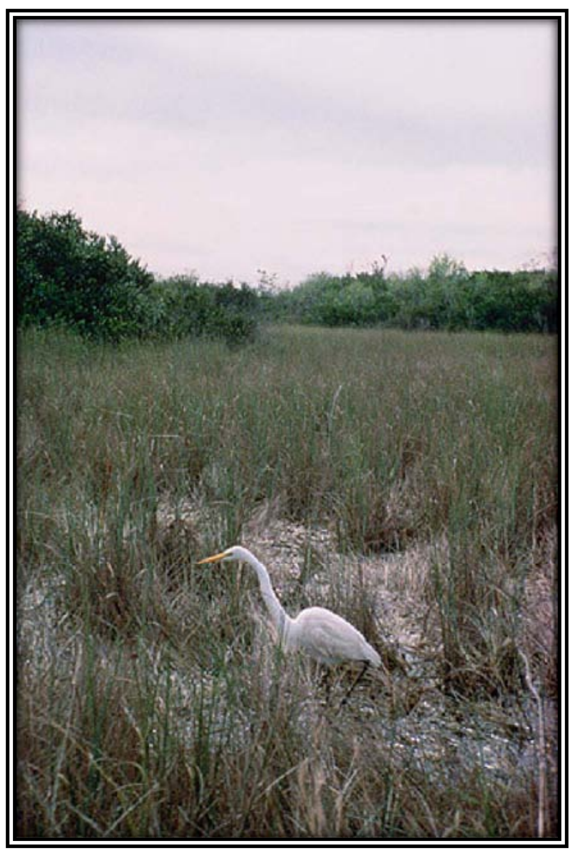
Case Study: Evaluating the Applicability of the CCVI as Part of an Adaptation Planning Framework

The NatureServe CCVI[3] is an Excel-based tool that that uses information about the natural history, distribution, and ecology of species to provide a relative assessment of species vulnerability in relation to climate change (Box 3). The CCVI assigns scores based on projected exposure to climate change within the species' range and the following factors associated with vulnerability to climate change: (1) indirect exposure to climate change, including sea level rise, the potential impact of barriers on species' range shifts, and potential impacts of land use changes resulting from human responses to climate change, (2) species-specific factors that determine sensitivity (e.g. dispersal ability, physiological constraints, physical habitat specificity, interspecific interactions, and genetic factors), and (3) documented response to climate change (when available).

A numeric score is assigned to each factor, based on a series of categorical descriptions corresponding to the hypothesized effect on vulnerability, ranging from "greatly increases vulnerability" to "decreases vulnerability." Not all factors can be assigned the full range of scores. For example, allowable scores for the factor related to dietary versatility range from "increases vulnerability" to "somewhat decreases vulnerability." As a result, some factors have the potential to more heavily influence the overall index score. Scores corresponding to factors that are thought to be affected by projected changes in climate are weighted by a "climate stress index" when calculating the numeric sub-score for those factors. These sub-scores are then summed across the factors and an index rank is assigned based on a set of threshold values. Additional information regarding the algorithm used in the CCVI is available in Appendix A and Young et al. (In press).

The CCVI provides a means to assess relative vulnerability across a set of species within a geographic area within a certain time frame, as well as the relative importance assigned to the factors contributing to vulnerability. The CCVI *only* addresses vulnerability to climate change. It does not capture factors that are considered in other conservation status assessments, such as population size, range size and demographic factors that affect species or population viability. The CCVI results should be used in combination with other conservation status assessments that address the full range of factors that affect the conservation status of a particular species.

Perhaps the CCVI's greatest value is not the final vulnerability score, but as an evaluative framework that facilitates assessment of a complex problem by breaking it down into its constituent parts. As with any model, the output–in this case the index score–reflects the information and assumptions used to parameterize the model. The quality of the analysis is dependent on the input provided by participants as well as the availability of data. Differences in expertise, alternative interpretations of the category descriptions, and personal biases will all affect the output of the CCVI. We include a detailed description of the assumptions and values used to parameterize the index for each species in Appendix A. This information can be reviewed and updated as new data become available.



[3] The CCVI can be downloaded at: http://www.natureserve.org/prodServices/climatechange/ccvi.jsp

Box 3. Parameters used in the NatureServe Climate Change Vulnerability Index

Exposure to Local Climate Change

1. Projected changes in temperature assessed using downscaled temperature projections to calculate the percentage of the species' distribution/range that will be exposed to different levels of warming by 2050. NatureServe suggests using downscaled data from Climate Wizard
2. Projected changes in moisture assessed using the Hamon AET:PET moisture metric to calculate the percentage of the species' distribution/range that will be exposed to different moisture regimes by 2050

(Indirect Exposure to Climate Change)

3. Exposure to sea level rise assessed by estimating the percentage of the range that occurs at low elevations (< 1m suggested)
4. Degree to which natural barriers limit a species' ability to shift its range assessed by comparing the extent of barriers relative to the current species' distribution
5. Degree to which anthropogenic barriers such as urban or agricultural development limit a species' ability to shift its range assessed by comparing the extent of barriers relative to the current species' distribution
6. Degree to which land use changes resulting from human responses to climate change have the potential to impact the species within the assessment area

Species-specific Sensitivity or Life History Data

1. Dispersal ability/distance in the absence of barriers
2. Historical thermal niche based on the temperature variation that the species has experienced in the past 50 years
3. Physiological thermal niche based on the percentage of range that is restricted to cool or cold environments likely to be impacted by climate change
4. Historical hydrological niche based on the precipitation variation that the species has experienced in the past 50 years
5. Physiological hydrological niche based on the percentage of range in which the species is dependent on a specific aquatic/wetland habitat or localized moisture regime that is likely to be impacted by climate change
6. Dependence on a specific disturbance regime that is likely to be impacted by climate change (such as fires, floods, severe winds, pathogen outbreaks)
7. Dependence on ice or snow cover habitats based on the percentage of subpopulations or range associated with this habitat type
8. Restriction to uncommon geological features such as a particular soil/substrate, geology, water chemistry, or specific physical feature for one or more portions of the life cycle
9. Dependence on specific species to generate habitat necessary for completion of the life cycle

10. Dietary versatility (animals)
11. Pollinator versatility (plants)
12. Dependence on specific species for propagule dispersal
13. Dependence on other interspecific interactions for persistence
14. Measured genetic variation as compared to related taxa, or if genetic variation has not been assessed over a substantial proportion of the species range, information regarding the occurrence of bottlenecks in recent evolutionary history may be used
15. Assessment of phenological responses to altered seasonal temperature or precipitation dynamics within the species' range

Documented or Modeled Response to Climate Change (optional)

1. Documented response to recent climate change such as range contraction or population declines due to mismatches in phenology and the availability of critical resources
2. Modeled future (2050) change in range or population size evaluated in relation to the assessment area
3. Percentage overlap of modeled future (2050) range with current range
4. Occurrence of protected areas in modeled future (2050) distribution in relation to modeled future distribution within the assessment area (as percentage overlap)

Definition of Index Scores

Extremely Vulnerable (EV): Abundance and/or range extent within geographical area assessed is extremely likely to substantially decrease or disappear by 2050

Highly Vulnerable (HV): Abundance and/or range extent within geographical area assessed is likely to decrease significantly by 2050

Moderately Vulnerable (MV): Abundance and/or range extent within geographical area assessed is likely to decrease by 2050

Not Vulnerable/Presumed Stable (PS): Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change substantially by 2050, actual range boundaries may change

Not Vulnerable/Increase Likely (IL): Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050

Important note: Factors such as population size, range size, and demographic factors influence both conservation status and vulnerability to climate change. Because these factors are already captured in conservation status rankings, they are not used in the calculation of CCVI scores. As a result, rankings from both systems should be used together.

This information was adapted from: Young, B., E. Byers, K. Gravuer, G. Hammerson, and A. Redder. 2010. Guidelines for Using the NatureServe Climate Change Vulnerability Index. NatureServe, Arlington, VA.

Species Selection

Target species may be selected for a wide variety of reasons, depending on the objectives of the particular project. In some cases, existing conservation priorities or species of concern may serve as appropriate targets. However, some studies have suggested that focusing exclusively on at-risk species may miss currently common species that are vulnerable to climate change (Young et al. 2009). For this project, FWC was interested in understanding how the CCVI performed across species with diverse attributes. FWC approached species selection by first identifying categories that reflected diverse ecological and management attributes of interest and then selecting species that varied across these attributes (Table 1). A total of 35 species were initially identified for inclusion in the CCVI analysis. Of these, species experts were identified for 26 species and assessments were completed for the 22 species included in Appendix A.

Expert Elicitation

Most assessments using the CCVI to date have relied primarily on literature reviews in consultation with staff biologists and other species experts (e.g., Young et al. 2009, Byers and Norris 2011, Schlesinger et al 2011). Generally, a staff biologist assembles the required natural history and distribution information, uses this information to assign scores to the CCVI factors, and reviews the available information and/or scores with species experts as needed. There are several advantages to this approach, including potentially smaller investment of time and personnel resources and greater control over consistency in interpretation of the scoring across a wide number of species. Complementary approaches, such as the expert elicitation approach used here, also provide a means to synthesize opinions of experts with specific geographic and organismal knowledge and provide an opportunity to assess uncertainty around their views.

Species experts were identified by FWC and invited to participate in the CCVI assessment process. Each expert was asked to individually fill out a worksheet module (see Appendix B) developed by Defenders staff to elicit the information required to assign scores for the indirect exposure and sensitivity factors included in the CCVI. In addition to selecting a score for each factor, a series of follow up questions asked the experts to document the underlying information associated with each selection and provide a qualitative assessment of the uncertainty associated with each of those components. After completing the worksheet module, species experts participated in a conference call to discuss their responses.

Selecting Proxies for Species' Distributions

We considered a number of sources for distribution data sets, including range maps from NatureServe and potential habitat models developed by FWC. Species experts were asked to review maps of the available data sets. When available, we ran the CCVI with multiple inputs in order to examine sensitivity of the index score to the type of data used to approximate the species distribution. We also included a number of point data sets, primarily element occurrence data from the Florida Natural Areas Inventory (FNAI), in our analysis in order to evaluate performance of the tool. NatureServe suggests using extent of occurrence maps of species' distributions rather than point maps of actual populations due to the relatively course scale of the climate data (e.g., point maps of actual populations may not capture the extent of exposure across the species' range in the assessment area). Although we included occurrence data for comparison with other distribution data, we did not specifically evaluate how well the occurrence data approximated the range extent for a given species in our analysis.

Building a Baseline Exposure "Scenario"

The CCVI uses distribution data to estimate relative exposure for each species by calculating the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture. These categories are based on the range of projected exposure across the continental U.S (see Young et al. 2010). Within Florida, mid-century projected temperatures fall on the low end of this range (Figure 4), corresponding to low or insignificant increases in temperature relative to other parts of the continental U.S. Projected drying is much more variable across the state, with values falling in all but the lowest and highest categories (Figure 4).

We provided species experts with maps depicting projected changes in the annual averages (which is the

Table 1. Species initially identified for inclusion in the CCVI analysis were selected to vary across a range of attributes. As indicated, not all species were assessed.

	Common name	*Scientific name*	Broad range	Restricted range	Listed	Inland	Coastal	Aquatic	Terrestrial	Abundant	Rare	Information rich	Information poor	Hunted/fished	Nongame	Exotic	Vulnerable	Not vulnerable	Spatial data	SGCN	Non-SGCN	Charismatic	Non-charismatic
Birds	Short-tailed hawk	*Buteo brachyurus*	•			•			•		•		•		•			•	•	•			•
	Clapper rail	*Rallus longirostris*	•				•	•		•		•		•			•			•			•
	Limpkin	*Aramus guarauna*	•			•		•			•		•		•			•	•	•		•	
	Least tern	*Sternula antillarum*	•		•		•		•		•	•			•		•		•	•		•	
	Mangrove cuckoo	*Coccyzus minor*		•			•		•		•	•			•		•		•	•			•
	Purple swamphen	*Porphyrio porphyrio*		•		•		•		•		•		•		•	•				•		•
Reptiles	Diamondback terrapin	*Malaclemys terrapin*	•				•	•		•			•		•		•			•			•
	Loggerhead turtle	*Caretta caretta*	•		•		•	•			•	•			•		•		•	•		•	
	Salt marsh snake	*Nerodia clarkii*	•		•		•	•		•			•		•		•		•	•			•
	Scrub lizard*	*Sceloporus woodi*		•		•			•		•	•			•			•		•			•
	American crocodile	*Crocodylus acutus*		•	•		•	•			•	•			•		•		•	•		•	
	Burmese python	*Python bivittatus*		•		•		•			•		•	•		•	•				•		•
Amphibians	Reticulated flatwoods salamander	*Ambystoma bishopi*		•	•	•			•		•	•			•			•	•	•			•
	Striped newt*	*Notophthalmus perstriatus*		•		•			•		•	•			•			•	•	•			•
	Squirrel tree frog	*Hyla squirella*	•			•			•	•		•			•			•			•		•
	Gopher frog	*Lithobates capito*	•		•	•			•		•		•		•			•		•			•
	Cuban tree frog*	*Osteopilus septentrionalis*	•			•			•	•		•		•		•		•			•		•
Mammals	Bonneted bat†	*Eumops floridanus*		•	•	•			•		•		•		•			•		•			•
	Marsh rabbit	*Sylvilagus palustris*	•			•			•	•			•	•				•			•		•
	River otter	*Lontra canadensis*	•			•	•	•		•		•		•				•		•		•	
	Florida panther	*Puma concolor coryi*		•	•	•			•		•	•			•		•		•	•		•	
	Key deer	*Odocoileus virginianus clavium*		•	•	•	•		•		•	•			•		•		•	•		•	
	Gambian pouch rat	*Cricetomys gambianus*		•		•	•		•		•	•		•		•	•				•		•
Invertebrates	Red widow	*Latrodectus bishopi*		•		•			•		•		•		•			•		•		•	
	Salt marsh skipper	*Panoquina panoquin*	•				•		•	•			•		•		•				•		•
	Highlands tiger beetle*	*Cicendela highlandensis*		•	•	•			•		•	•			•			•	•	•			•
	Florida tree snail*	*Liguus fasciatus*		•	•		•		•		•	•			•		•			•		•	
	Florida rainbow*	*Villosa amygdala*	•			•		•			•		•		•			•	•	•			•
	Red imported fire ant*	*Solenopsis invicta*	•			•	•		•	•		•			•	•		•	•		•		•
Fish‡	Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*		•	•	•					•	•			•		•		•	•		•	
	American eel*	*Anguilla rostrata*	•				•			•		•			•						•		•
	Snook	*Centropomus undecimalis*		•			•			•		•		•			•		•		•	•	
	Lake Eustis pupfish	*Cyprinodon variegatus hubbsi*		•	•	•		•				•			•			•	•	•			•
	Largemouth bass	*Micropterus salmoides*	•			•				•		•		•			•		•		•	•	
	Peacock bass*	*Chichla ocellaris*	•			•				•				•		•					•		•

*Species not assessed †Insufficient information for assessment (not shown in Figure 5) ‡ Data collected but CCVI analysis not completed

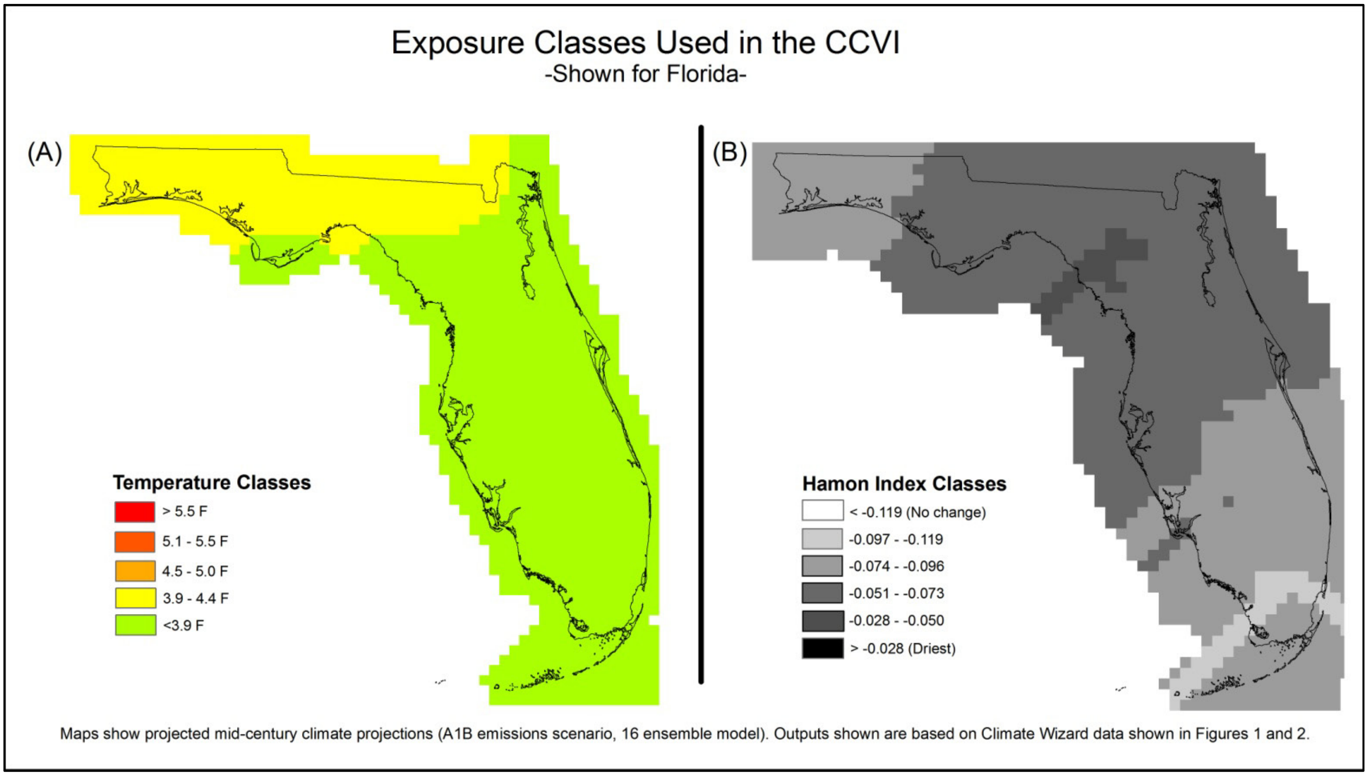


Figure 4. (A) Projected temperature increases and (B) projected decreases in moisture availability (indicated relative to historical baseline) for Florida as classified in the CCVI. The percentage of the species distribution falling within each category is used to calculate the "climate stress index" used in the CCVI algorithm (see Young et al. In press).

parameter used to estimate exposure in the CCVI) for temperature and moisture. In addition, we provided maps of projected changes in seasonal averages, again based on Climate Wizard data. These maps formed the basis of the assumptions for a common "scenario" for all of the assessments. Additional information provided in the worksheet module included habitat maps from Florida's SWAP (FWC 2005), a map of 1-meter sea level rise, a map of the Silvis Wildland-Urban Interface (to assess anthropogenic barriers), and a map showing the likelihood of shoreline protections along the Atlantic coast. Most reviewers assumed an increase in the frequency of intense hurricanes and more intense fire regimes as a result of climate change, but did not attempt to quantify the magnitude of change to these disturbance regimes. The time frame considered for the vulnerability assessment was 2050.

Special considerations for historical niche factors

Two of the sensitivity factors, historical thermal niche and historical hydrologic niche, explicitly require spatial inputs, and species experts were not asked to assess these factors. These factors are intended to approximate species' climatic tolerances at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. These factors are not intended to capture species-specific physiological requirements (these are captured elsewhere), but are instead based on the assumption that species that have recently experienced large variation in climate will be less vulnerable to future changes (B. Young, pers. comm.). We scored these factors according to the guidance provided by NatureServe, however some reviewers questioned the relationship between these factors and vulnerability, particularly as they applied to species in Florida.

Identifying Additional Risk Factors

In a number of cases, species experts identified additional factors or related factors that were not fully captured in the descriptions associated with the CCVI inputs. In some cases, we simply adjusted the scores to capture these additional factors. For example, the descriptions associated with the factor addressing physiological thermal niche (C2bii) are biased towards species in cool/cold environments. It is not obvious how to apply these category descriptions to species that show a "preference for environments toward the warmer end of the spectrum" (which would be scored as "somewhat decreases vulnerability") but may be adversely affected by additional increases in temperature. In these cases, we made the decision to assign this factor a higher score (e.g. "somewhat increases vulnerability"). Similarly, some reviewers suggested that the scoring for this category could also include sensitivity to other aspects of exposure, such as changes in extremes (e.g. frequency of cold snaps). When appropriate, we adjusted the scoring of associated factors to capture these additional sensitivities. These are documented in the individual species accounts in Appendix A.

Of special note are the modifications we made when scoring barriers to habitat for several species (e.g., birds). The CCVI guidance suggests that this factor will be scored as neutral for most species that can fly over or around potential obstructions. While this may be true in many cases, a number of the species that were considered in this assessment are associated with narrowly defined habitats that are themselves restricted by natural or anthropogenic barriers. This issue is particularly relevant for many coastal habitats affected by sea level rise, for which there is only one possible direction of movement (i.e., inland) that may be blocked by coastal development or geologic attributes such as elevational gradients. In these situations, reviewers often felt that the increased vulnerability was not adequately captured in the recommended scores (for an example, see salt marsh skipper in Appendix A). When warranted, we modified the scoring guidelines to capture the indirect threat of barriers through impacts on the ability of habitat to shift under climate change. In addition, we expanded the scoring guidelines for barriers to include the ability of a species to shift *within* its range (as opposed to limiting the factor to barriers surrounding the species' current distribution) based on reviewer input. This distinction was relevant in the case of wide-ranging species whose ranges expanded beyond the assessment area (e.g., marsh rabbit).

Incorporating Uncertainty

The CCVI asks users to select a statement for each factor that best describes the focal species (with each statement corresponding to a score for the factor), but does not include a specific mechanism for capturing uncertainty in these input parameters. However, multiple scores can be selected for each factor, providing one method for capturing uncertainty.[4] The included Monte Carlo simulator randomly selects one score for each factor for 1000 iterations, assuming that all scores are equally likely. Therefore the set of index scores generated by the Monte Carlo simulation provides an estimate of sensitivity to the range of values associated with the input parameters. The range of scores can be used as a measure of how uncertainty associated with the factor scores influences the CCVI output.

In our worksheet module, we asked species experts to document the underlying information that they used to score each factor and assign a level of confidence in this information. We considered these confidence values as part of the final scoring for each factor. For species where we had input from multiple reviewers, these confidence levels were often already reflected in the range of scores assigned by different species experts.

[4] Note that other reasons–unrelated to uncertainty–exist for making multiple selections when scoring a particular factor, for example in some cases different descriptions may apply across the species range within the assessment area.

Reporting Index Scores

The standard output generated by the CCVI is a categorical index score or *rank* (e.g., "Moderately Vulnerable") and a histogram summarizing the frequency at which each rank occurs in the Monte Carlo simulation (1,000 iterations). Box 3 includes definitions of these categorical index scores. In addition, the output includes a "confidence score" that is a measure of uncertainty regarding the categorical assignment relative to the range of scores generated by the Monte Carlo simulations. It does not necessarily provide a measure of confidence in the sub-scores assigned to each factor.

The CCVI generates an index score calculated by summing the average of the sub-scores assigned to each factor and weighting them by an exposure factor. Factors scored as "unknown" do not contribute to the summed index score, and the index score is not corrected for the number of factors that have been scored. As a result species with more scored factors have the potential to generate higher index scores than those with fewer scored factors. To address this, the categorical ranks are assigned based on thresholds selected to correspond to possible scenarios of exposure and sensitivity (Young et al. In press). For example, the "Extremely Vulnerable" threshold is reached for species with high exposure and at least two indirect exposure/sensitivity factors scored as "greatly increase" vulnerability, or high exposure and three factors scored as "increase" vulnerability (Young et al. In press).

In the standard version of the CCVI (available on the NatureServe website), the user cannot access the numeric scores that are used to assign the categorical rank. However, NatureServe was kind enough to provide us with an unencrypted version of the excel spreadsheet (B. Young, pers. comm.), from which we obtained the associated numeric scores. More information regarding the CCVI algorithm is available in Young et al. (In press) and a short summary is provided in the overview in Appendix A.

We report both the categorical rank and associated numeric index score generated by the CCVI. However, instead of reporting the confidence score we include the range of scores generated by the Monte Carlo simulation. We report the numeric scores in addition to the categorical rank because we were interested in exploring the relationship between the choice of input parameters and the model output, which is not always apparent from the categorical index scores.

Integrating Vulnerability into an Adaptation Planning Process

Developing adaptation options for natural systems requires an understanding of how climate change may affect important species and habitats, as well as how effects may interact with other ongoing threats, ecological processes, and management actions. In April 2011, Defenders co-sponsored an adaptation workshop with MIT and FWC. As part of this workshop, Defenders facilitated a conceptual modeling exercise based on the "situation analysis" described in step 1 of the Open Standards for the Practice of Conservation (CMP 2007). This facilitated session was intended to provide participants with a framework for understanding how the results of a vulnerability assessment can be incorporated into a conservation planning process, with a goal of demonstrating a process by which the existing SWAP can be broadened to address climate change drivers and develop adaptation strategies. Although the facilitated workshop described here does not engage participants in the full planning process, future efforts could expand on this initial workshop and engage additional stakeholders in incorporating their expertise in developing management actions and monitoring strategies.

A situation analysis is a useful tool for documenting the drivers and threats affecting a biodiversity target, as well as for identifying conservation actions that can be applied to contributing factors, direct threats, or even biodiversity targets. For the FWC workshop, the biodiversity targets were identified as the six focal species used in MIT's Alternative Futures analysis (Flaxman and Vargas-Moreno 2011): short-tailed hawk, least tern, Atlantic salt marsh snake, American crocodile, Florida panther, and Key deer. Each species was addressed in a two-hour facilitated breakout session with species biologists, wildlife managers, and other conservation professionals. The primary outcome from each breakout session was the identification of potential adaptation strategies for each species.

Prior to the workshop, Defenders staff identified a preliminary set of threats and stresses for each species based on the existing SWAP and the vulnerability factors identified in the CCVI (Appendix C). Participants were asked to review and modify these components as needed, and used them as the starting point for the situation analysis, with particular emphasis on incorporating climate drivers and interactions with other drivers. In some cases, the climate-related factors identified through the CCVI corresponded to direct threats or drivers of direct threats. In other cases, the CCVI results identified stresses, or biophysical impacts on the system. When this occurred, we worked backwards from the stress to identify the climate driver associated with the stress. Box 4 provides further information on the different components of the

Box 4. The components of a conceptual model described in the Open Standards for the Practice of Conservation (CMP 2007).

Biodiversity targets: The biological entities (species, communities, or ecosystems) that a project is trying to conserve. Some practitioners also include ecological and evolutionary phenomena and processes as targets. Synonymous with *focal conservation targets* and *biodiversity features*.

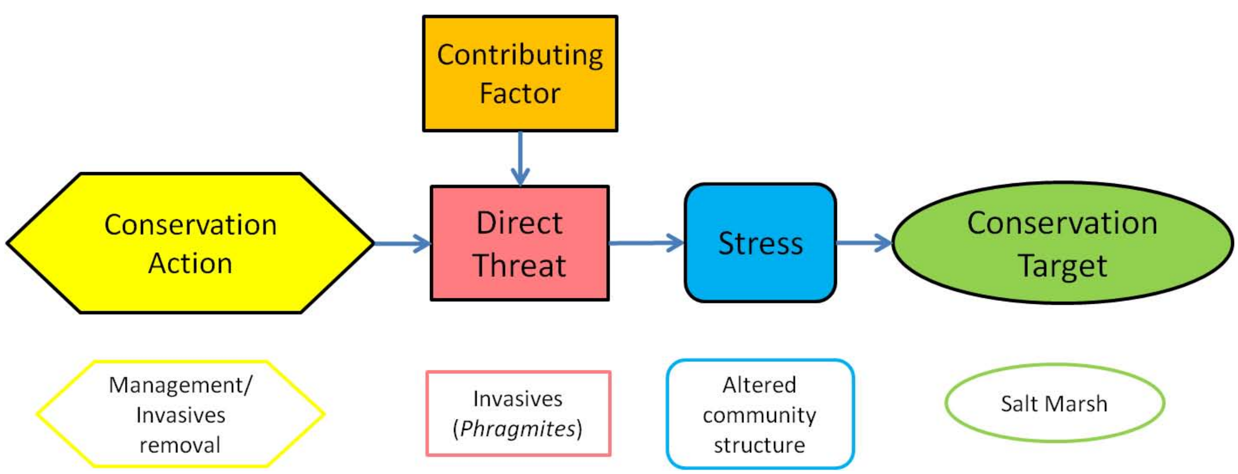
Direct threats: The proximate human activities or processes that cause destruction, degradation and/or impairment of biodiversity targets. Synonymous with *sources of stress*. Natural phenomena are also regarded as direct threats in some situations (i.e., climate change).

Contributing factors: The ultimate factors that enable or contribute to proximate direct threats. Synonymous with *underlying factors*, *drivers*, or *root causes*.

Stresses: The biophysical impacts of a direct threat on a target, i.e., attributes of a conservation target's ecology that are impaired directly or indirectly by human activities.

Conservation actions: Interventions undertaken to reach the project's objectives and ultimate conservation goals. Actions can be applied to contributing factors, direct threats, or directly to the targets. Synonymous with *strategies*, *interventions*, *activities*, *responses*.

Sources: Salafsky et al. 2008, FOS 2009



conceptual models that were developed as part of the situation analysis.

The situation analysis provided a framework for participants to better understand how target species and habitats are affected by existing threats, such as land-use change, while examining how regional changes in climate may interact with or exacerbate existing threats. Participants were asked to rank the top three to five threats, focusing on those threats either directly or indirectly related to climate change. Participants were then asked to identify specific management actions that could be taken to reduce those threats and map them on the conceptual model. We asked groups to start with the general categories of conservation actions as described in the SWAP (Box 5), and used these as the basis for identifying specific actions to address the threats identified in the situation analysis. Each group generated a short-list of strategies and was asked to document the criteria that were used in the ranking. Strategies having a spatial context were identified and forwarded to an additional set of breakout sessions designed to translate these strategies into spatially explicit actions and identify where these actions should be implemented on the landscape as part of MIT's Alternative Futures approach (Flaxman and Vargas-Moreno 2011).

CCVI Results

Of the candidate species identified by FWC, a total of 26 species were assessed by at least one species expert. Here, we summarize the results for five native bird species, four native reptiles, three native amphibians, four native mammals[5], two native invertebrates and three non-native, invasive species. Details on the individual species assessments are included in Appendix A. Although we received completed worksheets from species experts for four fish species, these were not analyzed in time to be included in this report.

Across the assessed species, index scores ranged from "Not Vulnerable/Presumed Stable" to "Extremely Vulnerable" (Figure 5). The taxa included in the assessment were fairly evenly distributed across the vulnerability categories. Seven species ranked as "Presumed Stable" (PS), four species ranked as "Moderately Vulnerable" (MV), six species ranked as "Highly Vulnerable" (HV) and five species ranked as "Extremely Vulnerable" (EV). [6] However, for most species, there was some uncertainty associated with the assigned rank as indicated by the range of scores produced by the Monte Carlo simulations. Of the species assessed, birds generally ranked lower on the vulnerability scale, whereas reptiles tended to rank at the upper end of the scale. Among the mammals, those restricted to the Florida Keys ranked higher than the other mammals that were evaluated. Two of the non-native species that were assessed scored as "Not Vulnerable." The third, Gambian giant pouched rat, ranked somewhat higher, primarily as a result of exposure factors affecting the Florida Keys (where it currently occurs), rather than sensitivity to projected climate change.

Birds

Birds may have an advantage over other groups in that they have very good dispersal abilities. However, several of the species evaluated in this assessment had specific habitat requirements that may limit the degree to which these species may be able to shift their range. For example, several of the species utilize coastal habitats that require particular geologic or hydrologic conditions that may limit habitat migration. These habitats are also more vulnerable to factors such as sea level rise and increased hurricane activity. For this reason, sea level rise and disturbance regimes ranked high among the factors leading to increased vulnerability for many of these species.

Potentially incompatible human responses to climate change, such as coastal armoring, also played a significant role in increased vulnerability, due to the potential to greatly reduce availability of suitable nesting habitat for some of the evaluated species. In the specific cases of the least tern and the clapper rail, exposure to

[5] Although an assessment was completed for bonneted bat, the species experts did not feel that there was enough known about the species to accurately characterize vulnerability. An individual species account is included in Appendix A, but results are not reported in the summary.

[6] Short-tailed hawk (winter), Atlantic salt marsh snake and Lower Keys marsh rabbit are not included in these tallies.

sea level rise, potential anthropogenic barriers and human response to climate change, and changes in disturbance regimes act together to yield vulnerability rankings of "Highly Vulnerable." These species depend on specific habitat that is likely to be significantly affected by those factors, sandy beaches and estuarine habitat respectively. Species with less restricted habitat requirements tended to rank lower on the CCVI.

Reptiles

Most of the reptiles considered in this assessment scored as "Highly Vulnerable" or "Extremely Vulnerable" to climate-related risk factors, the notable exception being the Burmese python, an introduced species which is currently expanding its range. Most of the native species that were evaluated occur in coastal habitats, and therefore sea level rise, together with anthropogenic barriers, were key factors influencing the vulnerability rankings. Barriers may limit habitat migration in response to sea level rise as well as preventing species from tracking habitat shifts.

Changes in hydrology and timing/intensity of hurricanes affecting nesting habitat availability and suitability were also important factors affecting the vulnerability ranks several of the reptile species considered in this assessment. Compared to the vulnerability rank based on the species-level assessment for salt marsh snake, Atlantic salt marsh snake ranked significantly higher. The Atlantic race of the salt marsh snake is likely to be severely impacted by the loss of salt marsh habitat through both sea level rise as well as the potential for mangrove intrusion northward.

Amphibians

Amphibians may be particularly sensitive to changes in climate (Blaustein et al. 2010). Moderate dispersal ability combined with specific hydrologic requirements often contributes to vulnerability to climate change for species within this group. These factors may be magnified by natural or anthropogenic barriers that further limit dispersal. Of the amphibian species evaluated as part of this assessment, two out of three were rated as "Highly Vulnerable" (gopher frog) or "Extremely Vulnerable" (reticulated flatwoods salamander). Sea level rise and disturbance regimes also

Box 5. Action categories identified in the FL SWAP:

- Land/Water Protection
  - Establishing or expanding protected areas
  - Establishing protection or easements of some specific aspect of the resource
- Land/Water/Species Management
  - Management of protected areas and other resource lands Habitat & Natural Process
  - Enhancing degraded or restoring missing habitats
  - Controlling and/or preventing spread of invasive species and pathogens
  - Managing specific plant and animal populations of concern.
- Education and Awareness
  - Enhancing knowledge, skills, and information exchange Awareness
  - Raising environmental awareness and providing information
- Policy
  - Influencing legislation or policies
  - Influencing implementation of laws
  - Implementing voluntary standards & professional codes that govern private sector practice
  - Monitoring and enforcing compliance
- Planning and Standards
  - Setting, implementing, influencing, or providing input into planning directives, codes, and standards
- Economic and Other Incentives
  - Providing alternatives that substitute for environmentally damaging products and services
  - Using direct or indirect payments to change behaviors and attitudes
- Capacity Building
  - Institutional & civil society development
  - Alliance & partnership development
  - Raising and providing funds for conservation work
- Research

contributed to the vulnerability rank of these species, both of which occur in coastal habitats. A third species, squirrel treefrog, placed in the "Not Vulnerable/Presumed Stable" category, reflecting differences in dispersal ability and broader hydrologic requirements compared to the other species.

Mammals

Many of the mammals included in this assessment had relatively high dispersal ability, and therefore have the potential to be able to track climate related changes; however natural and anthropogenic barriers may limit species' ability to track climate related shifts in habitat. Due to the unique geography of the Florida Keys, species or populations found there are inherently more vulnerable to sea level rise and hydrologic constraints than those on mainland. For example, the threatened Lower Keys marsh rabbit ranked as "Extremely Vulnerable" to climate-related threats, whereas mainland populations of marsh rabbit ranked as "Moderately Vulnerable" largely due to reduced exposure to sea level rise. In the case of Key deer, natural barriers, sea level rise, and hydrology were all factors leading to its "Highly Vulnerable" ranking.

Florida panther ranked fairly low in this assessment, receiving a rank of "Not Vulnerable/Presumed Stable." The vulnerability ranking for this species applies specifically to climate change drivers and was heavily influenced by the assumption that the species' habitat

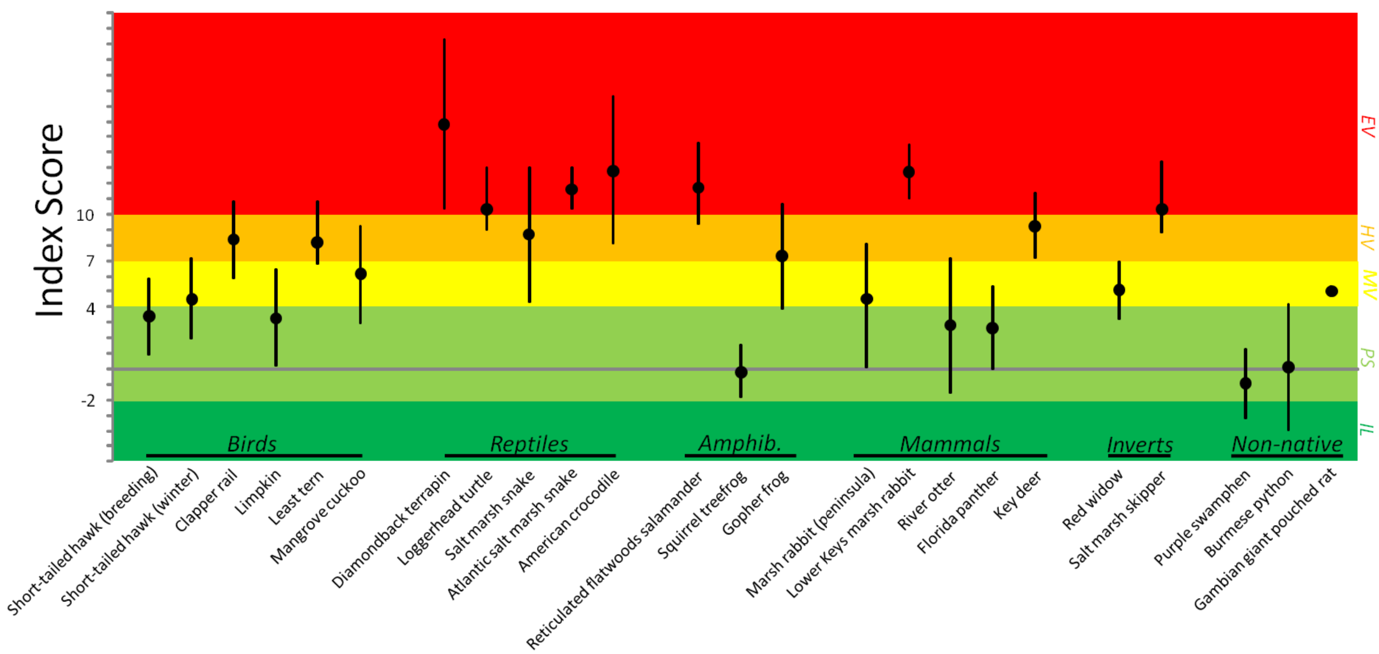


Figure 5. CCVI Index scores for the indicated species within their ranges in Florida. The index score (black circle) is shown along with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Not Vulnerable/Presumed Stable "(green), "Not Vulnerable/Increase Likely" (dark green).

Scores shown are based on parameters derived from the following data sets, short-tailed hawk: phm; clapper rail: habitat proxy; limpkin: edited NS range; least tern: FWC nest survey; mangrove cuckoo: phm = habitat proxy; diamondback terrapin: NS range; loggerhead turtle: FWRI nest survey; salt marsh snake: phm; Atlantic salt marsh snake: phm; American crocodile: phm = USFWS consult area; reticulated flatwoods salamander: phm; squirrel treefrog: NS range; gopher frog: NS range =NAA counties=phm (altered fire regime considered beneficial); marsh rabbit (peninsula): entire peninsula; Lower Keys marsh rabbit: Lower Keys; river otter: NS range; Florida panther: phm=USFWS primary habitat; Key deer: phm; red widow: county occurrences; salt marsh skipper: county occurrences= habitat proxy; purple swamphen: EDDSMapS occurrences=habitat proxy; Burmese python: EDDSMapS occurrences; Gambian giant pouched rat: EDDSMapS occurrences (see Appendix A for details).

will not be vulnerable to climate change. Even though significant barriers to dispersal exist, they are not scored as increasing vulnerability when the species' habitat is not considered vulnerable to climate change (because in these cases the species would not need to shift its range in response to climate change). As noted earlier, the CCVI rank does not address factors that are already considered in conservation status assessments, such as demography and range size, which clearly affect Florida panther. These factors are captured in the conservation ranking of this species as Critically Imperiled (S1; NatureServe 2011) and are not duplicated in the CCVI rank.

Associations with habitats that are dependent on a specific hydrology contributed to vulnerability scores for several of the mammals included in the assessment. For example, although river otter ranked as "Not Vulnerable/Presumed Stable," dependence on aquatic habitats was the highest ranked factor contributing to vulnerability for the species. We assessed one invasive mammal species, Gambian giant pouched rat, which has been introduced to the Florida Keys. This species ranked as "Moderately Vulnerable" to climate change. Of course, in the case of a potentially invasive species, the real concern is whether climate change is likely to promote range expansion, not whether the species is vulnerable to climate change. The score for Gambian giant pouched rat assumes that the species distribution will continue to be limited by the natural barriers generated by the Florida Keys. If the species were to reach peninsular Florida, the lack of barriers and greater access to freshwater would change the scoring for several factors, likely generate a lower vulnerability rank.

Invertebrates

As a group, invertebrates exhibit such a range of life history traits and ecological diversity that it difficult to reach any general conclusions about how species will be impacted by climate change. For instance, some insects may benefit from increased temperatures and track changing environmental conditions. For other species, habitat changes and associated changes in the availability of food or host plants can greatly affect species survival. Only two invertebrates were addressed in this assessment, the salt marsh skipper and red widow, both of which occur in fairly restricted habitats. The red widow spider, which ranked as "Moderately Vulnerable," depends on a vegetation-type restricted to sandy soils. The salt marsh skipper, which ranked as "Highly Vulnerable," occurs in habitats that are vulnerable to sea level rise and associated changes in hydrology. In addition, the larval stage is dependent on specific-species associations that potentially increase vulnerability to climate change.

Table 2. Numbers (and percentages) of assessed species that rank in the higher vulnerability (EV-HV) and lower vulnerability (MV-PS) categories across a number of different species attributes. (Totals include the taxa shown in Figure 5, except for Lower Keys marsh rabbit and Atlantic salt marsh snake, N = 21)

CCVI score	Broad range	Restricted range	Inland‡	Coastal‡‡	Aquatic*	Terrestrial	Abundant	Rare	Hunted/fished	Non-game	Non-Native	Native	SGCN	Non-SGCN
EV-HV	7 (58%)	3 (33%)	2 (20%)	8 (80%)	4 (44%)	7 (58%)	4 (50%)	7 (54%)	1 (17%)	9 (60%)	0 (0%)	10 (56%)	9 (60%)	1 (17%)
MV-PS	5 (42%)	6 (67%)	8 (80%)	2 (20%)	5 (56%)	5 (42%)	4 (50%)	6 (46%)	5 (83%)	6 (40%)	3 (100%)	8 (44%)	6 (40%)	5 (83%)

Notes:
‡River otter removed from coastal-inland comparison
‡‡Key deer and Gambian pouch rat considered as coastal only
*Aquatic category does not include fish

Other comparisons

Table 2 shows the distribution of vulnerability ranks across a number of different attributes of interest as identified by FWC. For simplicity, we have combined the ranks from the CCVI into higher vulnerability, which includes species ranked as "Extremely Vulnerable" (EV) and "Highly Vulnerable" (HV), and lower vulnerability, which includes species ranked as "Moderately Vulnerable" (MV) and "Presumed Stable" (PS). The most striking comparison is between inland and coastal species, where 80% of the coastal species selected for assessment ranked as EV-HV, but only 20% of the inland species ranked as EV-HV, most likely reflecting the additional threat of sea level rise for coastal species. Most of the other categories had little correspondence to the vulnerability ranks. For example, abundant and rare species were roughly equally distributed between the higher and lower vulnerability categories. The same was true for aquatic and terrestrial species, suggesting that these characteristics are not strongly correlated with vulnerability to climate change for the species addressed in this assessment. Although proportionately fewer range-restricted species ranked in the higher vulnerability category, the comparison does not include Lower Keys marsh rabbit and Atlantic salt marsh snake, two range-restricted subspecies that ranked as "Extremely Vulnerable" in Florida. The non-native species (n=3) all ranked as either MV or PS. The non-native species included in this assessment are all of tropical origin and have successfully established in Florida. Approximately 60% of the SGCN included in the assessment ranked as EV or HV, however the set of species assessed were not necessarily a representative sample of SGCN. Half of the non-SGCN species included in the assessment were non-native species, which when combined with a very low sample size for non-SGCN, makes it difficult to draw any generalizations regarding the potential vulnerability of SGCN versus non-SGCN.

Model sensitivity

Exposure. Across the state of Florida, projected increases in temperature by mid-century were relatively low (either < 3.9°F or between 3.9 - 4.4 °F). Drier conditions were expected mid-century, but the magnitude was more variable. In some cases, the accuracy and/or resolution of the distribution data had little effect on the calculated exposure metrics (e.g., Florida panther), whereas in other cases, relatively small differences in the distributions affected the calculated exposure metrics (e.g., loggerhead turtle). However, these differences rarely resulted in changes to the categorical vulnerability score. In most cases, the scale of the downscaled exposure data was the limiting factor, rather than the resolution or scale of the distribution data.

NatureServe suggests that extent of occurrence maps of species distributions should be used rather than point maps of actual populations because of the relatively coarse scale of the climate data. We examined model output to point data (using FNAI element occurrences) for a number of species. In some cases, there was there was little difference in the resultant vulnerability scores. However, in other cases the analyses parameterized with element occurrence data tended to produce higher index scores. When using point data, an assumption is that the points are representative of the sampled distribution. Element occurrences likely differ in how well they represent the "true" species' distribution across species. We did not attempt to quantify the extent to which element occurrence distributions approximated the true range extent for each species.

Capturing uncertainty in factor scores. The model was fairly sensitive to multiple scores, and multiple score selections certainly affected the range of numeric scores produced in the Monte Carlo simulations (compare for example, the range bars for Gambian giant pouched rat to those of American crocodile in Figure 5). In some cases, we explored uncertainty by assigning multiple scores to factors in separate model runs, essentially generating scenarios based on different assumptions of projected change and exploring the effect on the resulting vulnerability rank. For example, in the case of mangrove cuckoo, we created a scenario in which we assigned scores based on the assumption that mangroves would decrease in extent in response to climate change (scoring sea level rise and natural barriers as "increasing" vulnerability) and compared the results to a scenario in which we assumed that the habitat would not be vulnerable to climate change. The results suggest that factors related to indirect exposure contributed greatly to the vulnerability rank for this species.

Lessons Learned from the CCVI

Perhaps the most valuable aspect of the CCVI was that it provided a framework for assessing vulnerability to climate change by breaking a complex phenomenon into an assessment of its constituent parts. In fact, several of the species experts participating in this project told us that simply assessing the suite of factors identified in the CCVI provided them with new insights regarding the potential impacts of climate change, even for species that might not have been thought to be particularly vulnerable to climate change. This information fed directly into our threat assessment in the conceptual modeling workshop.

The CCVI is essentially a model for integrating the components of vulnerability into a summary rank or score. However, it is the process of assessing the parameters affecting vulnerability, not simply the composite score, that provides the context for successful adaptation planning. Vulnerability assessment is most useful when considered as a <u>process</u> that leads to an understanding of not only *which* resources are likely to be vulnerable, but *why* these resources are likely to be vulnerable (Glick and Stein 2011). This latter component is critical from a management perspective as it provides a framework for identifying appropriate management and conservation responses. In the steps outlined in Box 1, the CCVI provides one possible approach to addressing many of the components listed in step three. Other causal models of vulnerability could be identified that would address climate-related threats and stresses at additional scales (e.g., habitats or landscapes) or that might capture additional threats and stresses unique to Florida's species and habitats. The basic components of such a causal model should (1) identify the factors contributing to vulnerability, (2) provide criteria for scoring how each factor is expected to influence vulnerability to climate change, and (3) document the reasoning and assumptions behind each score.

Prior to the assessment, FWC staff categorized the focal species according to a priori assumptions regarding the vulnerability of the species. These a priori predictions of vulnerability corresponded to the CCVI vulnerability rank in about two-thirds of cases, but there were potential surprises. Unfortunately, it is difficult to validate a model that projects a potential trajectory, particularly one that we hope to modify. However, evaluating these mismatches can better inform our understanding of the factors contributing to vulnerability across a range of species.

The CCVI scores should best be interpreted as a summary statistic that synthesizes the underlying information and interpretations associated with the input parameters, with the relative rankings likely being more informative than the individual score. This information may help resource managers better understand relative susceptibility across a group of species when combined with information on conservation status, however the scores cannot capture information that we do not know or do not include in the input parameters. By documenting the assumptions and decisions underlying the vulnerability assessment, as we have done in Appendix A, subsequent updates can capture new information as it becomes available.

One of the strengths of the CCVI is that it provides a basic framework for explicitly assessing all the three components of vulnerability: exposure, sensitivity, and adaptive capacity. (Within the CCVI framework, "sensitivity" factors scored as somewhat decreasing or decreasing vulnerability are essentially a measure of adaptive capacity.) Dawson et al. (2011) suggest that understanding these different aspects of vulnerability may inform conservation responses. For example, species with high sensitivity and/or low adaptive capacity that are projected to face low exposure might be best addressed with preparedness strategies, whereas more intensive interventions may be required as both exposure and sensitivity increase. Individual species responses are more likely to be tied to specific changes, such as temperature extremes, changes in hydroperiod, or the timing of seasonal precipitation events or disturbance regimes–factors which are not explicitly incorporated into the exposure component of the

CCVI. A number of these derived exposure variables are embedded within the sensitivity scores, making it difficult to tease apart these components of vulnerability (and requiring the user to evaluate both the species sensitivity as well as estimate changes in exposure, a task many of our species experts felt ill-equipped to do). In our experience, this increased the uncertainty associated with a number of the sensitivity factors incorporated in the CCVI. Identifying species where there was more consistency across reviewers in the scoring of factors could help to identify underlying sources of uncertainty in the assessment.

The species accounts in Appendix A provide a number of case studies examining different aspects of the CCVI, but in fact many of the issues we identified are broadly applicable to any type of vulnerability assessment. Below we summarize the main findings:

A priori assumptions about which species will be most vulnerable may not be accurate. For example, range-restricted species or rare species did not necessarily rank as more vulnerable than widely distributed or common species. Nor do existing conservation status rankings necessarily correlate with vulnerability to climate change. Incorporating a threat ranking exercise into the situation analysis can help to identify climate-related threats that are likely to have the greatest impacts (e.g. in terms of scope, severity and irreversibility) on biodiversity targets. Biodiversity targets that are impacted by these threats may be more vulnerable to climate change.

The unit of analysis is important. A species-level assessment may not capture differences in exposure and/or sensitivity among subspecies or populations or where there are differences in exposure or sensitivity during different parts of the year or life cycle. For example, mainland populations of marsh rabbit had very different indirect exposure scores than the Lower Keys marsh rabbit and consequently had very different vulnerability ranks. Species experts also found it more challenging to assign scores to species with complex life histories. In these cases, it may be informative to also run separate analyses for individual life stages, populations, or subspecies in order to identify geographic or temporal differences in vulnerability.

In some cases, there were difficulties capturing complex system dynamics. For some species, reviewers identified factors that were not captured in the model or were not well-defined. For example, many reviewers felt that barriers to habitat shifts and habitat dynamics did not fit easily into any of the current categories. For some factors, the species experts felt Florida's unique geography might warrant higher scores than those assigned based on the current category descriptions. This issue often came up for species that occur in linear, coastal habitats which are associated with particular geologic and hydrologic conditions that restrict habitat shifts under climate change. Other applications of the CCVI have noted similar limitations. For example, Schlesinger et al. (2011) observed that species with few barriers to dispersal, but which require habitats that may not be able to shift, ranked lower than expected on the vulnerability scale. Our response in these situations was to reinterpret the scoring system in these cases to better reflect the perceived vulnerabilities.

Some factors were difficult to score or were interpreted differently by individual species experts. For example, some species experts found it difficult to assign scores to barriers for species with ranges exceeding the assessment area as the guidelines focus on assessing how barriers border the current distribution and do not explicitly address fragmentation within the assessment area. In other cases there were differences among reviewers in terms of how they interpreted the scoring guidance (e.g., what to consider a "guild" in terms of dietary versatility). We addressed these issues in the follow up phone calls with the species experts for each species.

Reviewers also questioned some of the scoring guidelines, particularly as they related to Florida and/or particular species. For example, for species with much larger historical distributions, such as Florida panther, the calculations of historical thermal and hydrologic niche (which are based on distribution) may be too restrictive when applied to the current extent and could perhaps be more appropriately calculated based on the species historical range. The way in which these factors are scored slightly increases the vulnerability score for most Florida species relative to species that occur in temperate areas. The underlying assumption is that populations in Florida may have a different capacity to handle climate change than populations elsewhere in the range where there may have been greater climate fluctuations, but some reviewers have questioned the way in which this parameter is addressed within the CCVI. In other cases, reviewers felt that some factors, such as sea level rise, should contribute more heavily to the overall score under certain situations. For example, one expert suggested that species restricted to low-lying islands that are highly vulnerable to sea level rise should rank as "Extremely Vulnerable" regardless of the scores assigned to the sensitivity factors. Future efforts could include a review of the causal model of vulnerability utilized in the CCVI and incorporate modifications based on stakeholder input.

The factors associated with the largest amount of uncertainty were those that required a combined evaluation of both sensitivity and exposure. In these cases, the uncertainty was often associated with projecting the magnitude or direction of the exposure factor and its associated impacts rather than the species' sensitivity. For example, species experts could quite easily characterize a particular species' dependence on vernal pools for breeding, but they might be much more uncertain in characterizing whether projected changes to hydroperiod would disrupt breeding across a significant portion of the species' range. A scenario planning approach, in which information is brought in regarding the range of projected change in these derived variables is one way to address these uncertainties and would provide a mechanism to separate the uncertainty associated with exposure and sensitivity factors.

Place-based tools such as the CCVI may have different implications for broadly-distributed and narrowly distributed species. The vulnerability rank for a particular species applies only within the assessment area and may not be applicable within other portions of the species range, where factors such as climate exposure, ecological dynamics, and connectivity may differ. For example, both marsh rabbit and red widow ranked as "Moderately Vulnerable" within their ranges in Florida. Red widow is endemic to sand pine scrub in central and southeastern Florida, and factors such as restricted range or small population size may significantly increase vulnerability to climate change. In contrast, marsh rabbit occurs throughout the Coastal Plain of the Southeastern U.S.. For broad-ranging species, vulnerability assessments conducted in different portions of the range, as well as at broader scales, would be needed to understand potential impacts for the species. Different management considerations may be required for species that are vulnerable in only a portion of their range versus those that are vulnerable across their entire range.

The CCVI scores are designed to be used in combination with other assessments of conservation status. These factors may magnify or interact with species vulnerability to climate change. For example, Florida panther ranked fairly low in this assessment, but climate change is likely to exacerbate the existing threats affecting the species. In addition, this tool is not meant to capture the impact of climate change on the conservation actions needed for recovery of imperiled species. Therefore it is important to consider the index scores in combination with other assessments that capture these additional threats.

We found benefits to engaging species experts in combined individual-group assessment, although it was a fairly time-intensive approach. Species experts generally spent 2-4 hours on the worksheet module in addition to a one hour conference call for each species that was assessed, considerably longer than other reported applications of the CCVI that have relied less heavily on expert input (e.g., the Nevada Species Assessment: Case Study 1 in Glick and Stein 2011). Species experts were certainly able to provide more detailed knowledge about the species biology and current management program. While this was beneficial in obtaining the information required for the CCVI, it is possible that some of the information could have been gathered by a non-specialist followed by expert review. However, we found that during the conceptual modeling workshop most groups relied heavily on the specialized knowledge provided by species experts, with a number of participants suggesting that the process could have benefited from additional expert participation.

Repeatability and transparency of the vulnerability assessment process requires extensive documentation of assumptions and uncertainties. One criticism of the CCVI has been that, while it is repeatable in the sense that a particular set of input parameters will generate the same output score, it may be less repeatable across users (i.e., different users may assign different scores to the vulnerability factors). In addition, several authors (e.g., Schlesinger et al 2011) have commented that the underlying algorithm is not particularly transparent, although an unencrypted version of the CCVI is available from NatureServe upon request. Providing extensive documentation supporting the scoring decisions and involving multiple species experts is essential to ensuring the repeatability and transparency of any vulnerability assessment. For algorithm-based tools, such as the CCVI, exploring the sensitivity of the underlying algorithm to the input parameters, as we have done in Appendix A, can inform users of potential strengths and limitations of assumptions inherent in the underlying causal model used in the assessment.

Conceptual Modeling Workshop Results

For the conceptual modeling exercise, workshop participants started with an initial set of potential threats and drivers drawn from the Florida State Wildlife Action Plan (FWC 2005) and the CCVI assessment (Appendix C). This information was incorporated into a situation analysis describing how climate drivers interact with other threats to influence each focal species. Each group identified a set of priority strategies based on their conceptual model. Diagrams of the conceptual models produced for each focal species are shown in Figures 6 - 11. A summary of each breakout session is included below. In follow-up sessions, participants translated these strategies into spatially explicit actions and identified where these actions should be implemented on the landscape as part of MIT's Alternative Futures approach. The resulting geodesign maps are included in Flaxman and Vargas-Moreno (2011).

Short-tailed Hawk

Participants separated the target habitat into breeding and winter habitat in order to better capture threats that affected short-tailed hawk in these habitats (winter habitat overlaps with the southernmost portion of the breeding range, see Map A2-1 in Appendix A). The primary "non-climate" stressors included in the model (Figure 6) were incompatible forestry practices, fire and land conversion (primarily affecting breeding habitat) and incompatible water management practices (primarily affecting winter habitat). The group identified a number of ways in which these stresses were likely to be magnified by interactions with climate change. For example, drier conditions would exacerbate water management issues, making it more difficult to maintain intact hydrologic processes, which could affect both forested swamps (breeding habitat) and prey availability in the winter habitat. Sea level rise and drying of wetlands could potentially increase demand for development in the breeding habitat, as people move away from the coast and former wetlands become more attractive to development. Climate change could also impact breeding habitat through changes in fire regime affecting vegetative succession and drier conditions that promote incompatible logging practices in previously flooded areas.

The group identified five top-ranked threats, considering certainty, rate of change, and feasibility of measures to address them. Although not all of these threats were directly climate-related, they interacted in some way with the climate drivers as indicated in the conceptual model. The threats were split among those primarily affecting the breeding and winter habitat.

Breeding habitat:

- Conversion to housing and urban development (magnified by potential changes in demand and development pressure associated with climate change)
- Incompatible forestry practices resulting in habitat destruction and fragmentation (magnified by potential changes in availability of harvestable forests associated with climate change)
- Incompatible fire altering community structure

Winter habitat:

- Sea level rise resulting in inundation and loss of habitat
- Incompatible land uses such as wind farms

In developing the conceptual model, participants identified a number of sources of uncertainty that they felt limited their ability to fully characterize the system. For the breeding habitat, there was inadequate information available to assess whether natural barriers limit the potential for habitat shifts under climate change (i.e., whether currently unsuitable habitat would be able to transition to suitable habitat). The role of temperature on the species' current range limits and the potential for range expansion under climate change are also poorly understood. Within the winter range, the primary source of uncertainty identified by the group was the inability to characterize the impacts of sea level rise and changes to hydrology on the availability of key prey species. Short-tailed hawk relies on a fairly narrow taxonomic range of prey (avian migrants) during the winter, and it is unclear whether this prey base will be able to follow habitat shifts or become less concentrated and/or less abundant as a result of climate change.

Strategies identified by the group (Table 3) spanned planning, land protection, management, and policy contexts. Ecologically-based community planning was the highest ranked strategy targeting breeding habitat. Other strategies targeting breeding habitat called for incorporating specific practices into planning, management and protection. Two such examples were prioritizing land protection of current or potential habitat that is more likely to be developed and incorporating species-specific best management practices into easements and management plans for both forestry and fire. Strategies that targeted winter habitat focused on restoring public lands and/or using easements in the Water Management Districts and the Everglades Agricultural Area to protect critical areas.

Least Tern

Participants focused their conceptual model (Figure 7) on the factors affecting least tern in its nesting habitat within the assessment area, which includes sandy beaches as well as gravel roofs. Participants discussed a number of conservation threats generally associated with human activities including changes in the construction codes eliminating gravel roofs and incompatible recreational activities on beaches (e.g. disturbance of nesting sites by people, dogs, and vehicles) The group identified a number of stresses that were likely to be magnified by interactions between climate change and these human activities, ultimately affecting the availability of nesting habitat. These include shoreline hardening, loss of beach habitat due to sea level rise and more intense storm surge, and the lack of post-nourishment management of beaches to maintain suitable habitat.

Although not all of the threats identified by the group were directly climate-related, many of the threats would be exacerbated by projected habitat loss resulting from sea level rise as indicated in the conceptual model. The group identified the following top-ranked threats:

- Changes in construction codes eliminating gravel roofs
- Incompatible recreational activities (human use of beaches, presence of dogs/vehicles)
- Beach nourishment (negative effects due to lack of post-nourishment protection measures)
- Shoreline hardening (more likely as a result of sea level rise and a potential barrier to habitat migration)
- Coastal development (potential barrier to habitat migration)

- Stronger hurricanes and storm events that potentially disrupt habitat or overwash nests
- Changes in timing of storms that may increase interference with nesting

In developing the conceptual model, participants identified the effects of sea level rise and storm surge on future beach nourishment activities as primary sources of uncertainty that they felt limited their ability to fully characterize the effects on the species. The group ranked strategies based on effectiveness and ease of implementation. Strategies identified by the group (Table 3) were primarily focused on developing best practices for beach management (e.g. reducing disturbance associated with beach raking, maintaining natural shorelines), establishing natural storm buffers by protecting coastal land through fee-simple or easement acquisition, drafting model building codes that would retain gravel roofs as nesting habitat, and restricting beach use near nesting grounds (e.g. mark off) during breeding season.

Atlantic Salt Marsh Snake

Participants focused their conceptual model (Figure 8) on the factors affecting the Atlantic subspecies of salt marsh snake, rather than on the species as a whole. Atlantic salt marsh snake is restricted to coastal areas of Volusia County and is threatened by loss and degradation of coastal marshes due to habitat conversion and altered hydrology (e.g., draining and impoundments). Several of the following top-ranked threats identified by the group, although not directly climate-related, could be exacerbated by human responses to sea level rise and changes in hurricane activity:

- Increases in coastal development resulting in fragmentation and loss of habitat
- Sea level rise resulting in inundation of habitat
- Species range shifts and disrupted biotic functions, for example, loss of species required to generate habitat, reduced availability of key prey species, and replacement of the Atlantic salt marsh snake by the mangrove salt marsh snake with the potential northward progression of mangroves
- Interior development resulting in fragmentation and loss of habitat (magnified by potential changes in demand and development pressure associated with climate change)
- Stronger hurricanes and storm events limiting the formation of habitat

In developing the conceptual model, participants identified sources of uncertainty that they felt limited their ability to fully characterize the potential effects of climate change on the snake. The primary sources of uncertainty identified by the group were the inability to characterize the impacts of sea level rise, temperature, and precipitation changes on the habitat. Strategies identified by the group (Table 3) focused on habitat management and land protection of potential habitat migration corridors, as well as an emphasis on research targeted towards understanding vegetative succession under sea level rise.

American Crocodile

Participants focused their conceptual model (Figure 9) on the factors affecting American crocodile in its core habitat areas. [7] These areas were identified by species experts during the first workshop as part of the Alternatives Futures approach (Flaxman and Vargas-Moreno 2011), and are located primarily in the Everglades and surrounding Keys. Participants discussed a number of conservation threats generally associated with proximity to humans (e.g., development, shoreline hardening, beach nourishment), but decided that they were unlikely to have a large impact on the focal species due to the current protections afforded to much of the habitat in these core areas.

The primary "non-climate" stressor included in the conceptual model was incompatible water management practices. The group identified a number of stresses that were likely to be magnified by interactions between climate change and water management practices, ultimately affecting the availability of nursery habitat and survival of young.

[7] These are more restrictive assumptions than those used in the CCVI analysis (see Appendix A).

Table 3. Workshop participants used the conceptual models to identify a set of priority strategies addressing climate-related threats for each focal species. Where spatially-explicit actions could be identified, these were integrated into the Alternative Futures approach and mapped on the landscape (see Flaxman and Vargas-Moreno 2011).

	Potential priority strategies
Short-tailed hawk	PLANNING: Ecologically-based community planning (targets breeding habitat) LAND PROTECTION: Targeting potential or current habitat likely to be developed (breeding habitat) MANAGEMENT: Restore public lands and protected private land in WMD and EAA (winter habitat) MANAGEMENT: Indicator-based water management in response to fire (breeding habitat) MANAGEMENT: Ensure that management plans require species-specific best management practices regarding forestry (breeding habitat)
Least tern	MANAGEMENT: Develop best management practices for beach management (e.g. beach raking, natural shorelines) LAND PROTECTION: Maintain natural storm buffers by protecting coastal land through fee-simple or easement acquisition PLANNING: Draft model building codes for keeping gravel roofs as nesting habitat MANAGEMENT: Restrict use (e.g. mark off) beach during nesting season
Atlantic Salt marsh snake	MANAGEMENT: Restoration of habitat using dredge soils LAND PROTECTION: Protect corridors for inland migration of salt marsh via fee simple or easements acquisition. RESEARCH: Model vegetation succession with downscaled sea level rise models POLICY: Rezone low elevation areas
American crocodile	RESEARCH: Increase understanding of how mangroves will shift and appropriate vegetation management responses MONITORING: Changes to population size, trends and habitat MANAGEMENT: Create nesting/nursery habitat if needed (as indicated by monitoring) POLICY: Ensure water management in Everglades is consistent with crocodile management (impacts to salinity) RESEARCH: Model effects of cold snaps on crocodile population
Florida panther	PLANNING: Conduct long-term spatial conservation planning to incorporate panther habitat into land use planning LAND PROTECTION: Secure travel/habitat corridors via fee simple or easements acquisition, especially for crossing over to areas north of the Caloosahatchee River. MONITORING AND MANAGEMENT: Maintain robust monitoring and maintain healthy panther populations across current range to bolster resilience to future changes
Key deer	POLICY: Develop a habitat conservation plan MANAGEMENT: Fill/remove mosquito ditches LAND PROTECTION: Fee-simple or easement acquisition, including road underpasses RESEARCH: Disease/disease management MANAGEMENT: Implement appropriate fire regime

The top climate-related threats and associated stresses that were identified by the group were:

- Sea-level rise resulting in inundation and habitat loss
- Sea level rise generating changes in vegetation (i.e., mangroves)
- Water management practices that alter hydrologic regime (exacerbating hydrologic impacts of sea level rise)
- The potential for increased frequency of cold snaps resulting in direct mortality

In developing the conceptual model, participants identified a number of sources of uncertainty that they felt limited their ability to fully characterize the system. The primary source of uncertainty identified by the group was the inability to characterize the impacts of sea level rise on hydrology and associated vegetative and biophysical dynamics that impact the formation and loss of essential crocodile habitat (for example, predicting where nursery or nesting habitat would be created/lost). Other issues that were raised included concerns about small population size and/or genetic factors that may reduce adaptive capacity, and whether crocodiles will be able to effectively migrate around Miami as habitat shifts, citing a lack of knowledge in potential constraints (e.g., female site fidelity).

Strategies identified by the group (Table 3) were primarily focused on research and monitoring to address data gaps and sources of uncertainty in the response of the system to the identified threats (noted as biophysical impacts in the conceptual model). Management strategies focused on creating nesting and/or nursery habitat that might be lost as a result of sea level rise and other associated threats. An opportunity to address water management practices through policy was also identified. Notably absent from the list were any land protection strategies. Most of the areas considered as current and/or potential future habitat are already in protected status. Assuming that these protections remain in place, participants did not think that additional land protection would be particularly effective in mitigating the identified threats. Instead, participants focused on continued population monitoring and subsequent management intervention.

Florida Panther

Participants focused their conceptual model (Figure 10) on the factors affecting the Florida panther in its current areas of occurrence. These areas were identified by species experts during the first workshop as part of the Alternatives Futures approach (Flaxman and Vargas-Moreno 2011) and are located primarily in the Everglades and areas north to the Caloosehatchee River, which acts as a natural barrier to dispersal of female panthers. Participants discussed a number of conservation threats generally associated with proximity to humans (development, increased agriculture intensity, and road mortality). The river as a natural barrier and conflicts with humans were identified as the primary "non-climate" stressors included in the conceptual model. The group identified a number of stresses that were likely to be magnified by interactions between climate change and these non-climate factors, which would ultimately affect the availability of habitat for the panther.

The top climate-related threats and associated stresses that were identified by the group were:

- The movement of residential and commercial development away from the coast, due to sea level rise and increased storm surge, into panther habitat areas in the interior of the state
- An increase in the intensity of agricultural development in response to a higher demand for growing food more efficiently under climate change
- The development of more roads within panther habitat, leading to direct mortality and fragmentation of habitat. These roads can also act like levees, trapping runoff and increasing the area inundated after severe storms, and they limit the ability of managers to conduct prescribed burns to maintain grassland habitat
- Flooding that exacerbates the barrier imposed by the Caloosehatchee River, further limiting potential northern range shifts of the panther
- Sea level rise in the Everglades resulting in a direct loss of habitat.

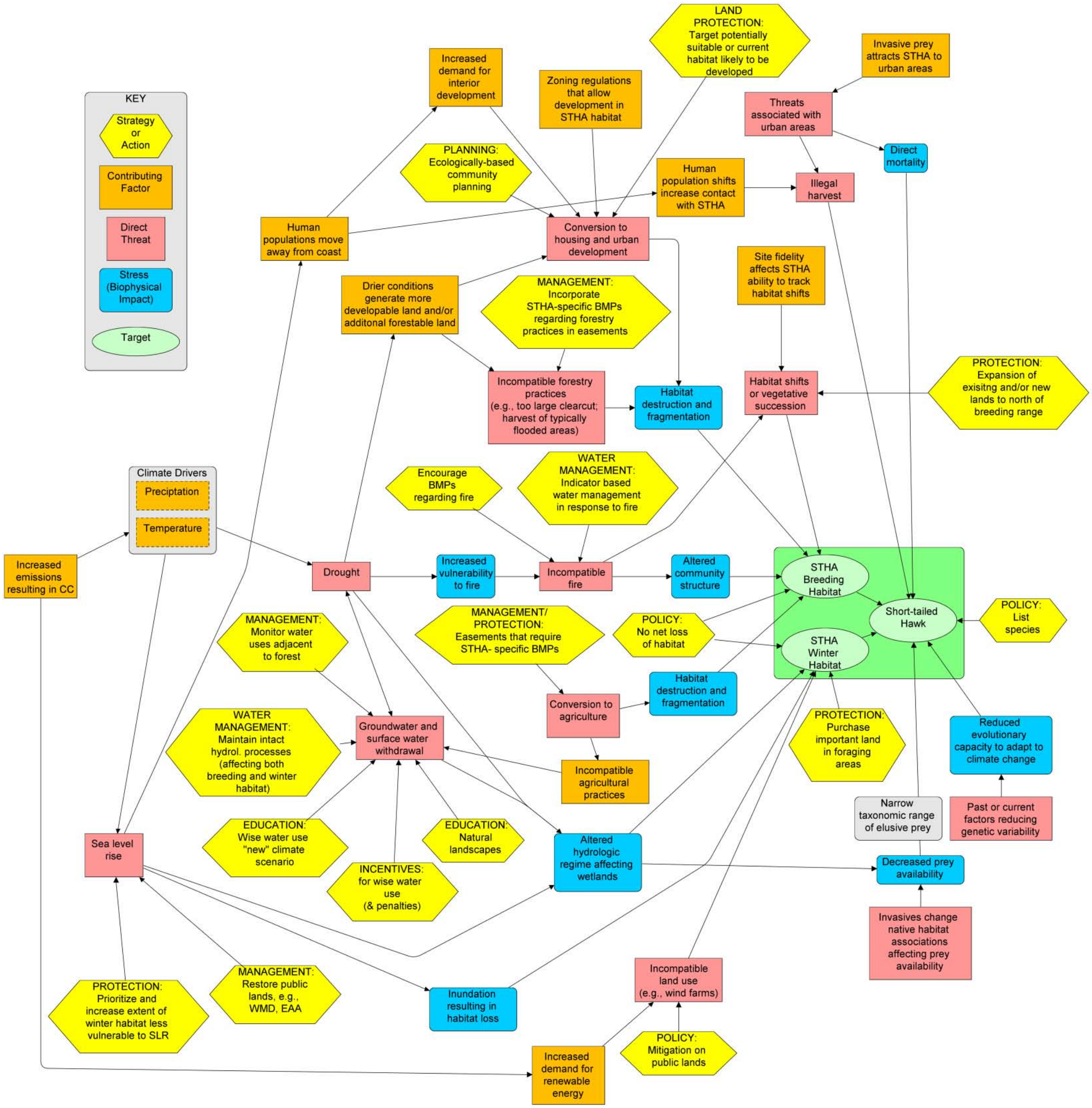


Figure 6. Conceptual model developed for short-tailed hawk. Workshop participants developed a conceptual model describing climate-related threats affecting short-tailed hawk within its range in Florida. They used the model to develop adaptation strategies which were translated into spatially-explicit actions in conjunction with the Alternative Futures approach (Flaxman and Vargas-Moreno 2011).

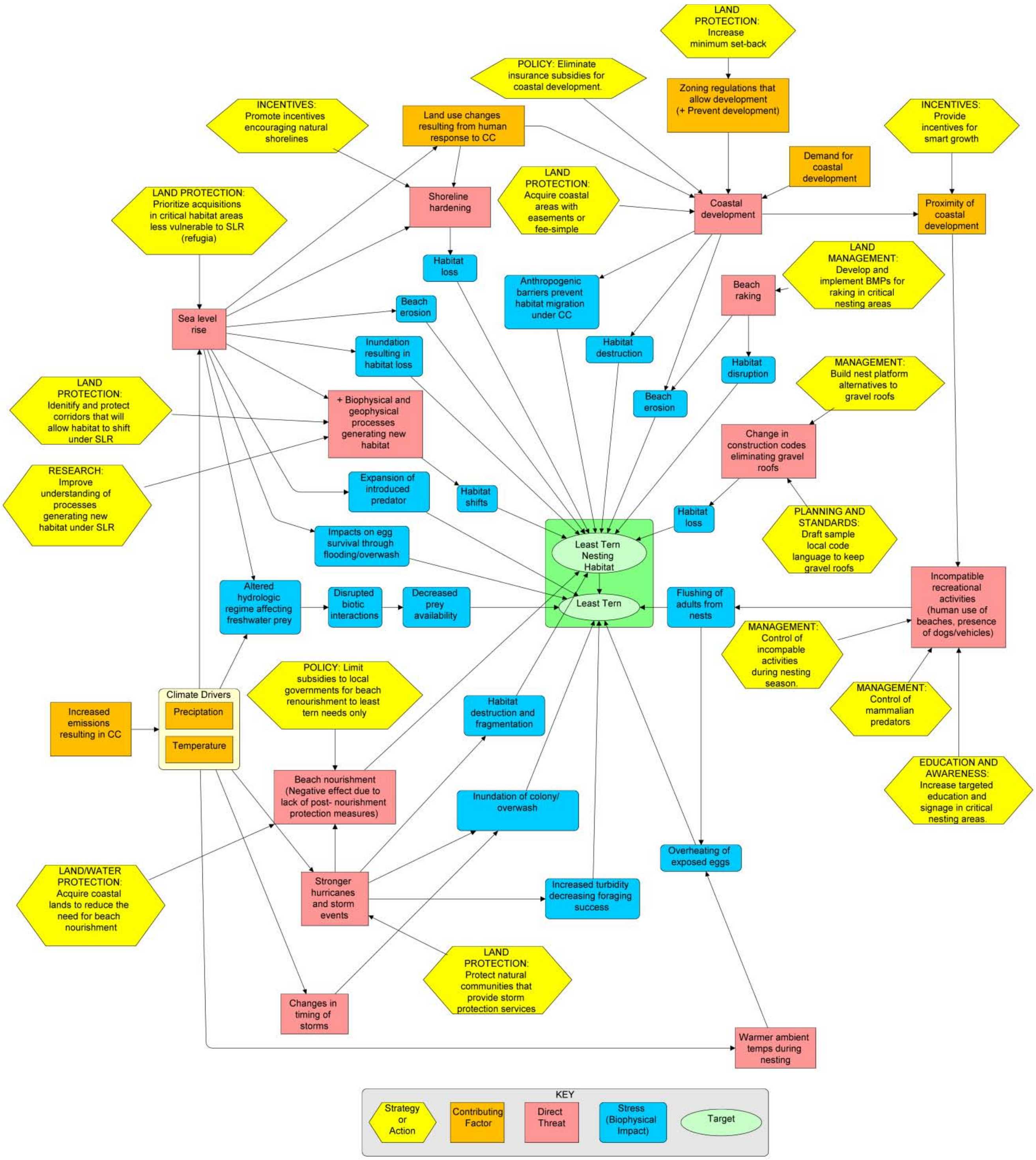


Figure 7. Conceptual model developed for least tern. Workshop participants developed a conceptual model describing climate-related threats affecting least tern within its range in Florida. They used the model to develop adaptation strategies which were translated into spatially-explicit actions in conjunction with the Alternative Futures approach (Flaxman and Vargas-Moreno 2011).

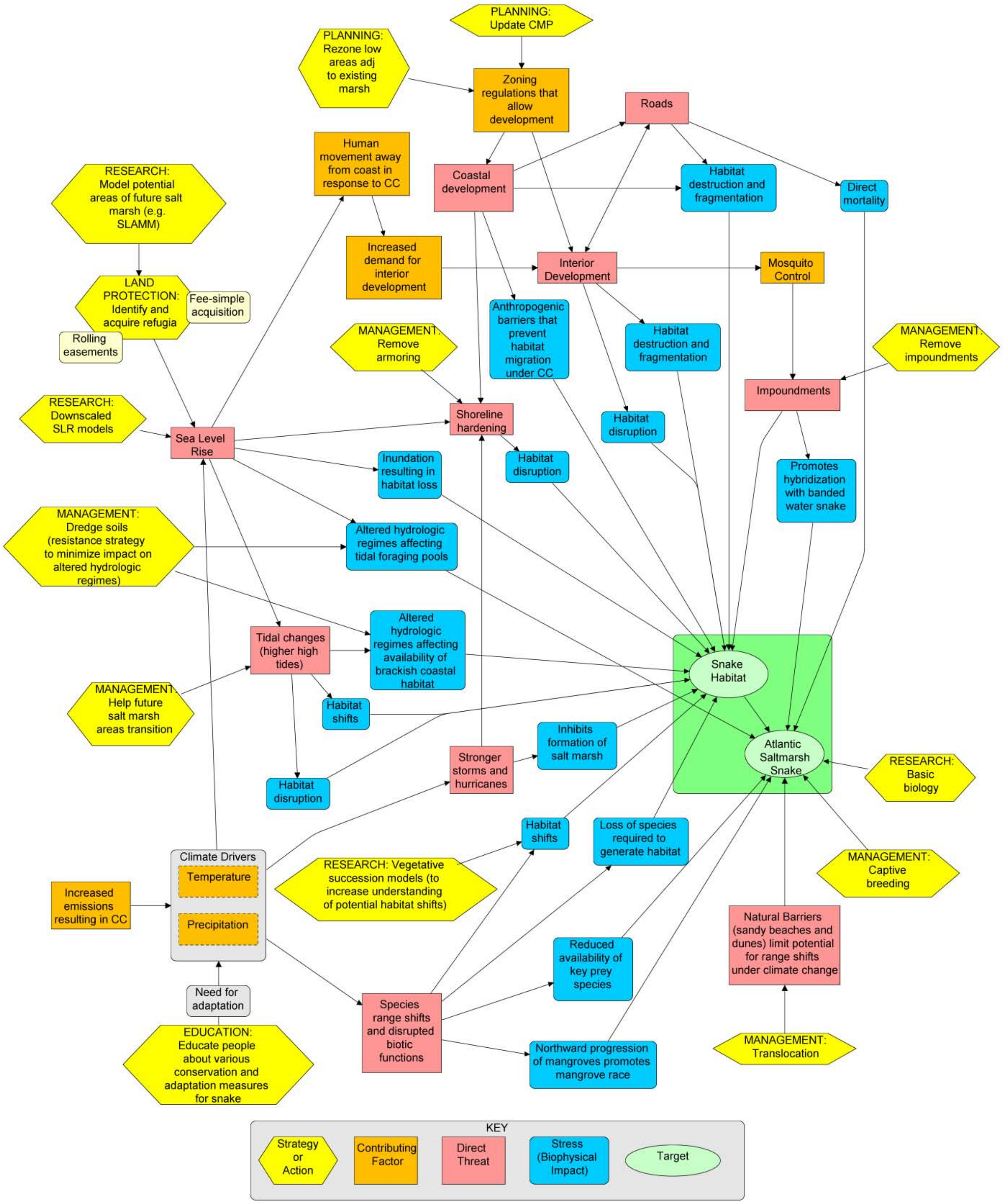


Figure 8. Conceptual model developed for Atlantic salt marsh snake. Workshop participants developed a conceptual model describing climate-related threats affecting Atlantic salt marsh snake within its range in Florida. They used the model to develop adaptation strategies which were translated into spatially-explicit actions in conjunction with the Alternative Futures approach (Flaxman and Vargas-Moreno 2011).

Figure 9. Conceptual model developed for American crocodile. Workshop participants developed a conceptual model describing climate-related threats affecting American crocodile within its range in Florida. They used the model to develop adaptation strategies which were translated into spatially-explicit actions in conjunction with the Alternative Futures approach (Flaxman and Vargas-Moreno 2011).

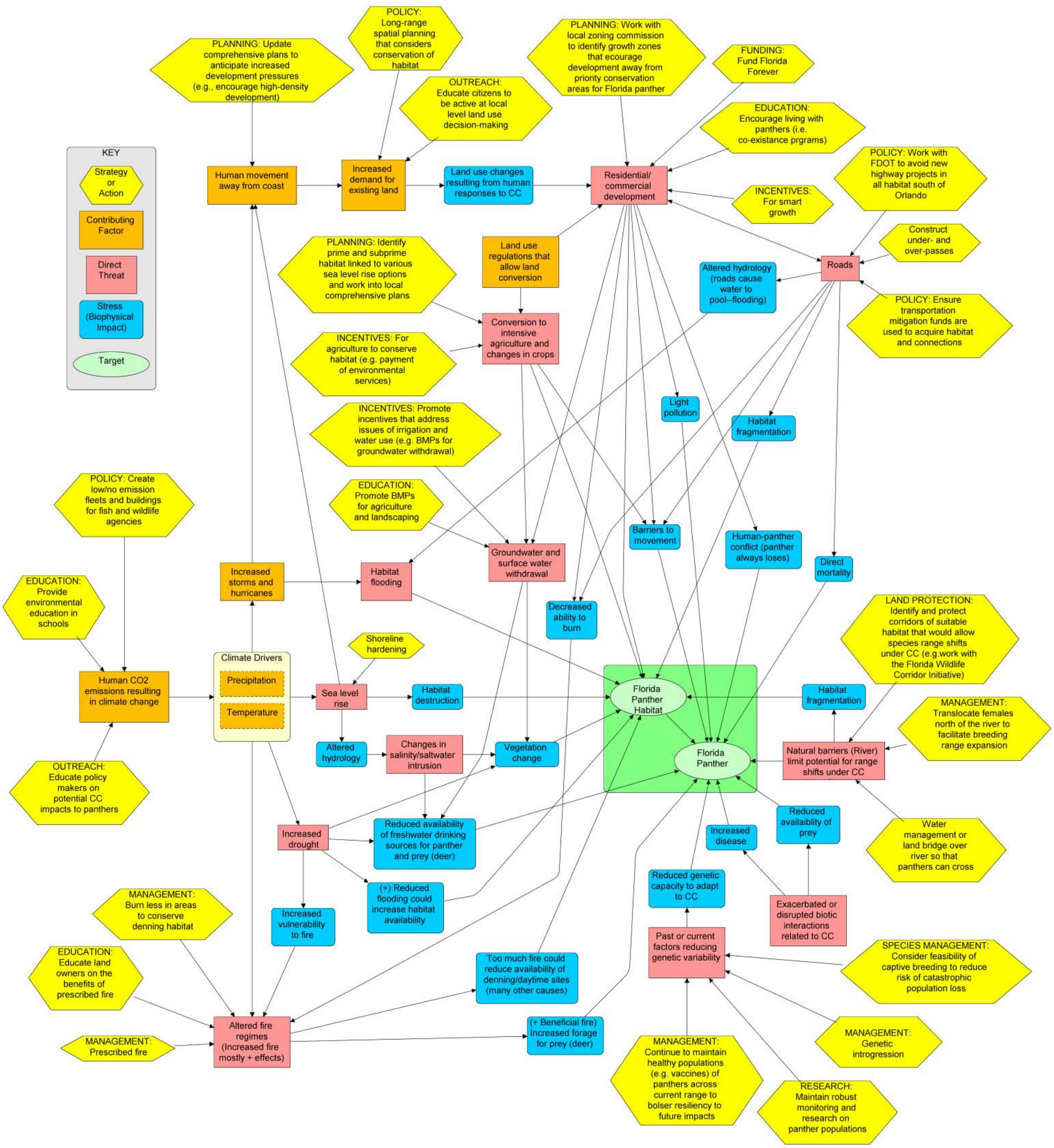


Figure 10. Conceptual model developed for Florida panther. Workshop participants developed a conceptual model describing climate-related threats affecting Florida panther within its range in Florida. They used the model to develop adaptation strategies which were translated into spatially-explicit actions in conjunction with the Alternative Futures approach (Flaxman and Vargas-Moreno 2011).

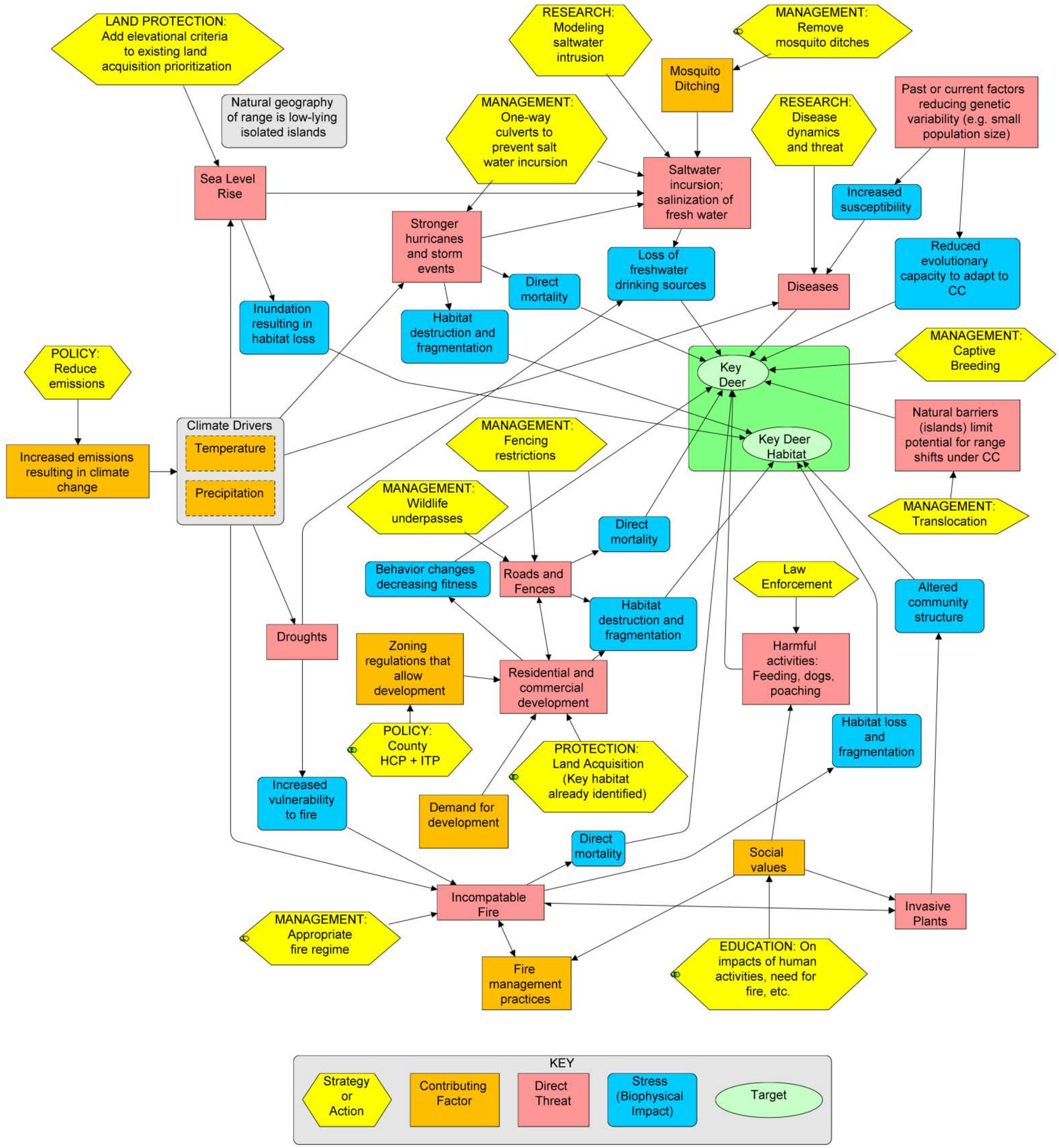


Figure 11. Conceptual model developed for Key deer. Workshop participants developed a conceptual model describing climate-related threats affecting Key deer within its range in Florida. They used the model to develop adaptation strategies which were translated into spatially-explicit actions in conjunction with the Alternative Futures approach (Flaxman and VargasMoreno 2011).

In developing the conceptual model, participants identified sources of uncertainty that they felt limited their ability to fully characterize the potential effects of climate change on panthers. The primary source of uncertainty identified by the group was the inability to characterize the impacts of temperature and precipitation changes and sea level rise on vegetation dynamics (more specifically invasive species) and habitat loss.

Strategies identified by the group (Table 3) were primarily focused on land protection, especially near the Caloosahatchee River, to facilitate female panther dispersal and range expansion to the north. Management strategies focused on maintaining healthy populations of panthers across the current range to bolster resilience to future impacts, such as disrupted biotic interactions. An opportunity to address water management through agricultural best management practices and payment for ecological services was also identified. Participants also identified policy strategies for encouraging smart-growth (e.g. compact urban areas) and long-term spatial analysis to plan for human movement and road corridors away from the coast, while preserving corridors to facilitate northward panther movement.

Key Deer

Many of the factors that participants identified in their conceptual model (Figure 11) are associated with the unique geography of the species' range, which is restricted to the Florida Keys. Participants discussed a number of current "non-climate" threats to the species generally associated with roads and fences as well as commercial development. The group identified a number of stresses that were likely to be magnified by interactions between climate change and these human activities, ultimately affecting the availability of habitat. These include inundation of habitat due to sea level rise and more intense storm surge.

Top climate-related threats and associated stresses that were identified by the group were:

- Sea level rise resulting in loss of habitat and salinization of drinking water sources
- Natural barriers (water) to migration off the Keys (and high likelihood of genetic introgression with white-tailed deer if colonized on the mainland)
- Drought resulting in loss of habitat and drinking water supply
- Stronger storm events resulting in loss of habitat

In developing the conceptual model, participants identified the potential changes and impacts of disease dynamics as a primary source of uncertainty that they felt limited their ability to fully characterize the effects on the system. Strategies identified by the group (Table 3) were primarily focused on protecting habitat through fee-simple or easement acquisition, developing the habitat conservation plan, land management practices to facilitate movement within the Keys and protect water sources, and education.

Integrating Approaches

We found that using a vulnerability framework informed the adaptation planning process. Specifically, we used the vulnerability assessment to identify climate drivers (exposure in the vulnerability assessment) and stresses (often related to sensitivities in the vulnerability assessment) on the system and followed up with a conceptual modeling approach to identify potential interactions between these climate-related factors and existing threats and stresses to the system. This approach allowed the workshop participants to identify management strategies that could be specifically targeted to reduce exposure to threats or increase adaptive capacity of the species or habitat. In many cases, participants were able to identify existing ("non-climate") threats that might be exacerbated. As a result, some existing strategies might become higher priorities or be applied in different ways. For example, land protection for Key deer might incorporate elevation into selection criteria.

By running this process in parallel with the MIT Alternative Futures approach, we observed several opportunities in which these approaches could inform each other. For example, during the first workshop, those participants who had participated in the CCVI had a more complete understanding of the interactions between exposure and species-specific sensitivity and may have been able to better translate the spatial aspects of vulnerability onto the landscape. Participants also found ways to incorporate the mapping exercises and land use scenarios produced as part of MIT's Alternative Futures approach into their conceptual models. For example, they had a better idea of potential land use changes associated with sea level rise, such as increased demand for interior development, and where those changes were more likely to occur relative to the species' habitat. Finally, while the conceptual modeling exercise provided a framework for identifying potential adaptation strategies, it was only in combination with the Alternative Futures scenarios that participants were able to translate these strategies into specific, spatially-explicit actions.

Incorporating vulnerability into a comprehensive planning process requires understanding the factors, as well as the strength of interactions between the factors contributing to vulnerability. One adaptation strategy may be to prioritize conservation attention on species where management actions can reduce vulnerability, not simply on the most vulnerable species (Mawdsley 2011). The CCVI provides a causal model of vulnerability that incorporates species-specific sensitivity, but lacks a spatial context in that it does not identify where those vulnerabilities may play out on the landscape. The strength of the Alternative Futures approach is that it is explicitly spatial, but as a result, the focus tends towards landscape factors affecting vulnerability through exposure. Incorporating a causal vulnerability framework may also help to identify groups of species that are likely to respond to similar management strategies, which could be used to identify a representative set of species that can be assessed with the more computationally intensive Alternative Futures approach. For example, the team from MIT focused the second day workshops around species with similar landscape contexts that potentially influence management response. Adaptation will likely require different strategies under these different contexts, but species with similar vulnerabilities may benefit from similar strategies.

Addressing climate change within a conservation planning framework requires an understanding the conceptual linkages connecting climate threats to the stresses affecting a conservation target. A vulnerability assessment should provide the evaluative framework to help elucidate these linkages, thereby providing the foundation for integrating adaptation planning into existing planning frameworks. As such, adaptation does not replace current conservation practices and standards, but expands the applicability of these tools to better address the realities of a changing world.

Recommendations and Next Steps

1. Assess future needs for assessing the vulnerability of species and habitats and identify suitable assessment targets. Vulnerability assessments are flexible and can be tailored to specific situations and purposes. Before deciding on any particular approach, it is important to first identify the decision problem and the applicability of any particular tool to the problem at hand. For example, a species-level approach (such as the CCVI) may not be the most appropriate unit of analysis for land management, and other methods may be needed to address management at different scales. No matter which approach is taken, it will be important to evaluate the causal model of vulnerability forming the basis of the assessment relative to the potential physical and biological impacts of climate change on species and habitats in the assessment area to determine whether there are specific exposure or sensitivity factors that could be added or weighted differently to address unique aspects of the geography and ecosystems in the assessment area.

2. Integrate multiple approaches for assessing the vulnerability of species to climate change. The CCVI provides a conceptual framework for incorporating additional approaches to vulnerability assessment, including ecophysical modeling, population models and direct observation. Complementary methodologies are likely to better inform our understanding of the potential impacts on species and habitats (Dawson et al. 2011). Understanding the conceptual linkages connecting climate threats to the stresses affecting a conservation target provides the context within which to evaluate current priorities, strategies and responses, and whether these still make sense under climate change.

3. Identify the current decision-making process for developing and implementing wildlife manage-

ment strategies across divisions and programs. Assess whether the current process has the flexibility incorporate climate change response strategies, and if needed define a process for revising current practices and management actions to achieve conservation goals under climate change.

4. Implement actions and monitor effectiveness as part of a comprehensive planning framework. Formulate specific "theories of change" (TNC 2009) regarding the expected results and outcomes for adaptation strategies and monitor the effectiveness of conservation and management activities employed to achieve these results. Adjusting to new information and refining what is done will become even more important given the uncertainties of exactly how climate change will affect natural systems.

Summary

Addressing climate change within a conservation planning framework requires an understanding of the particular impacts and pathways of impact on a conservation target. Vulnerability assessments can provide an evaluative framework to help elucidate these linkages and identify sources of uncertainty, as well as provide a foundation for integrating adaptation planning into existing conservation planning frameworks. The case study presented here illustrates a process for integrating the information obtained from vulnerability assessments into a conceptual modeling process as part of a comprehensive planning process to identify adaptation strategies and management opportunities for species likely to be vulnerable to the impacts of climate change.

Acknowledgments

Funding for this work was provided by the Doris Duke Charitable Foundation, the Kresge Foundation and the Educational Foundation of America. We extend sincere thanks to the species experts who volunteered more than 200 collective hours on the vulnerability assessments. We sincerely hope that we have accurately captured their views in the species accounts included in Appendix A. In addition, we wish to thank the participants in the vulnerability and adaptation workshops hosted in St. Petersburg and Orlando in January and April 2011, our partners at the Florida Fish and Wildlife Conservation Commission and the Flaxman lab (Michael Flaxman and Juan Carlos Vargas) from MIT's Department of Urban Studies and Planning. Bruce Young kindly answered questions regarding technical aspects of the CCVI. The Florida Natural Areas Inventory provided element occurrence data for a number of species included in this assessment. Sara O'Brien and Noah Matson provided helpful comments on earlier versions of this paper. This document represents the work and views of the authors and does not necessarily imply endorsement by any of our partners or the participants in this project. Any errors in this document are the sole responsibility of the authors.

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Appendix A: Species Accounts

Florida FWC Climate Change Vulnerability Assessment
Summary of Expert Input for CCVI

CONTENTS

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OVERVIEW

Vulnerability assessments provide a means to identify those species or systems that are likely to be most strongly affected by projected changes in climate as well as to explain why particular species are likely to be vulnerable. As such, these tools provide the basis for developing appropriate management and conservation responses under climate change. This project was developed to evaluate the applicability of the NatureServe Climate Change Vulnerability Index (CCVI) (Young et al. 2010) as part of an adaptation planning process undertaken by the Florida Fish and Wildlife Conservation Commission's Legacy Initiative. The CCVI is designed to help identify plant and animal species that are particularly vulnerable to the impacts of climate change.

Defenders of Wildlife worked with FWC to facilitate the CCVI process using an expert elicitation approach. FWC selected a set of species and identified potential species experts. Participating species experts were asked to complete a worksheet developed to elicit the information required for the CCVI. Defenders' staff then contacted species experts to discuss their responses and issues of uncertainty in the available data. The species accounts contained in this Appendix describe the inputs used in the CCVI analysis based on information provided by the species experts. The results of this assessment were used in combination with a scenario-based modeling approach developed by a team from MIT (Flaxman and Vargas-Moreno 2011) to identify adaptation strategies and implemented through workshops held in January and April 2011. Additional information is available in the main report.

CCVI Algorithm

The CCVI combines information on exposure and sensitivity to tabulate a numerical score (Young et al. In press). Individual factors are scored on a scale ranging from 3 (for "greatly increases" vulnerability) to -2 (for "decreases" vulnerability).[1] "Neutral" and "unknown" are assigned values of zero. Not all factors can be assigned the full range of scores. For example, allowable scores for factor C4b (*dietary versatility*) range from "increases" vulnerability (2) to "somewhat decreases" vulnerability (-1). As a result, some factors have the potential to more heavily influence the overall index score than others. Sensitivity factors that are affected by changes in climate are weighted by an exposure metric reflecting the degree of exposure when calculating the subscore for those factors. Categorical index ranks are assigned based on the threshold values indicated below.

Score	***Categorical rank***
> 10.0,	Extremely Vulnerable
7.0 - 9.9	Highly Vulnerable
4.0 - 6.9	Moderately Vulnerable
-2.0 - 3.9	Presumed Stable
< -2.0	Increase Likely

These ranks are only intended to capture vulnerability to climate change. The index does not capture factors that are considered in other conservation status assessments, such as population size, range size and demographic factors that affect viability. The CCVI results should be used in combination with other conservation status assessments that address the full range of factors that affect the conservation status of a particular species.

In cases where more than one score is assigned to a factor, the index uses the average value when calculating the overall index score. In addition, a Monte Carlo simulation calculates the index score for 1,000 iterations using just one of the scores for factors for which multiple scores have been assigned, assuming that all scores are equally likely to represent the "true" value.

The standard CCVI output is the categorical rank based on the average values of the scores assigned to each factor and a "confidence level." However, since we were interested in exploring the sensitivity of the

[1] Factor scores include: greatly increases vulnerability, increases vulnerability, somewhat increases vulnerability, neutral, somewhat decreases vulnerability, and decreases vulnerabilty

CCVI to uncertainty in the parameter estimates, we report scores somewhat differently from this standard output. We report the numeric index score associated with the categorical rank along with the range of scores produced by the Monte Carlo simulation.

The species accounts summarize the information provided by the species experts and the input parameters used for the CCVI for each species. More information on how the factors are scored is available in Young et al. (2010). Version 2.1 of the CCVI was used in this analysis.

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A1. SHORT-TAILED HAWK *(Buteo brachyurus)*

Species Expert(s): Ken Meyer and Karl Miller

Within the United States, short-tailed hawks are found only within Florida but are much more widely distributed throughout Central and South America (Miller and Meyer 2002). Their habitat generally includes mangroves, coastal marshes, swamp forests, pine savannas, prairies, and pastures, as well as suburban settings with trees and shrubs. Florida's population is distinct from other populations and is separated from the closest population in Mexico by more than 800 kilometers. The Florida population remains in the state year-round but migrates to the southern peninsula and Florida Keys during the winter (Miller and Meyer 2002).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A1-1) included a range map from NatureServe (Ridgely et al. 2003), a potential habitat model (phm) developed by FWC (Endries et al. 2009), and FNAI element occurrence data (FNAI 2011). The species experts felt that the NatureServe range underestimated the actual breeding distribution, which is not confined to the central ridge as indicated, and overestimated the wintering range (indicated as "year round"), which occurs south of Lake Okeechobee but tends to be concentrated in the southern Everglades. Based on these comments, we did not include the NatureServe range in our analysis. The potential habitat model was considered adequate but a bit conservative, with several known inaccuracies. The species experts are currently working with FWC to update the potential habitat model. We also ran the assessment using counties with known occurrences based on the Florida Breeding Bird Atlas (FWC 2003) to estimate the species' distribution. FNAI occurrence data included 43 records distributed throughout the peninsula, including two records in the Keys. Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

Initially, we asked the species experts to complete the worksheet based on the distribution maps as provided, which combines both the breeding and wintering range. However, after consulting with the species experts, it became apparent that the wintering range differs in exposure (particularly sea level rise) and other associated factors, and there was concern that the unique aspects of vulnerability associated with these different spatial and temporal components of the life history might not be captured in a combined analysis. In order to explore this issue, we ran two separate analyses, one focused on the breeding distribution and the other on the winter distribution. There was a natural break in the potential habitat south of Lake Okeechobee which we used to delineate the winter range (Figure A1-1). We used this same line to delineate the FNAI occurrence data. The winter range is essentially a portion of the breeding range, with the exception of the Florida Keys, where birds winter but do not breed (K. Meyer and K. Miller, pers. comm.). However, none of the datasets shown in Figure A1-1 currently include the Florida Keys as part of the breeding range.

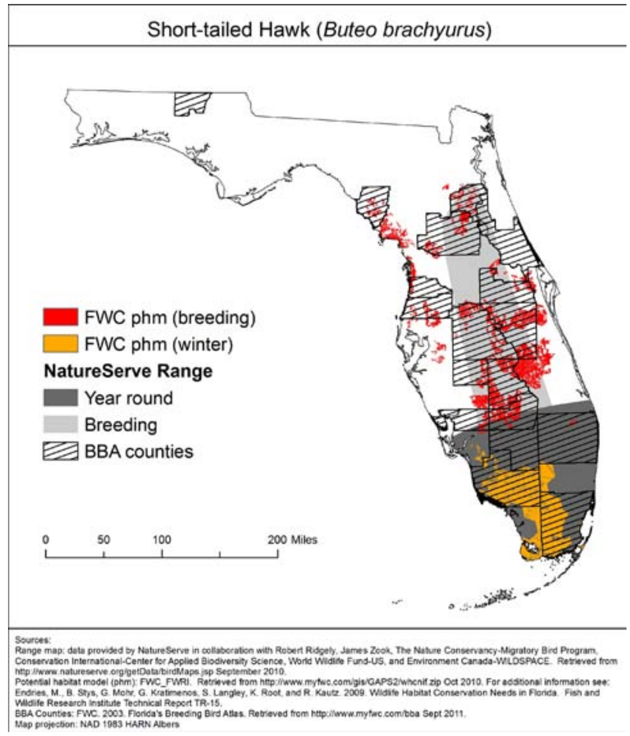

Figure A1-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A1-1 and A1-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). Species experts assigned different scores for the winter and breeding distributions. Both reviewers estimated that 10% or less of the breeding range would be impacted by a 1-meter sea level rise and provided estimates of 25% and 50-90% for the winter range. These estimates corresponded to a score of *neutral* for the breeding range and *somewhat increases* to *increases* vulnerability in the winter range.

Potential impact of barriers on range shifts. Experts indicated that the species nesting habitat consists of mature swamp forest, adjacent mixed-species prairie and wooded habitats in various earlier successional stages. During the winter, this species congregates in mangrove estuaries in the Everglades. Both reviewers considered these habitats to be vulnerable to climate change, particularly wintering habitat. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural Barriers (B2a). The issue of scale came up in reviews' responses to this factor. One reviewer scored this factor at a state-wide scale, considering natural barriers to completely surround the species' range in the form of the ocean to the west, south and east, and unsuitable habitat to the north. However, both

Table A1-1. Projected temperature exposure for short-tailed hawk in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm Breeding	FWC phm Winter	BBA counties	FNAI Occur.
> 5.5°F warmer	0%	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%	0%
3.9 - 4.4 °F	0%	0%	3%	0%
< 3.9°F warmer	100%	100%	97%	100%
(E_T)	*0.4*	*0.4*	*0.4*	*0.4*

Table A1-2. Projected moisture exposure (based on the Hamon Index) for short-tailed hawk in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm Breeding	FWC phm Winter	BBA counties	FNAI Occur.
< -0.119 (Driest)	0%	0%	0%	0%
-0.119 - -0.097	12%	27%	6%	7%
-0.096 - -0.074	61%	73%	49%	72%
-0.073 - -0.051	26%	0%	42%	19%
-0.050 - -0.028	1%	0%	3%	2%
> -0.028 (No change)	0%	0%	0%	0%
(E_M)	*1.3*	*1.3*	*1.3*	*1.3*

experts agreed that the species would be able to track shifts in habitat that might occur under climate change. While the unsuitable habitat to the north may change currently function as a barrier to short-tailed hawk distributions, it was not clear from this discussion that this unsuitable habitat would represented a barrier to habitat shifts under climate change. For the breeding distribution, we conservatively assigned this factor a score of *neutral*. Reviewers did not directly specify whether natural barriers would be expected to impact habitat in the wintering range, but based on the habitat we also considered the impact of natural barriers on winter habitat to be *neutral*.

Anthropogenic barriers (B2b). One reviewer mentioned the impact of future urban development along the coasts and inland expansion with climate change, selecting the description corresponding to increases vulnerability. However, in order to maintain consistency across the different species' assessments, we captured the potential for increased interior development in response to human migration away from the coast in factor B3 and so have not included it here. In the breeding range, a large portion of the breeding habitat occurs in the interior peninsula and so coastal development would not be expected to pose a major barrier to the anticipated direction of habitat shifts to the north. In the wintering range, current habitat occurs primarily in protected areas. In considering the ability of the species to navigate around anthropogenic barriers, both reviewers agreed that short-tailed hawk could likely traverse existing barriers as the species migrates significant distances within the Florida peninsula. We adjusted the scores for this factor to *neutral* for both breeding and winter range.

Land Use Changes Resulting from Human Responses to Climate Change (B3). One expert considered risk from greater human development and density in the nesting range with inland movement from the coasts and an increasing ability to developing land acreage under drier conditions. In follow up discussion, the potential for increased forestry in these areas was also mentioned. Both reviewers expressed uncertainty in the scale and impact that these activities would have on the species. We captured this uncertainty by assigning scores of *neutral*, *somewhat increases* and *increases* vulnerability for the breeding range. We considered this factor to be *neutral* for the winter range, which has large overlap with a number of existing protected areas.

Sensitivity

Dispersal and movement (C1). Both experts characterized the species as having excellent dispersal. The species regularly migrates hundreds of kilometers up and down the Florida peninsula. This factor was scored as *decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *increases* and *greatly increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* One species expert characterized the species as showing a preference for environments towards the warmer end of the spectrum and the other expert indicated no associate with a particular thermal environment. We included scores of *somewhat decreases* and *neutral* to capture the range in reviewer responses.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution (combining the breeding and wintering ranges) with the maps provided by NatureServe to assess this factor. The calculated values for variation in precipitation corresponded to *somewhat increases* vulnerability using the potential habitat model and BBA counties and *increases* vulnerability using the FNAI occurrences as a proxy for the species' distribution.

Historical precipitation exposure
FWC phm/BBA counties: 46 - 59 inches
FNAI occurrences: 49 - 56 inches

*Physiological hydrologic niche (C2b*ii). Both experts cited reliance on mature swamp forest and wetland drainages during nesting. In addition the species relies on various wetlands in southern Florida for concentrations of migratory prey during the winter. One of the reviewers selected the description associated with a score of "increases" vulnerability for this factor, whereas the other reviewer indicated that there was insufficient information to select a response. Based on the written comments associated with this factor and our follow up discussions, we have adjusted the scores to capture the uncertainty associated with the potential level of impact on the species by including scores of *somewhat increases* and *increases* vulnerability for this factor.

Impacts of Changes to Specific Disturbance Regimes (C2c). Fire and drought were considered to have a potentially negative impact on nesting and cover habitats as well as prey populations. The uncertainty associated with the projected impacts was captured in the range of scores selected by the reviewers, which included *neutral*, *somewhat increases* and *increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Reviewers did not feel that the idea of specificity to a particular geologic feature or derivative was particularly relevant to this species, corresponding to score of *somewhat decreases* vulnerability.

Dependence on other species to generate habitat (C4a). The required habitat was not considered to be dependent on a very small number of species. Both reviewers assigned a score of *neutral* to this factor.

Dietary versatility (C4b). Experts indicated that the diet was fairly flexible, i.e. not dependent on one or a few species, although they considered the winter diet potentially more restricted due to the reliance on migratory birds that concentrate in southern Florida. We captured this dependence by including scores of *neutral* and *somewhat increases* vulnerability for the winter range and *neutral* for the breeding range.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Table A1-3. Scores assigned to factors associated with vulnerability to climate change for short-tailed hawk in the winter range in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

Measured genetic variation (C5a). Reviewers did not feel that there was enough information available to assess this factor. It was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). Reviewers did not feel that there was enough information available to assess this factor. The population in Florida is estimated at fewer than 500 individuals, but the population size has not changed in the last 100 years. It is unknown how recently the population separated from birds in the Caribbean. The definition for a population bottleneck provided by NatureServe for evaluation of this factor specifies that only species that suffered population reductions and then subsequently rebounded qualify. We scored this factor as *unknown* but also ran the model with this factor scored as *increases* vulnerability in order to evaluate the evaluate the model sensitivity to the assumption of reduced genetic variability.

Table A1-4. Scores assigned to factors associated with vulnerability to climate change for short-tailed hawk in the breeding range in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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) [1]		(•)	•			--	
Physiological hydrologic niche		•	•			--	
Disturbance regimes	--	•	•	•			
Ice and snow				•	--	--	
Physical habitat specificity	--				•		
Biotic habitat dependence				•	--	--	
Dietary versatility	--			•		--	
Biotic dispersal dependence	--			•	--	--	
Other interactions: none	--			•	--	--	
Genetic variation[2]	--					--	•
Phenological response	--					--	•

[1] The higher value is assigned to this factor when using the element occurrences to estimate the species' distribution.
[2] We also ran the model with this factor scored as increases vulnerability.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Short-tailed hawk ranked as "Not Vulnerable/ Presumed Stable" to climate change in the breeding range in Florida. When the analysis was restricted to

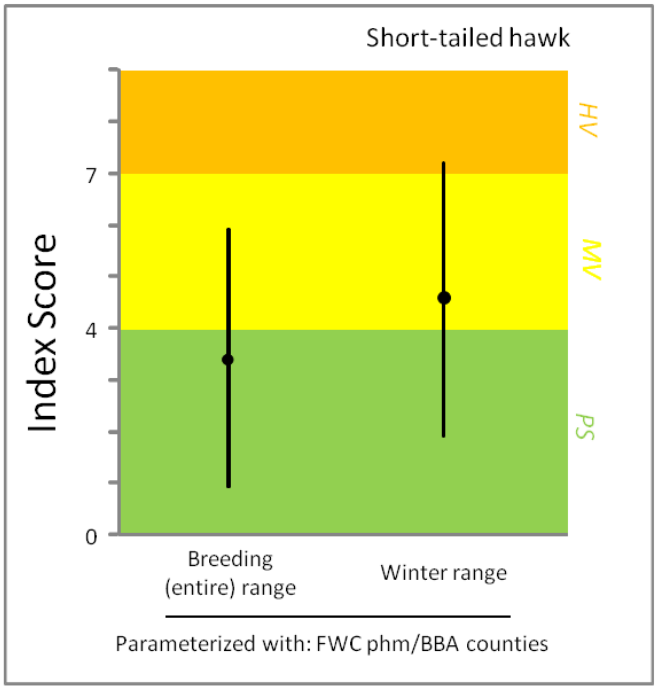

Figure A1-2. CCVI output (breeding and wintering range) for short-tailed hawk in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

the winter range, the vulnerability score increased to "Moderately Vulnerable." In the winter range, the primary factors contributing to vulnerability were sea level rise and the impact of potential changes in hydrology and disturbance regimes on migratory prey resources (Table A1-3). In the breeding range, potentially incompatible human responses to climate change posed a greater threat, but the impact of potential changes in hydrology and disturbance regimes on swamp forest were still important factors (Table A1-4). For both the breeding and winter range analyses, only two sensitivity factors were scored as unknown.

The three distribution data sets used in this analysis produced equivalent exposure metrics (Tables A1-1 and A1-2). The index score for the breeding range based on the FWC potential habitat model or BBA counties was 3.4 (range [0.9, 5.9]). Approximately 65% of the Monte Carlo simulations produced index scores in the "Presumed Stable" range, with the remaining simulations ranking as "Moderately Vulnerable." Including a score of "increases" vulnerability for factor C5b (*population bottlenecks*), increased the index rank to "Moderately Vulnerable" (index score: 4.8, range [2.4, 7.3]), with approximately 75% of simulations producing scores within this rank. Scores for the breeding range were somewhat higher when using FNAI occurrences parameterize the CCVI, with 72% of the Monte Carlo simulations producing scores in the "Moderately Vulnerable" range (index score: 4.7, range [2.3, 7.2]). The higher rank based on the FNAI occurrence data was due to the score assigned to factor C2b*i (historical hydrologic niche),* which is dependent on the distribution data, and not to differences in exposure.

Restricting the distribution to the winter range resulted in a score of 4.6 (range [1.9, 7.2], Figure A1-2) using the parameters associated with the potential habitat model or BBA counties, with approximately 68% of Monte Carlo simulations producing scores in the "Moderately Vulnerable" range and less than 1% ranking as "Highly Vulnerable." The remainder of the Monte Carlo simulations ranked as "Presumed Stable."

The species was flagged as potentially expanding range in the assessment area. This result is based on the low scores assigned to barriers combined with relatively high exposure and good dispersal while also taking the orientation of the assessment area relative to the species' range in to account.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for short-tailed hawk is G4/G5. The species is ranked S1 in Florida.

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A2. CLAPPER RAIL *(Rallus longirostris)*

Species Expert(s): Jim Rodgers

Clapper rails are found in Florida year-round but winter populations increase in number due to an influx of migrants from farther north (FWC 2003). The species' wider distribution encompasses coastal salt marshes and mangrove swamps from Massachusetts to Mexico and into South America. The diet consists mainly of insects, small crabs, and mollusks; at low tide they travel out on to mudflats to find food. Nests are placed in tall grass areas of salt marshes above the high tide line (FWC 2003).

Distribution Data

Distribution data are used to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A2-1) included a range map from NatureServe (Ridgely et al. 2003) and FNAI element occurrence data (FNAI 2011). Regarding the NatureServe range, the species expert indicated that the actual distribution for the species is more narrowly restricted along the coasts than indicated, so this data set may overestimate the actual distribution. The species expert also suggested using habitat as a proxy for the species' distribution. For this assessment, we used the mangrove and salt marsh habitat layers from the Florida Comprehensive Wildlife Conservation Strategy (2005). Alternative data sets are available that could be used to delimit the habitat types where clapper rails occur based on survey data (J. Rodgers, pers. comm..) and should be considered for future updates. FNAI occurrence data included 11 records for this species occurring along the Gulf coast and South Florida. Although we included the occurrence data for comparison with other range information, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture

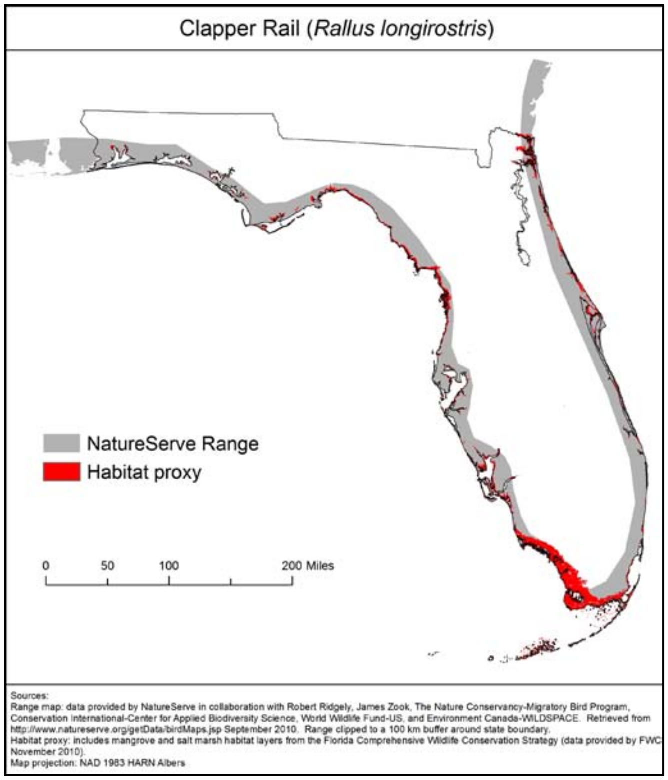

Figure A2-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To estimate exposure, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data with the distribution or occurrence data (Tables A2-2 and A2-3). For point data sets, we assigned a single value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). The species expert estimated that approximately 100% of the species' current range is expected to be impacted by a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability. The other end of the spectrum of scores for this factor applies to intertidal habitat that is expected to increase in extent with rising sea level. In follow up discussion with the species expert, we asked the species expert to consider the potential for shifts and/or increases in the distribution of mangroves. Under sea level rise, he felt that it was possible that interior progression of habitat might be able to provide similar amounts of estuarine habitat, but there was a large amount of uncertainty as to whether this would or could occur.

Potential impact of barriers on range shifts. The species expert described the species as requiring estuarine habitat for nesting and foraging and considered this habitat to be to be vulnerable to climate change (see sea level rise above). Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). The species expert took associations with habitat into account when assessing this factor, mentioning that along the east coast, the topography is rather steep and that less habitat would be created than the current mangrove/salt marsh habitat. Along the Gulf coast, however, he felt that the more gentle slope/topography would facilitate inland migration of habitat. Natural barriers were assigned a score of *increases* vulnerability, which applies to situations in which 50-90% of the current distribution is impacted by natural barriers.

Anthropogenic barriers (B2b). The species expert took associations with habitat into account when assessing this factor, mentioning that development, especially along the Atlantic coast and the Naples to Tampa region along the Gulf coast would prevent interior habitat shifts. He considered up to 90% of the range boundary could be impacted by these barriers, which corresponds to a score of *increases* vulnerability for this factor.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert identified shoreline hardening as a potential factor having a negative impact on the ability of habitat to shift under climate change. He also considered high human population densities as a barrier to habitat shifts for this factor. Since the latter impact had already been captured in factor B1b, we used the lower of the two

Table A2-1. Projected temperature exposure for clapper rail in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe range	Habitat proxy	FNAI occurrences
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	22%	5%	45%
< 3.9°F warmer	78%	95%	55%
(E_T)	*0.8*	*0.4*	*0.8*

Table A2-2. Projected moisture exposure (based on the Hamon Index) for clapper rail in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe range	Habitat proxy	FNAI occurrences
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	3%	15%	0%
-0.096 - -0.074	41%	52%	55%
-0.073 - -0.051	53%	32%	45%
-0.050 - -0.028	3%	1%	0%
> -0.028 (No change)	0%	0%	0%
(E_M)	*1.0*	*1.3*	*1.3*

scores that he selected for this factor: *somewhat increases* vulnerability.

Sensitivity

Dispersal and movement (C1). The species expert characterized the species as having moderate to good dispersal capability, corresponding to individuals regularly dispersing 100 – 1,000 meters (moderate dispersal) or 1-10 kilometers (good dispersal). The species expert indicated that little is known about dispersal or migration. Most populations in Florida are non-migratory or exhibit short-distance movements. Dispersal by clapper rails during breeding season is thought to be generally low, ranging from 200-500 meters. Fledglings will disperse further (up to 22 km) but it is not known how frequently this occurs. The species expert mentioned a current study under way in Louisiana and Mississippi that has radio-instrumented clapper rails and may provide information on movement patterns. The species expert captured the uncertainty associated with this factor by selecting multiple selections, which corresponded to scores for this factor of *neutral* and *somewhat decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area, and is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of greatly increases, increases and somewhat in*creases* vulnerability.

Physiological thermal niche (*C2a*ii*).* The species expert characterized the species as showing a preference for environments towards the warmer end of the spectrum, indicating that clapper rails tend to nest during late spring to summer along coastal habitats that tend to be the warmer portions of the state and may benefit from warmer temperatures by a longer nesting season. This factor was scored as *somewhat decreases* vulnerability. The score selection agrees with our interpretation of this category as appropriate in cases in which the current range may be limited by temperature, such that warmer temperatures might promote range expansion.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Although calculated value for variation in precipitation varied somewhat across the three distribution data sets, in all cases the factor was scored as *somewhat increases* vulnerability.

Historical precipitation exposure
NatureServe distribution: 47 - 67 inches
Habitat proxy: 47 - 67 inches
FNAI occurrences: 50 - 66 inches

*Physiological hydrologic niche (C2b*ii). The species expert considered the dependence on estuarine/coastal habitats for this factor, however there was uncertainty in whether these hydrologic requirements were likely to be significantly disrupted in a major portion of the range as a result of climate change. Written comments indicated that a major source of uncertainty was related to the impact of higher salinities on the habitat and prey. The species expert selected descriptions associated with scores of *neutral* and *somewhat decreases* vulnerability. This latter selection is supported by written comments that overall, were it not for anthropogenic threats, future conditions might benefit the habitat and/or prey and therefore potentially benefit the species.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species expert did not feel there was enough information available to select a response for this factor, however written comments indicated that an increase in the frequency of early season tropical storms could negatively impact the species by disrupting nesting, flooding nests, and/or drowning fledglings. There was no indication that the projected changes in storm intensity would have a positive effect on habitat, therefore we felt we could restrict the scores to those associated with a neutral or negative impact. We included scores of *neutral*, *somewhat increases* and *increases* vulnerability for this factor.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The species expert indicated that the species is widespread in salt marsh and mangrove habitats, but otherwise is not associated with a specific geologic feature. This factor was scored as *somewhat decreases* vulnerability, which applies to species for which the idea of specificity to a particular geologic feature or derivative is not relevant.

Dependence on other species to generate habitat (C4a). The species expert considered the required habitat to be generated by one or more of not more than a few species, corresponding to a score of *somewhat increases* vulnerability for this factor. Written comments indicated that clapper rails are dependent upon *Spartina*, *Juncus*, and mostly black mangrove.

Dietary versatility (C4b). The species expert indicated that in Florida, clapper rails are primarily dependent on fiddler crab (mangrove crab in the extreme south), taking other prey to a much lesser extent. The species expert noted that more than one categorization applies across the species' range, which also complicates scoring for this factor. The reviewer selected descriptions corresponding to both *neutral* and *somewhat increases* vulnerability.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). This species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). The species expert indicated that there was no information available on population genetics for this species. Some mtDNA information exists at the species level, suggesting close similarity to the king rail, with which it may hybridize in the northern Gulf coastal regions. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor was scored as *neutral*, corresponding to no evidence for the occurrence of a bottleneck during the past 500 years.

Phenological response (C6). The species expert was not aware of any research specifically assessing the correspondence between changes in seasonal

Table A2-3. Scores assigned to factors associated with vulnerability to climate change for clapper rail in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

dynamics and changes in the timing of phenological events. This factor was scored as *unknown*. Based on the relationship between temperature and the availability of fiddler crabs, clapper rails might be expected to respond to changes in the timing of food availability. Cooler springs reduce the availability of fiddler crabs, delaying the initiation of the nesting season. If warmer spring temperatures increase fiddler crab availability, clapper rails might be expected to start nesting earlier.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Clapper rail ranked as "Highly Vulnerable" to climate change in Florida when both the habitat proxy and NatureServe range were used to estimate the species' distribution. The major factors contributing to the vulnerability of this species included sea level rise, natural and anthropogenic barriers that may inhibit the species ability to track climatic shifts, and potentially incompatible human responses to climate change (Table A2-3). To a lesser degree, dependence on a limited number of species to generate habitat and a somewhat restricted diet also contributed to vulnerability. Only one sensitivity factor was scored as unknown.

The Monte Carlo simulations produced scores ranging from "Highly Vulnerable" to "Extremely Vulnerable" (Figure A2-2). The index score based on the parameters derived from the habitat proxy was 8.3 (range, [6.5, 12.5]), with approximately 80% of the Monte Carlo simulations producing index scores within this rank. Differences in the calculated exposure stress derived from the distribution inputs explain the higher scores produced using the other distribution data sets. The index score parameterized with the NatureServe range was 9.5 (range [6.5, 12.5]), still ranking as "Moderately Vulnerable" but with 68% of the Monte Carlo simulations in this range. The subset of points in the FNAI occurrence data tended to be sample points projected to experience somewhat higher temperatures, which accounts for the higher index scores based on the occurrence data (index score: 10.3, range [6.9, 13.7]), corresponding to a rank of "Highly Vulnerable." Results based on the habitat proxy are shown in Figure 6 in the main report.

We also examined model output with natural and anthropogenic barriers scored as neutral, which would be appropriate if assessment of this factor is limited to barriers to the focal species, independent of the barriers impacting habitat shifts (i.e., the approach suggested in the CCVI guidance). Using these parameters, clapper rail scored as "Moderately Vulnerable," with an index score of 5.5 (range [3.0, 8.0]) using habitat as a proxy for distribution. Most birds are able to fly over or around potential obstructions, however this assumption will not capture the indirect threat of barriers through impacts on the ability of habitat to shift, which most reviewers felt was an important consideration.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for clapper rail is G5. *R.l. insularis* and *R.l. scotti* are ranked S3 in Florida.

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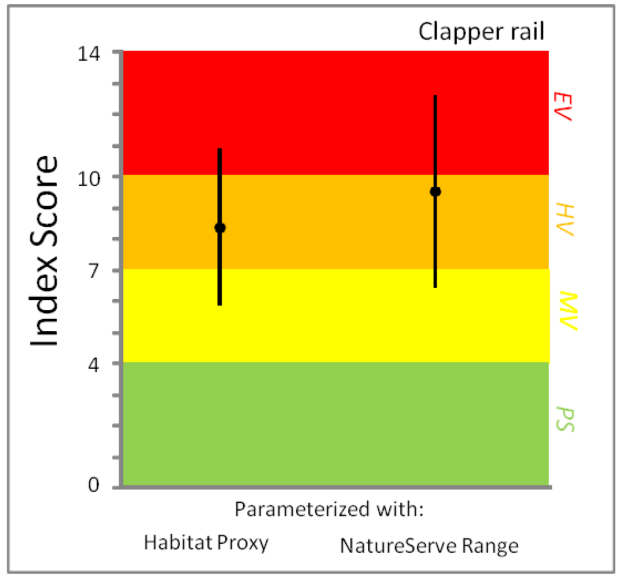

Figure A2-2. CCVI output for clapper rail in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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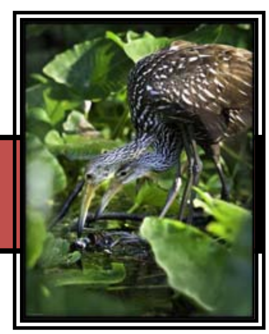

A3. LIMPKIN *(Aramus guarauna)*

Species Expert(s): Dana Bryan, Marty Folk, Jim Rodgers

Limpkins are generally found throughout freshwater wetlands in central and southern Florida, but are more broadly distributed in Central and South America (Hipes et al. 2001). Limpkin habitat includes swamps, springs, freshwater marshes, mangroves, and pond and river margins. Their nest sites include mounds of aquatic vegetation and marsh grasses as well as high in trees (Hipes et al. 2001).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A3-1) included a range map from NatureServe (Ridgely et al. 2003), a potential habitat model (phm) developed by FWC (Endries et al. 2003), and FNAI element occurrence data (FNAI 2011). Regarding the NatureServe range map, one of the species experts indicated that the distribution should extend northward to include Deer Point Lake and the lower Econfina River, Lake Talquin west of Tallahassee, and Tallahassee proper and Lake Lafayette. In addition, he indicated that the distribution should be restricted to non-coastal areas for the Panhandle and Gulf coasts (as delineated for the southeast and southwest coasts in the original distribution). We manually edited the NatureServe range to reflect these changes (designated as "NatureServe*" in the text). The species experts thought that the potential habitat model represented the minimum area of occurrence and likely underestimated the actual distribution. FNAI occurrence data included 44 records for this species. Roughly half of these records were concentrated in the wetlands surrounding Ocala National Forest. Although we included the occurrence data for comparison with other range information, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

The Florida Breeding Bird Atlas (FWC 2003) was also suggested as an alternative data set, but we did not include it in this analysis. The breeding range for limpkin is larger than, but inclusive of, the wintering range in Florida. We did not attempt to separate the breeding and wintering distributions for the assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and

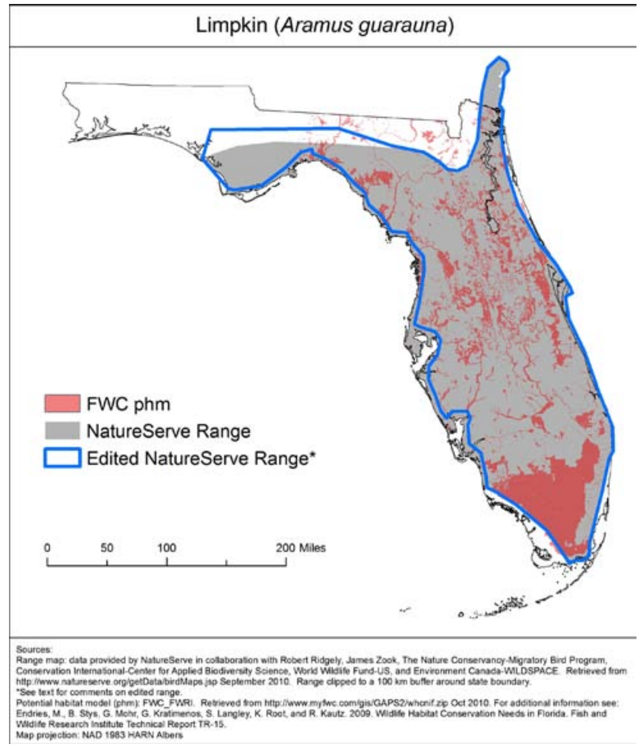

Figure A3-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A3-1 and A3-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). All reviewers indicated that less than 10% of the species' range is expected to be inundated under a 1-meter sea level rise, corresponding to a score of *neutral* for this factor.

Potential impact of barriers on range shifts. The species experts described the species' habitat as fresh water wetlands, riparian areas, and lake edges. All three reviewers considered the habitat to be vulnerable to reduction or loss under projected climate change with low confidence. Warmer and drier conditions could potentially reduce the amount of wetland habitat

Table A3-1. Projected temperature exposure for limpkin in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe range*	FWC phm	FNAI occurrences
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	11%	*4%*	5%
< 3.9°F warmer	89%	96%	95%
Weight (E_T)	*0.4*	*0.4*	*0.4*

**edited, see Figure A3-1*

Table A3-2. Projected moisture exposure (based on the Hamon Index) for limpkin in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe range*	FWC phm	FNAI occurrences
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	3%	14%	0%
-0.096 - -0.074	35%	48%	27%
-0.073 - -0.051	58%	36%	66%
-0.050 - -0.028	4%	2%	7%
> -0.028 (No change)	0%	0%	0%
Weight (E_M)	*1.0*	*1.3*	*1.0*

**edited, see Figure A3-1*

available to limpkins, but reviewers felt that the species should be able to move within larger wetlands and riparian systems to find available habitat. The species experts indicated that shifts in habitat location might result, but there was a large amount of uncertainty as to whether this would drastically reduce the amount of habitat in the long term.

Natural barriers (B2a). Significant natural barriers that would inhibit the ability of the species to track climatic shifts were not identified. This factor was scored as *neutral*. However, some species experts identified the apple-snail distribution as a natural barrier since it is a limiting factor to limpkin range. We captured this dependency in factor C4b.

Anthropogenic barriers (B2b). This factor was scored as *neutral* based on expert opinion that anthropogenic barriers were unlikely to significantly limit distributional shifts for this species. One species expert suggested that disturbance may prevent the species from foraging and nesting in some areas with increased human activity. However, a second reviewer indicated that limpkins live on lake margins in residential developments, suggesting that at least some types of development may not present a significant anthropogenic barrier to this species.

Land Use Changes Resulting from Human Responses to Climate Change (B3). Reviewers selected a range of responses for this factor. Some of the issues considered included potential habitat loss as humans moved inland from coastal areas in response to sea level rise and/or increased conflicts with human water use under drier conditions. One reviewer noted that limpkins have acclimated to impoundments by using these sites for nesting and foraging, even using water retention areas in the suburbs. Scores for this factor included increases vulnerability, neutral, and neutral/somewhat decreases vulnerability. The species expert selecting increases vulnerability did so on the assumption that there would be significant habitat loss due to increased demand for interior development, but indicated that there was moderate uncertainty associated with this assumption. In order to capture this uncertainty, we decided to include the range of scores bracketed by the reviewers' selections: *increases* vulnerability, *somewhat increases* vulnerability, *neutral*, and *somewhat decreases* vulnerability.

Sensitivity

Dispersal and movement (C1). Two species experts characterized the species as having excellent dispersal or movement capability, corresponding to individuals readily moving more than 10 km from natal or source areas. One of the species experts indicated that limpkins are known to disperse widely during flood and drought, and that individuals in the north probably migrate up to 400 miles to the wintering grounds. One species expert did not feel that there was sufficient evidence to assess this factor, but indicated that the species probably expands its range in Florida in response to periods of high rainfall, which increase the extent of wetlands, and then contracts its range during droughts. This suggests that dispersal is not a limiting factor on the species ability to track shifts in habitat. This factor was scored as *decreases* vulnerability.

*Historical thermal niche (C2a*i*)*. This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases*, and *somewhat increases* vulnerability.

*Physiological thermal niche (C2a*ii*)*. Two species experts characterized the species as having no association with a particular thermal environment ("neutral"), while the third expert characterized the species as being associated with a warm environment ("somewhat decreases" vulnerability). We have interpreted this latter category to be appropriate in cases in which the current range may be limited by low temperatures in the northern part of the assessment area, such that warmer temperatures might promote range expansion. One of the species experts suggested that the apple-snail may be limited by cooler temperatures in northern Florida, where its occurrence is associated with spring runs. If warmer temperatures allow apple-snail to spread northward, this could result in the spread of limpkins into new habitats. We included the range of scores associated with these responses from *neutral* to *somewhat decreases* vulnerability.

*Historical hydrologic niche (C2b*i*)*. This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Although the calculated values for variation in precipitation varied slightly across the three distribution data sets, in all cases the factor was scored as *somewhat increases* vulnerability.

Historical precipitation exposure
NatureServe distribution: 46 - 65 inches
Habitat proxy: 46 - 60 inches
FNAI occurrences: 47 - 60 inches

*Physiological hydrologic niche (C2b*ii). All species experts considered the species to be dependent on a wetland habitat that was vulnerable to climate change. The wording of the category descriptions may have contributed to the differences in scores across the experts. The descriptions asked the reviewers to characterize the species as "somewhat," "moderately" or "highly dependent" on a specific wetland habitat that is highly vulnerable to loss or reduction to climate change. While all reviewers agreed that the species is dependent on a wetland habitat that might be impacted by climate change, some indicated uncertainty as to whether the habitat should be characterized as "highly vulnerable". In their comments, reviewers explained that limpkins rely on apple-snails for most of their diet, which require a specific hydrologic regime that may be negatively impacted by wider fluctuations in marsh levels and/or drier conditions associated with climate change. We included the range of scores associated with the reviewers' selections as a means of capturing this uncertainty. This factor was scored as *greatly increases*, *increases* and *somewhat increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). One reviewer indicated that there was insufficient information for assessment of this factor. Other comments confirmed a degree of uncertainty in how specific disturbance regimes might change and potential impacts on the limpkin. One of the reviewers explained that apple-snails and limpkins are affected by occasional natural flooding which can temporarily suspend snail availability, destroy snail eggs, or destroy limpkin nests. He did not consider that population-level changes were likely, due to the sporadic nature of such natural events, but indicated that more frequent, severe, or prolonged flooding could potentially impact the limpkin. This species expert scored this factor as "neutral." The third species expert suggested that increased floods under climate change could provide a benefit through flooding of previously dry areas and recolonization of those sites with aquatic prey. Based on these responses, it appears that both the extent and duration of flooding would be important factors to consider. Fire was also mentioned as having potentially positive or negative effects on limpkins. The immediate impact of fire during droughts can severely affect the use of the Everglades and the littoral zone of larger lakes. However, fire can also remove thick emergent vegetation that may prevent limpkins from accessing aquatic prey as well as removing accumulated organic material that might allow snails and mussels from estivating through droughts. We included the range of scores associated with the reviewers' responses for this factor: *neutral* and *somewhat increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Two reviewers selected the description associated with "decreases" vulnerability for this factor, which characterizes the species as highly generalized relative to dependence on geologic features or derivatives. However, this selection appears to be intended to capture a broader range of substrates that those used by limpkin (i.e., "substrates that represent opposite ends of the spectrum"). Most reviewers indicated that specificity to a particular soil or substrate was not particularly relevant for this species, which more closely corresponds to the description associated with "somewhat decreases" vulnerability, which was selected by the third reviewer. In order to maintain consistency in scoring across species, we have adjusted the score for this factor to *somewhat decreases* vulnerability.

Dependence on other species to generate habitat (C4a). One reviewer appeared to consider the association with prey in this factor, which is captured in factor C4b, so we have not included it here. The other reviewers indicated that the required habitat was not considered to involve species-specific processes. This factor was scored as *neutral.*

Dietary versatility (C4b). Historically, limpkins have relied on *Pomacea paludosa*, the native Florida apple-snail. However, limpkins will also consume exotic apple-snails, which have become established locally in Florida during the last decade. Species experts selected the category describing diet as "completely or almost completely dependent on one species during any part of the year" and/or "completely or almost completely dependent on a few species from a single guild for any part of the year" for this factor, corresponding to scores of *increases* and *somewhat increases* vulnerability.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral.*

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulner-

Table A3-3. Scores assigned to factors associated with vulnerability to climate change for limpkin in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

ability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). None of the reviewers felt that there was sufficient evidence to evaluate this factor. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor was scored as *neutral*, corresponding to no evidence for the occurrence of a bottleneck during the past 500 years. One reviewer commented that historic records indicate that limpkins were hunted out of many locations, but that the observed scarcities may have been limited to areas with easy access to humans.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*. However, one reviewer referred to differences in the timing of breeding within the range in Florida, indicating that southern populations breed about one month earlier than northern populations, likely due to differences in timing of prey availability associated with earlier onset of warmer spring temperatures. This plasticity suggests that the species may be able to shift the timing of some phenological activities in response to changes in temperature or precipitation dynamics.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Limpkin ranked as "Not Vulnerable/Presumed Stable" or "Moderately Vulnerable" to climate change in Florida depending on the distribution data used to parameterize the model. The major factors contributing to the vulnerability of this species included dependence on a particular hydrologic regime (and associated impacts through prey), a narrow diet breadth, and potentially incompatible human responses to climate change (Table A3-3). Two sensitivity factors were scored as unknown. One other factor (*human responses to climate change*) was assigned four scores, indicating high uncertainty in this factor as well.

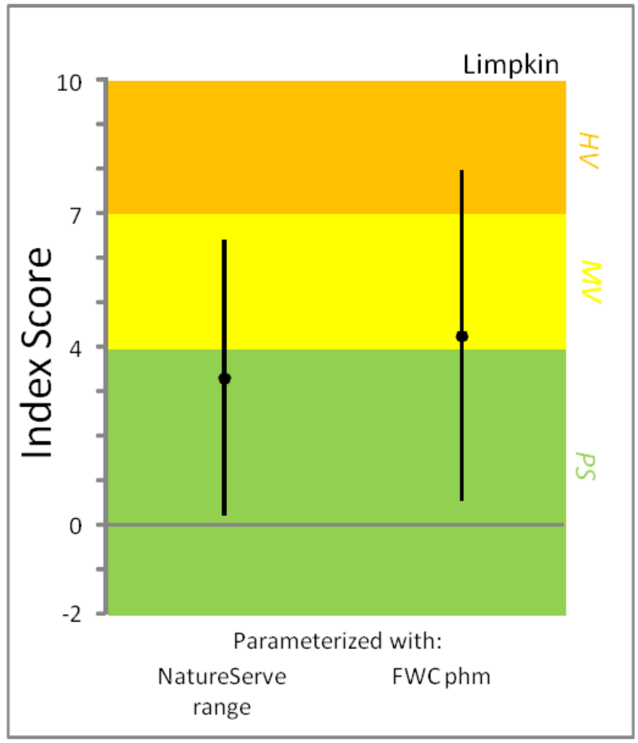

Figure A3-2. CCVI output for limpkin in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

The NatureServe range and FNAI element occurrences generated identical exposure metrics (Tables A3-1 and A3-2), producing identical outputs (index score: 3.3, range [0.2, 6.4], Figure A3-2). The index score based on the potential habitat model was slightly higher (index score: 4.2, range [0.5, 7.9], Figure A3-2). This result was due to exposure to drier conditions under the potential habitat model, magnifying the effect of the sensitivity to hydrologic regime captured in factor C2b*ii*. In all cases, the index score fell close to the cut-off between "Presumed Stable" and "Moderately Vulnerable," resulting in low to moderate confidence in resolving between these scores. The vulnerability of this species is highly dependent on the persistence of apple-snail populations. Results based on the edited NatureServe range are shown in Figure 6 in the main report.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for limpkin is G5. The species is ranked S3 in Florida.

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A4. LEAST TERN *(Sternula antillarum)*

Species Expert(s): Janell Brush, Nancy Douglass, Beth Forys

Least terns nest throughout most of coastal Florida in beaches, lagoons, bays, and estuaries (Hipes et al. 2001) and occur throughout the Western Hemisphere. Least terns generally nest in areas of dry sand or gravel with little vegetation. Their use of artificial nesting sites like rooftops, however, has led to increased use of inland locations, especially in Florida. Least terns are migratory and are absent from Florida between the months of November to February (Hipes et al. 2001). The species is listed as threatened

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A4-1) included a range map from NatureServe (Ridgely et al. 2003), FWC's shorebird database (FWC 2010) and FNAI element occurrence data (FNAI 2011).

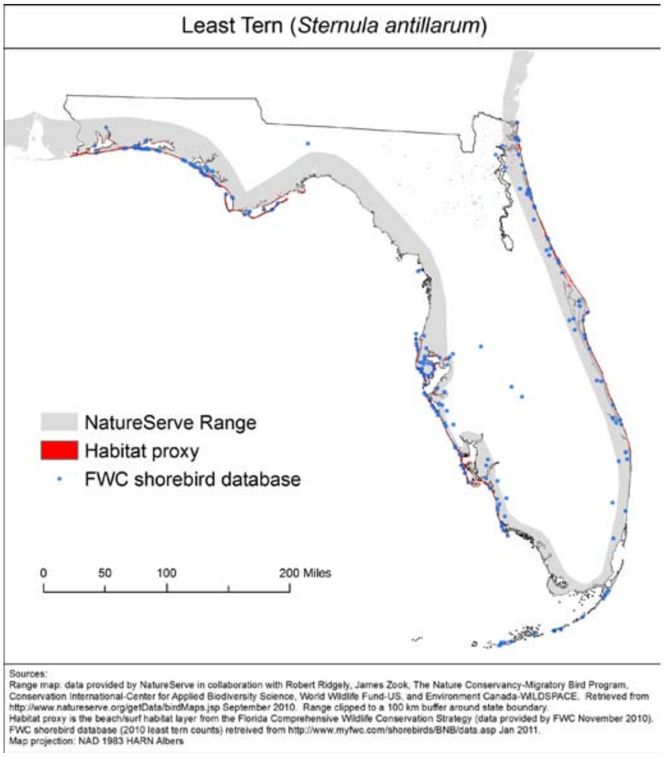

Figure A4-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Reviewers felt that the NatureServe range overestimated naturally occurring habitat, which is more narrowly restricted along the coast than is indicated by the NatureServe range. The species also uses gravel rooftops for nesting. Based on this input, we decided not to include the NatureServe range in our analysis. Instead, we used the beach/surf zone habitat layer from the Florida Comprehensive Wildlife Conservation Strategy (2005) as a proxy for the species' distribution, recognizing that it omits interior nesting on rooftops. We also ran the analysis using nesting occurrences from the FWC shorebird database (720 records) and FNAI occurrence data (179 records). Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A4-1 and A4-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). Experts indicated that between 15-100% of the species' range is expected to be impacted by a 1-meter sea level rise. The range in responses was primarily due to uncertainty regarding the percentage of the population occupying gravel-covered rooftops. Results from the 1998-2000 shorebird survey conducted by FWC indicate that approximately 85% of least terns are nesting on rooftops. However, the species experts indicated that it is likely that most of these rooftops will be converted to non-gravel rooftops within the next 10 years due to changes in construction codes and other factors. They suggested that the loss of gravel rooftops will result in a majority of the population returning to beaches. Based on this assumption, as well as the observation that all natural habitat occurs in areas expected to be subject to sea level rise, this factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. Experts described the species' nesting habitat as open, unvegetated substrates adjacent to water, including beaches and islands, as well a manmade habitats such as rooftops, dredge spoils, and phosphate mines. All three reviewers scored this habitat as vulnerable to reduction or loss under projected climate change. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Table A4-1. Projected temperature exposure for least tern in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	FWC Shorebird Database	Habitat proxy	FNAI occurrences
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	18%	40%	18%
< 3.9°F warmer	82%	60%	82%
(E_T)	*0.4*	*0.8*	*0.4*

Table A4-2. Projected moisture exposure (based on the Hamon Index) for least tern in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	FWC Shorebird Database	Habitat proxy	FNAI occurrences
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	0%	0%	0%
-0.096 - -0.074	35%	43%	52%
-0.073 - -0.051	65%	57%	48%
-0.050 - -0.028	0%	0%	0%
> -0.028 (No change)	0%	0%	0%
(E_M)	*1.0*	*1.0*	*1.3*

Natural barriers (B1a). Significant natural barriers that would inhibit the ability of the species to track climatic shifts were not identified. This factor was scored as *neutral.*

Anthropogenic barriers (B1b). One species expert scored this factor as *neutral*, based on NatureServe guidance that barriers do not exist for most birds (as they can fly around them). However, two experts took associations with habitat into account, mentioning coastal development and shoreline hardening as barriers to habitat migration, and scored this factor as *increases* vulnerability. Ballpark estimates for the percentage of the range boundary that is impacted by these barriers ranged from 70-75%, with low to moderate confidence in these estimates. The range of values estimated by the species experts fell well within the range associated with the assigned score (50-90%), so we did not feel it necessary to adjust the scores to capture additional uncertainty associated with this factor.

Land Use Changes Resulting from Human Responses to Climate Change (B3). All three species experts identified shoreline hardening as a potential factor that was likely or very likely to occur and would have a negative impact on the focal species. Beach nourishment was also mentioned as potentially having a negative impact where post-nourishment protection measures have not been put into place. This factor was assigned the highest score available, corresponding to *increases* vulnerability.

Sensitivity

Dispersal and movement (C1). All species experts characterized the species as having excellent dispersal or movement capability, corresponding to individuals readily moving more than 10 km from natal or source areas. This factor was scored as *decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. The CCVI guidance suggests using the proxy for both resident and migratory species because migratory species are affected by these variations through effects of food supply and habitat availability even if they are not physically present to experience these temperature variations. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases* and *somewhat increases* vulnerability.

Physiological thermal niche (C2aii). Two species experts initially characterized the species as showing a preference for environments towards the warmer end of the spectrum and scored this factor as "somewhat decreases" vulnerability. One expert selected insufficient evidence, noting that when birds are disturbed and fly off the nest, eggs are sometimes killed by heat, suggesting that eggs may be much more dependent on a cooler microhabitat (i.e., shade) and would be more at risk under climate change. In follow up, the other reviewers agreed that eggs might be near their upper thermal limit and would be adversely affected by further increases in temperatures. We captured this uncertainty by including non-continuous scores of *somewhat decreases* vulnerability and *somewhat increases* vulnerability for this factor.

Historical hydrologic niche (C2bi). This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was identical for all three distribution inputs, ranging from 49-67 inches, which corresponds to a score of *somewhat increases* vulnerability.

Physiological hydrologic niche (C2bii). Two species experts characterized the species as having broad moisture regime tolerances or benefitting from projected changes in hydrologic regime. However, their responses were based on potential decreases in nest flooding associated with extreme precipitation events. While increased temperatures are expected to result in drier conditions throughout much of the Southeast even under moderate increases in precipitation, most models suggest the intensity of storms will increase. This relationship is more appropriately captured in factor C2c (disturbance regime) so we did not include it here. The remaining species expert indicated insufficient evidence to score this factor, noting that sources of freshwater prey could be affected by changes in hydrology, having a negative impact on least terns under drier/drought conditions. In follow up discussions with the species experts, they agreed that changes to hydrology potentially impacting food supply could be a concern, particularly for resources needed for chicks. Changes in rainfall affecting salinity in estuaries were also mentioned as a potential factor influencing food supply. Based on this input, we adjusted reviewers' scores to capture some of the uncertainty associated with these impacts by selecting scores for both *neutral* and *somewhat increases* vulnerability for this factor

Impacts of Changes to Specific Disturbance Regimes (C2c). Species experts considered increased intensity of hurricanes as the major disturbance regime likely to affect least tern under climate change. However, there was a large amount of uncertainty associated with the net impact of increased storm intensity on the species. The experts noted that increased storms would likely create some new nesting habitat for the species, however changes in the timing or intensity of storms during spring/summer could increase egg mortality resulting from storm overwash. In addition, increased turbidity resulting from more intense storm activity was considered as having a potentially negative impact on foraging success. We included the range of responses selected by the reviewers in scoring this factor: *increases*, *somewhat increases*, and *decreases* vulnerability

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The wording of the descriptions associated with the scores for this factor lead all three species experts to select the description associated with a score of "neutral" for this factor. However, based on follow up discussions regarding the specificity to sandy beaches for nesting, which was considered a fairly common but not dominant substrate on the landscape, the score for this factor was elevated to *somewhat increases* vulnerability.

Dependence on other species to generate habitat (C4a). Required habitat was not considered to involve species-specific processes. This factor was scored as *neutral.*

Dietary versatility (C4b). Two species experts classified the diet as "flexible," whereas one species expert classified diet as dependent on a few species during any part of the year. Follow up discussion revealed that there is some evidence suggesting that the diet of young birds may be more specialized than that of adults, however there was a fair amount of uncertainty associated with the degree of specialization for young chicks. This topic remains an area for future research. We included the range of responses selected by the reviewers in scoring this factor: *somewhat increases* vulnerability and *neutral*.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Two reviewers felt that they did not have sufficient expertise in this area and deferred to the third reviewer who classified the reported genetic variation in this species as low compared to related taxa, corresponding to a score of *somewhat increases* vulnerability.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. However one reviewer referred to evidence that the related sooty tern has experienced extreme shifts in breeding phenology in the Keys, but the reason for the shift is unknown. Another species expert indicated that least terns tend to nest earlier in warmer years, but that this relationship has not been formally evaluated. This factor was scored as *unknown*.

Table A4-3. Scores assigned to factors associated with vulnerability to climate change for least tern in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicted by dashes.

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	--					--	•

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Least tern ranked as "Highly Vulnerable" to "Extremely Vulnerable" to climate change in its nesting habitat in Florida, depending on which distribution data set was used to parameterize the model. Of the distribution data sets used in this assessment, reviewers had greatest confidence in the FWC shorebird database, so we report the results based on parameters derived from the shorebird database in Figure 6 of the report[2]. The major factors contributing to the vulnerability of this species included sea level rise, anthropogenic barriers that may inhibit the species ability to track climatic shifts, and potentially incompatible human responses to climate change (Table A4-3). Other potential risk factors that were associated with greater uncertainty included temperature effects on egg and chick survival and adverse impacts from more intense hurricanes. To a lesser degree, potential hydrologic

[2] Even though the FWC shorebird data are represented as points rather than extent of occurrence, we felt that the sample size was sufficient (N = 720) to capture changes in exposure projected across the species' range in Florida.

effects on prey availability and relatively low genetic variation also contributed to vulnerability. Only one sensitivity factor was scored as unknown, however the scoring for the factor C2c (*disturbance regimes*) indicates a high degree of uncertainty regarding the impacts of potential changes in hurricane activity on least tern nesting habitat.

Although the index rank varied depending on the distribution data set used, fewer than two percent of Monte Carlo simulations produced any scores ranking as "Moderately Vulnerable" or lower. Using beach habitat as a proxy for the distribution produced the highest scores (index score: 10.28, range [8.27, 14.27], Figure A4-2). The beach/surf habitat layer used as the habitat proxy captured some scattered interior areas north of Gainesville, which fall outside the species' range.

Compared to the other data sets, the areas captured by the habitat proxy were projected to have greater exposure to higher temperatures, whereas FNAI occurrences were biased towards areas projected to be somewhat drier (Tables A4-1 and A4-2). The Monte Carlo simulation based on FWC shorebird data generated an index score of 8.2 (range [6.8, 10.8], Figure A4-2), with 92% of iterations producing scores of "Highly Vulnerable." The index score based on FNAI occurrences (9.2, range [7.6, 12.2]) fell close to the cut-off between "Highly Vulnerable" and "Extremely Vulnerable," resulting in low confidence in resolving between these scores.

The scores assigned to factor C2c (*disturbance regimes*) were non-continuous, reflecting uncertainty in how changes in the timing and/or intensity of hurricanes will influence vulnerability. However, the CCVI score was not highly sensitive to the scoring for this factor. Restricting scores for this factor to "increases" or "somewhat increases" vulnerability raised the index score slightly, but had little effect on the overall rank ("Highly Vulnerable," index score: 8.9, range [7.4, 10.8], parameterized with FWC shorebird distribution).

We also examined the CCVI output with natural and anthropogenic barriers scored as neutral, which would be appropriate if assessment of this factor is limited to barriers to the focal species, independent of the barriers impacting habitat shifts. Under these conditions, least tern scored as "Highly Vulnerable" or higher in 70% or more of the Monte Carlo simulations, regardless of the distribution estimate used. Index scores were 7.0 (range [5.6, 9.6]) based on parameters derived from the FWC shorebird data, 8.6 (range [6.5, 12.5]) based on parameters derived from the habitat proxy, and 7.8 (range [6.2, 10.8]) based on parameters derived from the FNAI occurrence data.

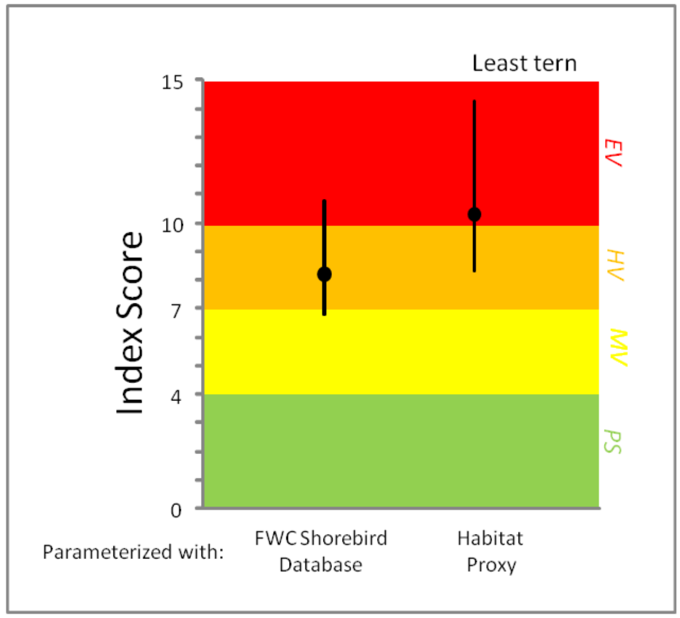

Figure A4-2. CCVI output for least tern based on three different data sets for distribution. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for least tern is G4. The species is ranked S3 in Florida.

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A5. MANGROVE CUCKOO *(Coccyzus minor)*

Species Expert(s): Terry Doyle, John Lloyd, Karl Miller

Mangrove cuckoos are commonly found in mangrove forests throughout many parts of Florida (Hipes et al. 2001). They also inhabit tropical hammocks in the Florida Keys and nearby mainland areas. Habitat requirements are poorly known, but larger forest tracts seem to be preferred. Mangrove cuckoos avoid heavily developed areas. The winter range appears to overlap somewhat with the breeding range, but records are patchily distributed. The range-wide distribution includes the Gulf coast from northern Mexico south to Nicaragua and from central Florida to the Antilles (Hipes et al. 2001).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A5-1) included a range map from NatureServe (Ridgely et al. 2003), a potential habitat model (phm) developed by FWC (Endries et al. 2009) and FNAI element occurrence data (FNAI 2011). The species experts felt that the NatureServe range grossly overestimated the species' distribution. Based on this input, we decided not to use this data set in our analysis. The FWC potential habitat model was considered adequate by the reviewers, although it appeared to exclude some potential coastal upland habitats along the southwest Florida coast. Based on comments from the species experts we also used the mangrove layer and hardwood hammock habitat layer from the Florida Comprehensive Wildlife Conservation Strategy (2005) as a proxy for the species' distribution in counties with known occurrences. FNAI occurrence data included 17 records for this species, the majority of which occur in the Keys. For comparison, we also ran the analysis at a very coarse scale, using counties with known occurrences to estimate distribution (Hipes et al. 2001). Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment. The Florida Breeding Bird Atlas (FWC 2003) was suggested as an alternative data set, but we did not include it in this analysis.

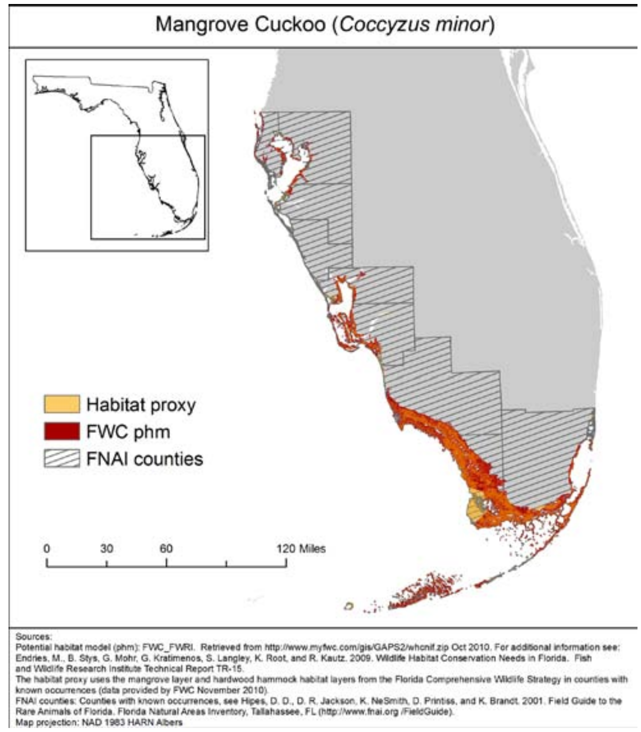

Figure A5-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric was downloaded from NatureServe, and is derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data.

For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). Experts indicated that between 90-100% of the species' current range is expected to be inundated under a 1-meter sea level rise. In follow up discussion, experts agreed that there would likely be both loss and gain of habitat depending on the response of mangroves to sea level rise. This factor was scored as *greatly increases* vulnerability. However, one of the species experts referenced a modeling study suggesting that the extent of mangroves will increase as a consequence of sea level rise and subsequent invasion of freshwater marsh. We considered this alternative scenario in a separate model run in which this factor was scored as *somewhat decreases* vulnerability.

Potential impact of barriers on range shifts. Experts indicated that the species' habitat consists of mangrove forest throughout Florida and tropical

Table A5-1. Projected temperature exposure for mangrove cuckoo in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm	Habitat proxy	FNAI occurrences	FNAI counties
> 5.5°F warmer	0%	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%	0%
3.9 - 4.4 °F	0%	0%	0%	0%
< 3.9°F warmer	100%	100%	100%	100%
(E_T)	*0.4*	*0.4*	*0.4*	*0.4*

Table A5-2. Projected moisture exposure (based on the Hamon Index) for mangrove cuckoo in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm	Habitat proxy	FNAI occurrences	FNAI counties
< -0.119 (Driest)	0%	0%	0%	0%
-0.119 - -0.097	20%	20%	6%	17%
-0.096 - -0.074	74%	74%	94%	50%
-0.073 - -0.051	6%	6%	0%	33%
-0.050 - -0.028	0%	0%	0%	0%
> -0.028 (No change)	0%	0%	0%	0%
(E_M)	*1.3*	*1.3*	*1.3*	*1.3*

hardwood hammock in the Keys. Due to the strong association with a restricted habitat, we took habitat into account when scoring this factor, because this is a limiting factor affecting whether the species' distribution can shift. Whether the habitat is considered vulnerable under climate change affects the scoring of the factors B2a and B2b. Therefore we have scored these factors under two different scenarios: Scenario A (mangroves vulnerable, decreasing in extent under climate change) and Scenario B (mangroves expanding under climate change).

Natural barriers (B2a). Two reviewers scored this factor as "neutral," based on NatureServe guidance that barriers do not exist for most birds (as they can fly around them). However, little is known about the migration patterns of mangrove cuckoo. Mangrove cuckoos in southern Florida may be non-migratory and more sedentary than most bird species. One expert took associations with habitat into account and scored this factor as "somewhat increases" vulnerability but with lower confidence in evaluating how readily the mangrove ecosystem will migrate inland, suggesting that upland landforms could present natural barriers to mangroves. Under Scenario A, we scored this factor relative to the impact on habitat and captured some of the uncertainty by including scores of both *neutral* and *somewhat increases* vulnerability. Under Scenario B, this factor was scored as *neutral* because the habitat is not considered vulnerable to climate change.

Anthropogenic barriers (B2b). Two reviewers considered the impact of anthropogenic barriers (primarily urban development in the Tampa Bay area and along the Atlantic Coast) on the potential for habitat shifts and considered that 10-25% of the range boundary would be impacted by these barriers, corresponding to a score of "somewhat increases" vulnerability. One of these reviewers also included a score of "neutral" to capture uncertainty in the magnitude of the impact of anthropogenic barriers on distributional shifts. The third reviewer scored this factor as "neutral" based on NatureServe guidance that barriers do not exist for most birds. The experts agreed that the factor should be scored as "neutral" if based only on the impact of these barriers to the focal species and not through associated habitat. Our decision in scoring this factor was to capture the indirect threat of barriers through impacts on the ability of habitat to shift. We used the reviewers' scores of *somewhat increases* vulnerability for Scenario A and scored this factor as *neutral* under Scenario B.

Land Use Changes Resulting from Human Responses to Climate Change (B3). All three species experts mentioned shoreline hardening and seawalls as a potential factor having a negative impact on the ability of habitat to shift under climate change, but with a large amount of uncertainty surrounding the extent to which future shoreline protection would impact the species. Two reviewers scored this factor as "somewhat increases" vulnerability, to capture the threat of mitigation/adaptation-related land use changes that may occur. One reviewer also included a score of "neutral," characterizing the species as being unlikely to be affected by mitigation/adaption-related land use changes that may occur. We included both scores (*somewhat increases* vulnerability and *neutral*) under scenarios A and B.

Sensitivity

Dispersal and movement (C1). The species experts characterized the species as having good to excellent dispersal, corresponding to individuals readily moving 1-10 km (good dispersal) or more than 10 km (excellent dispersal). Species experts assumed that birds are capable of traversing the matrix but noted that little is known about the species dispersal capability, including whether the species is migratory or non-migratory. In follow up discussion, experts noted that the species is found on a number of islands, so it can be assumed that the species is capable of fairly long distance dispersal. This factor was scored as *somewhat decreases* and *decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *increases* and *somewhat increases* vulnerability.

Physiological thermal niche (C2aii). Two species experts characterized the species as showing a preference for environments towards the warmer end of the spectrum, noting the association with mangroves which are limited to subtropical areas that do not freeze. These reviewers scored this factor as "somewhat decreases" vulnerability. The third expert selected insufficient evidence, but indicated that the thermal environment was not likely to be reduced by climate change, allowing us to exclude scores associated with preferences for cool/cold environments that may be reduced under climate change. We included scores of *neutral* and *somewhat decreases* vulnerability to capture the range of reviewer responses. The scores assigned this factor reflect the species association with mangrove forest. It is unknown whether mangrove cuckoo is directly limited by a narrow thermal tolerance.

Historical hydrologic niche (C2bi). This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Although the calculated values for variation in precipitation varied only slightly across the three distribution data sets, these minor differences range corresponded to different scores: *somewhat increases* vulnerability for the FWC phm, habitat proxy, and FNAI counties and *increases* vulnerability for the FNAI occurrence data.

Historical precipitation exposure
FWC phm/Habitat proxy: 49 - 60 inches
FNAI counties: 48 - 60 inches
FNAI occurrences: 50 - 60 inches

Physiological hydrologic niche (C2bii). The species experts considered the dependence on mangrove forests for this factor, however there was uncertainty in whether these hydrologic requirements were likely to be significantly disrupted in a major portion of the species' range. Written comments indicated that a major source of uncertainty was related to changes in freshwater flows that could result from drier conditions and inland water management. We tried not to duplicate vulnerability directly associated with sea level rise in this factor. Two reviewers scored this factor as neutral and one reviewer selected the description associated with "somewhat decreases" vulnerability, which states that the species has "very broad moisture tolerances" or would benefit from the projected change in hydrologic regime. Under scenario A, we assigned scores of *somewhat increases* vulnerability and *neutral* to this factor, in order to capture uncertainty in whether changes in hydrologic regime would have a negative impact on mangroves.

Under scenario B, where mangroves are assumed to increase in extent, we assigned scores of *neutral* and *somewhat decreases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). Species experts considered increased intensity of hurricanes as the major disturbance regime that might have negative impact on the amount of quality of breeding habitat. However, there was a large amount of uncertainty associated with the degree to which the disturbance regime would change and/or the impact on the species. One reviewer did not make a selection, another selected the description corresponding to "somewhat increases" vulnerability and the third included "neutral," "somewhat increases" and "increases" vulnerability. From their comments, there was no indication that reviewers thought that the projected changes in storm intensity would have a positive effect on habitat. As a result, we felt we could restrict the scores to those associated with a neutral or negative impact. We included scores of *neutral*, *somewhat increases,* and *increases* vulnerability for this factor.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Two reviewers felt there was not enough information to assess this factor. One of these reviewers mentioned salinity requirements for mangroves, which were captured in factor C2bii and so have not been included here. The third reviewer selected the description associated with "decreases" vulnerability. Based on NatureServe guidance regarding the appropriate selection for species for which the idea of specificity to a particular geologic feature or derivative is not relevant, we have adjusted the score for this factor to *somewhat decreases* vulnerability.

Dependence on other species to generate habitat (C4a). Most reviewers considered some level of dependence on the few species that make up mangrove forest in Florida. There was some divergence in whether this dependence would suggest a score of *neutral* (required habitat is generated by "more than a few" species) or *somewhat increases* vulnerability (required habitat is generated by "not more than a few" species). We included both scores for this factor.

Dietary versatility (C4b). Reviewers conveyed that there was little information available regarding diet. The Birds of North America species account was provided as a reference indicating that a range of insects and arthropods are consumed. Based on this information, this factor was given a score of *neutral.*

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral.*

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulner-

Table A5-3. Scores assigned to factors associated with vulnerability to climate change for mangrove cuckoo in Florida. Scores shown are for Scenario A[1], which assumes that mangroves will be negatively impacted by climate change. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

[1] See text for scores assigned under scenario B.

ability were not identified. This factor was scored as *neutral.*

Measured genetic variation (C5a). Reviewers did not feel that there was enough information available to assess this factor. This factor was scored as *unknown.*

Occurrence of bottlenecks in recent evolutionary history (C5b). Reviewers did not feel that there was enough information available to assess this factor. The population in Florida appears to be small but it is unknown how genetically isolated the population is. This factor was scored as *unknown.*

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown.*

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Under scenario A (which assumes that mangroves will be negatively affected by climate change), mangrove cuckoo ranked as "Moderately Vulnerable" to climate change in Florida using on the exposure parameters associated with the FWC potential habitat model, habitat proxy, or county occurrences. The species' rank dropped to "Not Vulnerable/Presumed Stable" under scenario B, in which climate change was assumed to have neutral or somewhat positive effects on the availability of mangrove habitat.

For scenario A, many of the factors contributing to vulnerability were associated with indirect exposure in the form of sea level rise and barriers (Table A5-3). These factors were scored as having neutral or somewhat positive effects on mangroves under scenario B. For both scenarios, dependence on only a few species to generate habitat, altered disturbance regime (i.e., more intense hurricanes) and potentially incompatible human responses to climate change were identified as factors contributing to vulnerability

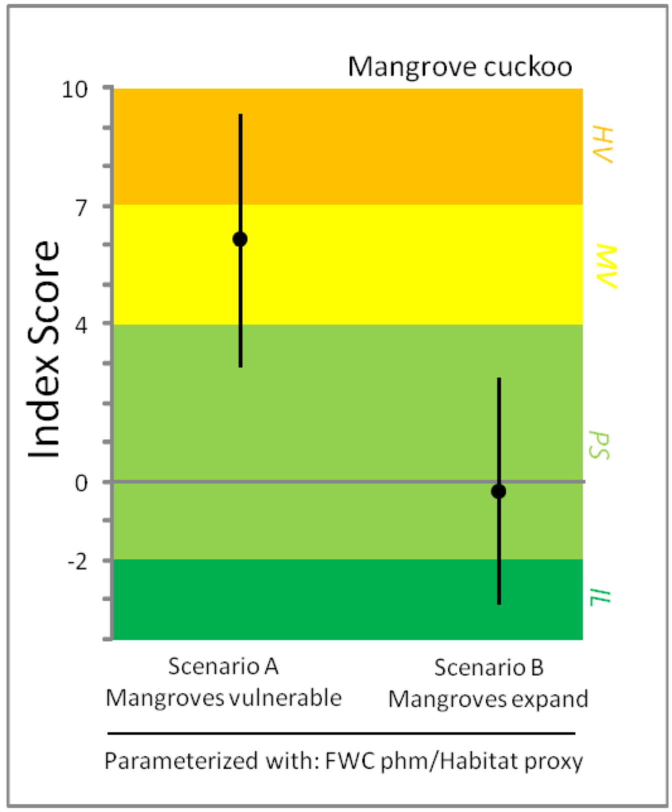

Figure A5-2. CCVI output for mangrove cuckoo in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green), "Increase Likely" (dark green).

for this species. Only two sensitivity factors were scored as unknown.

Under scenario A, the index score was 6.1 (range [2.9, 9.3], Figure A5-2) for models parameterized with the FWC potential habitat model, habitat proxy, or county occurrences. The index flagged this species as potentially expanding its range, although this would of course depend on the availability of mangrove habitat under climate change. When mangroves were assumed likely to increase in extent (scenario B), the index score dropped into the "Presumed Stable" rank (index score: -0.3, range [-3.1, 2.5]; Figure A5-2). Results based on scenario A are shown in Figure 6 in the main report.

All four of the data sets included in Tables A5-1 and A5-2 generated identical exposure metrics, and therefore are equivalent in terms of exposure. This is perhaps not surprising given that the fairly coarse resolution of the exposure data (approximately 15 km) and the relatively narrow distribution of this species habitat along the coast. However, the FNAI element occurrence data generated a narrower range of historical precipitation exposure (factor C2bii), resulting in a higher score for this factor. This single difference in the input parameters increased the index rank to "Highly Vulnerable" (index score: 7.4, range [4.2, 10.6]) under scenario A.

We also examined model output with natural and anthropogenic barriers scored as neutral (keeping the other scores the same as scenario A), which would be appropriate if assessment of this factor is limited to barriers to the focal species, independent of the barriers impacting habitat shifts (i.e., the approach suggested in the CCVI guidance). Under these conditions, mangrove cuckoo still scored as "Moderately Vulnerable" (FWC phm/habitat proxy), but the index score decreased to 5.0 (range [2.2, 7.8]), with 80% of the Monte Carlo runs scoring as "Moderately Vulnerable" compared with 75% under scenario A. Most birds are able to fly over or around potential obstructions; however this assumption will not capture the indirect threat of barriers through impacts on the ability of habitat to shift, which most reviewers felt was an important consideration.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for mangrove cuckoo is G5. The species is ranked S3 in Florida.

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A6. DIAMONDBACK TERRAPIN *(Malaclemys terrapin)*

Species Expert(s): Kristen Hart

Diamondback terrapins occur in brackish coastal waters along the Florida coasts and are typically found in coastal marshes, tidal flats, coves, estuaries, and protected waters behind barrier beaches (NatureServe 2011). Outside of Florida, their distribution spans the Atlantic and Gulf coasts from Cape Cod to Texas. Females nest along sandy marsh edges or dunes above the high tide mark. Hatchlings move to terrestrial vegetation after emergence from the nest. Diamondback terrapins eat a variety of mollusks, crustaceans, and annelids (NatureServe 2011). Five of the seven recognized subspecies occur in Florida (ITIS 2011).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A6-1) included a range map from NatureServe (NatureServe 2011) and FNAI element occurrence data (FNAI 2011). The NatureServe range overestimates the true distribution of this species, which occurs mainly in estuarine habitats including salt marsh and mangroves. FNAI occurrence data included 14 records for this species all of which were located in the Keys. Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

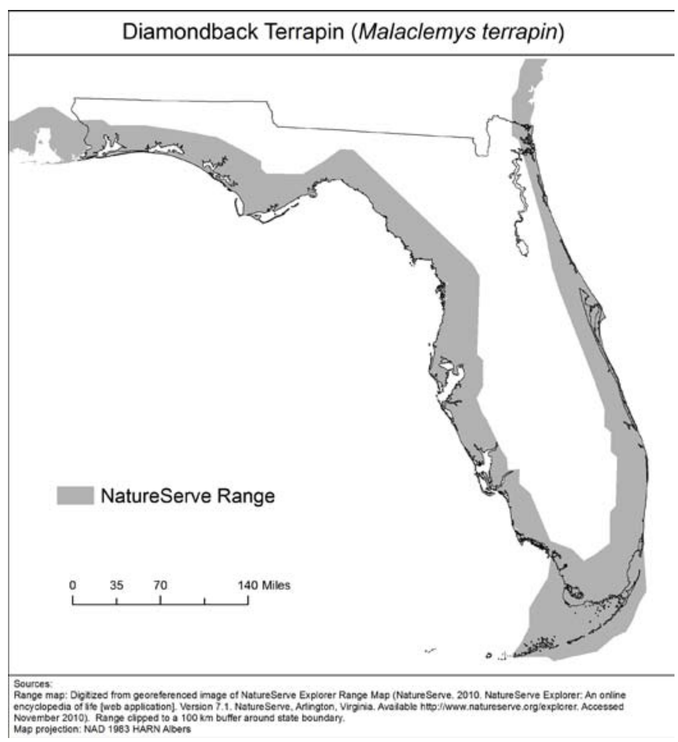

Figure A6-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or

Table A6-1. Projected temperature exposure for diamondback terrapin in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe range	FNAI occurrences
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	21%	0%
< 3.9°F warmer	79%	100%
(E_T)	*0.8*	*0.4*

Table A6-2. Projected moisture exposure (based on the Hamon Index) for diamondback terrapin in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe range	FNAI occurrences
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	7%	14%
-0.096 - -0.074	45%	86%
-0.073 - -0.051	45%	0%
-0.050 - -0.028	3%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.3*	*1.3*

moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A6-1 and A6-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). The species expert indicated that approximately 99% of the species' range is expected to be inundated under a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. The species expert described the habitat as salt marsh and mangroves occurring along the coast, including brackish to full salinity water and considered this habitat to be vulnerable to climate change (see sea level rise above). Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). The species expert indicated that there were few natural barriers to the aquatic habitat occupied by this species, although she indicated uncertainty regarding natural barriers that may affect nesting areas, which were characterized as sandy upland habitat. The species expert did not select a score for this factor. We captured the uncertainty associated with this factor by selecting scores of *neutral* and *somewhat increases* vulnerability. We also ran the model with this factor scored as *unknown.*

Anthropogenic barriers (B2b). The species expert indicated that urban areas pose barriers that would prevent habitat shifts and that roads pose a significant threat to individuals. She estimated that urban areas (Miami, Tampa and Naples) impacted approximately 40% of the range boundary and considered that these barriers were likely to greatly impair any climate change-caused distributional shifts. This factor was scored as *increases* vulnerability.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert considered shoreline hardening, dredging, beach nourishment, and marsh alteration/draining as factors that were likely or very likely to occur in response to climate change and would have a negative impact on diamondback terrapin. Impacts included loss of access to nesting beaches or loss of actual nesting habitat, entrainment in dredge intakes, and threats associated with increased proximity to humans. This factor was assigned the highest score available: *increases* vulnerability.

Sensitivity

Dispersal and movement (C1). The species expert noted that females swim to nesting areas 5 km away in the Everglades and that hurricanes frequently disperse animals significant distances. This factor was scored as *somewhat decreases* vulnerability with high confidence in the associated information.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the range map provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases*, and *somewhat increases* vulnerability. A score of *greatly increases* vulnerability corresponded to the area encompassing the FNAI occurrences, which were restricted to the Keys.

*Physiological thermal niche (C2a*ii*).* The species expert indicated that adults were not particularly sensitive to microclimate within the assessment area and selected the corresponding score of "neutral." However, she indicated that the species was sensitive to changes in temperatures affecting nest substrate through impacts on offspring sex ratios (warmer temperatures tend to bias nests towards females). We have captured this uncertainty by including scores of *neutral* and *somewhat increases* vulnerability for this factor.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Due to the differences in distribution between the NatureServe range and the FNAI occurrences, the calculated value for variation in precipitation varied across the two data sets, corresponding to a score of *somewhat increases* vulnerability for the NatureServe range and *increases* vulnerability using the FNAI occurrences to approximate distribution.

Historical precipitation exposure
NatureServe range: 49 - 67 inches
FNAI occurrences: 50 - 64 inches

*Physiological hydrologic niche (C2b*ii). Due to the species high dependence on salt marsh and mangrove habitats, the species expert scored this factor as "greatly increases" vulnerability. In written comments, the species expert indicated that changes in hydrology might lead to drier conditions in the nesting habitat which could have a negative impact on nest success. Changes in hydrology could also increase salinity in the species' aquatic habitat. For other species (e.g., American crocodile and loggerhead turtle) that might be similarly affected by changes in hydrology, we captured the reviewers' uncertainty regarding the magnitude and impact of these changes by also including scores of "increases" and "somewhat increases" vulnerability for this factor. In an effort to apply consistent scoring across the species, we have adjusted the scoring to include these additional scores, scoring this factor as *greatly increases*, *increases*, and *somewhat increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species expert considered increased intensity of hurricanes in combination with projected sea level rise as the major disturbance likely to affect diamondback terrapin due to the potential risk of increased nest flooding and erosion. This factor was scored as *increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The species expert expressed uncertainty as to whether the species' dependence on nesting beaches with sufficient elevation should be considered for this factor and did not initially provide a score for this factor. Based on follow up discussion, we scored this factor as *neutral* and *somewhat increases* vulnerability to capture the uncertainty associated with this potential dependence on a particular substrate and elevation.

Dependence on other species to generate habitat (C4a). Due to the species' association with mangrove swamp, the species expert scored this factor as *somewhat increases* vulnerability. Since this species is also associated with other estuarine habitats, we also included *neutral* in the scoring for this factor.

Dietary versatility (C4b). The species expert selected a score of "somewhat increases" vulnerability for this factor based the diet being mainly limited to bivalves, periwinkles, and crabs. Based on the reviewer's comments, the diet for this species may fall somewhere between the description for "somewhat increases" vulnerability ("completely or almost completely dependent on a few species from a single guild") and that for "neutral" (diet "flexible"). As a result, we included scores of *neutral* and *somewhat increases* vulnerability for this factor.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral.*

Other interspecific interactions (C4e). The species expert scored this factor as "neutral." However, in her worksheet she indicated that habitat loss resulting from sea level rise might increase competition with other species, such as sea turtles and crocodiles, for nesting habitat. Although this is not an interspecific interaction directly included as part of this factor (the guidance includes, mutualism, parasitism, commensalism, and predator-prey relationships), we addressed it here by also assigning scores of *somewhat increases* vulnerability and *neutral* to this factor.

Measured genetic variation (C5a). The species expert categorized the genetic variation in diamondback terrapin as "average" or "high," corresponding to scores of *neutral* and *somewhat decreases* vulnerability.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a. The species expert did indicate that in some sub-populations there may be evidence of population reductions impacting genetic variation, however the factor is intended to assess range-wide genetic variation which was been included in the scoring of factor C5a.

Phenological response (C6). The species expert indicated that long term data sets on the start of nesting and dates of road kill at well-monitored sites exist and could potentially be used to assess phenological response in this species. However, she was not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown.*

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Diamondback terrapin ranked as "Extremely Vulnerable" to climate change in Florida, regardless of which distribution data set was used to parameterize the model. The primary factors identified as contributing to vulnerability to climate

Table A6-3. Scores assigned to factors associated with vulnerability to climate change for diamondback terrapin in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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)[1]	• (•)	•	•			--	
Physiological thermal niche			•	•		--	
Historical hydrologic niche (GIS)[1]		(•)	•			--	
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	--					--	•

[1] The higher values are assigned to these factors when using the element occurrences to estimate the species' distribution.

change for this species were sea level rise, anthropogenic barriers that may inhibit the species ability to track climatic shifts, and potentially incompatible human responses to climate change (Table A6-3). Altered disturbance regimes (i.e., increased intensity of hurricanes) and changes to hydrology that could affect moisture of the nest substrate and/or salinity of the aquatic habitat were also considered to have the potential to have a strong negative impact on diamondback terrapins. Only one sensitivity factor was scored as unknown, although two additional factors (B2a, *natural barriers*, and C2b*ii, physiological hydrologic niche*) were also associated with relatively high uncertainty.

Despite the differences in the exposure estimates produced by the two data sets used to estimate distribution, the Monte Carlo simulation consistently produced index scores falling in the "Extremely Vulnerable" category (NatureServe range: 15.8, range [10.4, 21.3], Figure A6-2; FNAI occurrences: 14.7, range [11.0, 18.3]). Parameters derived from FNAI occurrences, which were restricted to the Keys, resulted in a lower temperature exposure metric (Table A6-2) but slightly higher scores for historical thermal and hydrological niche. As a result there was little difference between the index scores generated using the NatureServe range and FNAI occurrences, even though the extent of occurrence differed greatly between the two distributions.

We adjusted the reviewer's scores for factor C2b*ii* (*physiological hydrologic niche*) to capture some of the uncertainty associated with the impacts of potential hydrologic changes, but this had only minor effects on the calculated index scores, dropping the index score by approximately 1.5 points. In addition, scoring factor B2a (*natural barriers*) as unknown had a very small effects on the index score (15.3, range [10.4, 20.3], based on NatureServe range). Factors related to indirect exposure, which affect the landscape in which the species occurs, combined with fairly high exposure to drier conditions that could exacerbate the species dependence on a particular hydrologic regime accounted for approximately half of the overall index score.

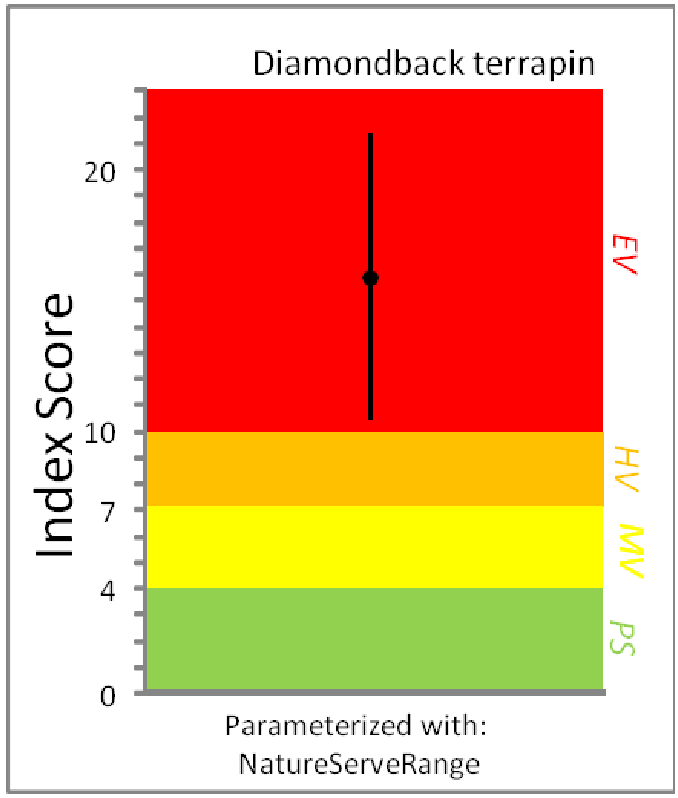

Figure A6-2. CCVI output for diamondback terrapin in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for diamondback terrapin is G4. The species is ranked S4 in Florida.

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A7. LOGGERHEAD TURTLE *(Caretta caretta)*

Species Expert(s): Kristen Hart

Loggerhead turtles are found throughout the coastal waters around Florida. Their on-shore nesting areas include Florida's entire Atlantic coast, throughout the Keys, and along the Gulf coast (Hipes et al. 2001). Within the U.S., loggerhead turtles nest mainly in coastal areas in Florida, Georgia, and South Carolina. Nests are generally found along dune lines at higher elevation. After hatching, young use offshore floating sargassum mats. Juveniles inhabit coastal lagoons, bays, and inlets (Hipes et al. 2001).

Currently, the CCVI is designed for use with terrestrial and freshwater species and is not recommended for use with marine species, such as sea turtles. We have included loggerhead turtle in our analysis in order to explore the limitations of the CCVI when applied to such species. These results should be interpreted with caution as they may not capture the full complement of factors influencing vulnerability in this species.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A7-1) included the FWRI Statewide Nesting Beach Survey (FWC 2010), a potential habitat model (phm) from FWC (provided by Beth Stys, FWC, October 2010), and FNAI occurrence data (FNAI 2011). The species expert indicated that these data sets omit known nest sites along the Everglades beaches and the Dry Tortugas, as well as some patchy occurrences north of St. Petersburg. FNAI occurrence data included 48 records for this species occurring along the Gulf coast and South Florida. Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To estimate exposure, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data with the distribution or occurrence data

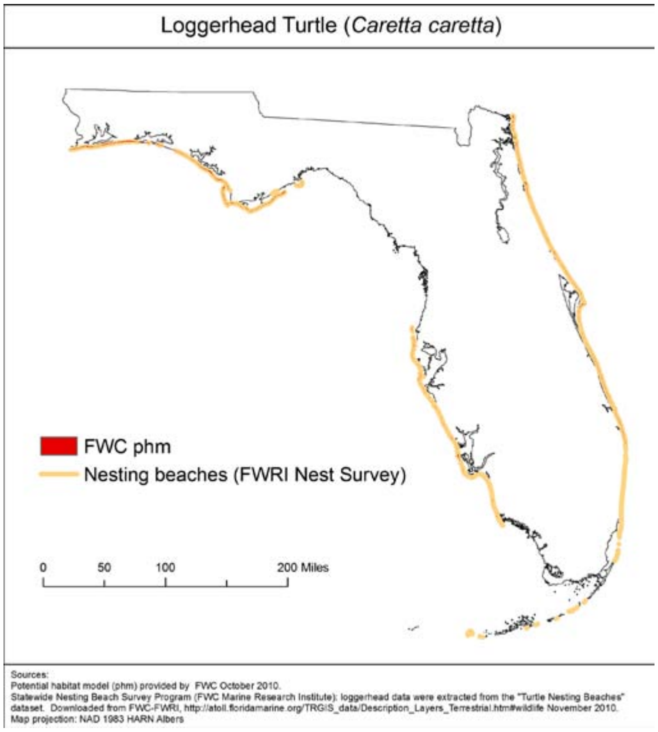

Figure A7-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

(Tables A7-1 and A7-2). For point data sets, we assigned a single value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). The species expert estimated that approximately 90% of the species' nesting habitat is expected to be impacted by a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. Loggerhead turtle is a marine species, using terrestrial habitats only for nesting. The species expert described the species' nesting habitat as coastal beach with adequate elevation and considered this habitat to be to be vulnerable to reduction or loss under projected climate change (see sea level rise above). Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Significant natural barriers that would inhibit the ability of the species to track climatic shifts were not identified. This factor was scored as *neutral.*

Anthropogenic barriers (B2b). The species expert took associations with habitat into account when assessing this factor, mentioning that much of the nesting habitat is bordered inland by urban areas. The species expert selected the descriptions associated with scores of "increases" and "somewhat increases" vulnerability. Written comments indicated that she considered that up to 80% of the range boundary could be impacted by these barriers, which corresponds to a score of *increases* vulnerability for this factor. We assigned the higher score to the factor for analysis.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert identified shoreline hardening as a potential factor having a negative impact on the availability of nesting habitat and assigned the highest score available, corresponding to *increases* vulnerability.

Sensitivity

Dispersal and movement (C1). The species expert characterized the species as having excellent dispersal or movement capability, indicating that individuals regularly move up to 1,000 kilometers between nesting and foraging areas. Normally this description would be associated with a score of "decreases" vulnerability. However, individuals return to their natal beaches for nesting, which may limit their ability to shift their distribution within the nesting area. The species expert did not feel that the existing categories captured the full extent of the vulnerability associated with this factor, which is not surprising given that the CCVI is designed for terrestrial and freshwater species. Estimates from the literature suggest that female site fidelity ranges from 2 - 100 km. Based on this information, we adjusted the score by one category to *somewhat decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area, and is calculated as

Table A7-1. Projected temperature exposure for loggerhead turtle in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm	FWRI nest survey	FNAI occurrences
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	41%	14%	6%
< 3.9°F warmer	59%	86%	94%
(E_T)	*0.8*	*0.4*	*0.4*

Table A7-2. Projected moisture exposure (based on the Hamon Index) for loggerhead turtle in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm	FWRI nest survey	FNAI occurrences
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	0%	3%	8%
-0.096 - -0.074	42%	42%	52%
-0.073 - -0.051	58%	55%	40%
-0.050 - -0.028	0%	0%	0%
> -0.028 (No change)	0%	0%	0%
(E_M)	*1.0*	*1.0*	*1.3*

the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases,* and *somewhat increases* vulnerability.

Physiological thermal niche (*C2a*ii*)*. The species expert characterized the species as showing a preference for environments towards the warmer end of the spectrum, indicating that loggerhead turtles rarely nest north of Virginia along the Atlantic coast. This factor was scored as *somewhat decreases* vulnerability. However, the species expert also indicated that the species was sensitive to changes in temperatures affecting nest substrate through impacts on offspring sex ratios. Currently, this factor does not explicitly address indirect effects on the species through temperature-dependent sex determination. However, we have captured this uncertainty by also including a score of *somewhat increases* vulnerability for this factor.

*Historical hydrologic niche (C2b*i*)*. This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Although the calculated value for variation in precipitation varied somewhat across the three data sets, in all cases the factor was scored as *somewhat increases* vulnerability.

Historical precipitation exposure
FWC potential habitat: 50 - 67 inches
FWRI nest survey: 50 - 67 inches
FNAI occurrences: 50 - 64 inches

*Physiological hydrologic niche (C2b*ii). The species expert considered the dependence on suitable humidity and moisture for nesting, indicating that decreased moisture could have negative effects on egg incubation and development, however there was uncertainty in whether this moisture regime would be considered "highly vulnerable to loss or reduction with climate change." The species expert selected the description associated with a score of *increases* vulnerability. We also included a score of *neutral* to capture the possibility that these hydrologic requirements might not be significantly disrupted under projected changes in climate.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species expert considered increased intensity and changes in the timing of hurricanes and flooding events as the major disturbance regime likely to affect loggerhead turtle under climate change. Written comments indicated that a shift towards earlier storms could impact nest success and/or hatchling survival. Loggerhead nesting occurs May - August, with hatching occurring 55 days post-laying. This factor was scored as *somewhat increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The species expert selected the description corresponding to *somewhat increases* vulnerability based on the species' dependence on sandy beaches for nesting.

Dependence on other species to generate habitat (C4a). The nesting habitat was not considered dependent on species-specific processes. However, the species expert indicated that young turtles rely on *Sargassum* for shelter. We adjusted the score for this factor to *increases* vulnerability to capture this dependency.

Dietary versatility (C4b). The species expert indicated that the adult diet consists of bottom-dwelling invertebrates (crabs) and may also include scavenged fish. Hatchling loggerheads, which forage in *Sargassum* beds, are relatively omnivorous. The species expert selected the description of diet as omnivorous, corresponding to *somewhat decreases* vulnerability.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species expert indicated that young turtles live in and rely on *Sargassum* for food and shelter as well as dispersal. This factor was scored as *somewhat increases* vulnerability.

Other interspecific interactions (C4e). The species expert scored this factor as "neutral." However, she indicated that habitat loss resulting from sea level rise might increase competition with other species, such as American crocodile for nesting habitat. Although this is not an interspecific interaction specifically included as part of this factor (the guidance includes mutualism, parasitism, commensalism, and predator-prey relationships), we addressed it here by also including scores of *neutral* and *somewhat increases* vulnerability for this factor.

Measured genetic variation (C5a). The species expert indicated that genetic variation in this species was "average" compared to related species, but indicated that several genetically distinct subpopulations occur in the assessment area. This factor was scored as *neutral*, however based on information provided in factor C5b we also included a score of *somewhat increases* vulnerability for this factor.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is only scored if information is not available for C5a. The species expert cited substantial decreases in numbers of nesting females and large numbers of takes in longline fisheries in the recent past as evidence that populations have been significantly reduced. We have captured the score she assigned to this factor in C5a above.

Phenological response (C6). Increased sea surface temperature has been associated with advances in nesting in this species. The species expert considered the change in phenology to be average or greater than that of other species is similar taxonomic groups. The associated scores for this factor were *neutral* and

Table A7-3. Scores assigned to factors associated with vulnerability to climate change for loggerhead turtle in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--			•	•	--	

somewhat decreases vulnerability.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Loggerhead turtle ranked as "Extremely Vulnerable" to climate change in Florida regardless of which distribution data set was used to parameterize the model. The major factors contributing to the vulnerability of this species included sea level rise, anthropogenic barriers impacting the nesting habitat, and potentially incompatible human responses to climate change (Table A7-3). To a lesser degree, changes in the timing/intensity of storms that might impact nest success, possible impacts on temperature-dependent sex ratios, dependence on a limited number of species to generate habitat and for dispersal during the hatchling phase, and the potential for lower than average genetic variability also contributed to vulnerability. None of the sensitivity factors were assigned a score of unknown.

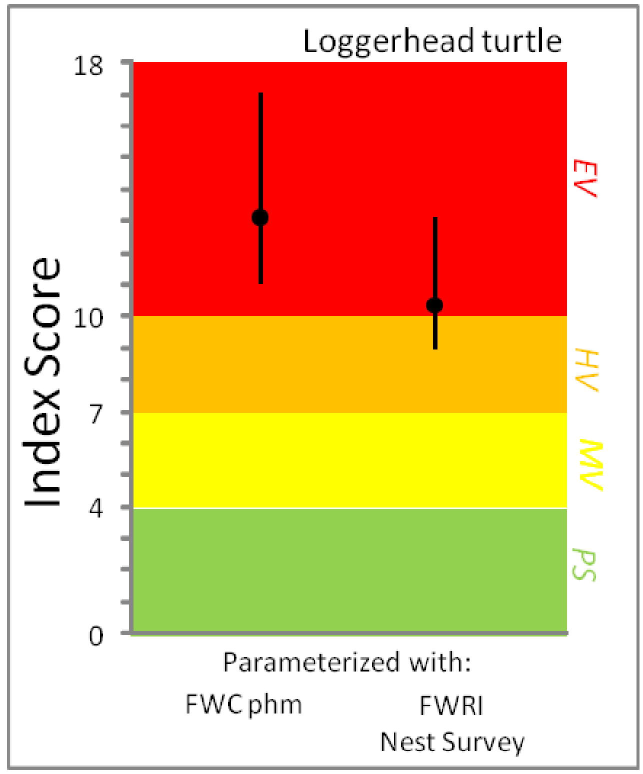

Figure A7-2. CCVI output for loggerhead turtle in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

The index score based on the potential habitat model (13.1, range [11.0, 17.0], Figure A7-2) was somewhat higher than those based on FWRI nest surveys (10.3, range [9.0, 13.0], Figure A7-2) and the FNAI element occurrence data (11.8, range [10.3, 14.9]). Results based on the nest survey data are shown in Figure 6 in the main report. The differences among the scores are due to differences in the exposure metrics derived from the distribution estimates. For example, using the FWC potential habitat model, roughly 40% of the habitat was projected to be 3.9 - 4.4°F warmer, whereas less than 15% of the nest surveys fell within this range. The FWRI nest survey data were mapped as a single pixel width line along beaches with known loggerhead nests, potentially underestimating exposure if beaches in the Panhandle tend to cover more area than those along the Atlantic and Gulf coasts. The species expert indicated that the datasets used as proxies for distribution omitted some known areas of nesting, for example the beaches between the Apalachicola National Forest and St. Petersburg on the Gulf coast and additional sites in the Everglades and the Dry Tortugas. These sites occur in areas with lower projected temperature exposure (< 3.9° F), however these portions of the Gulf coast are projected to be exposed to drier conditions than other parts of the species' range.

As noted earlier, the CCVI is not currently designed to address marine species. As a result, any vulnerabilities associated with the marine component of the life cycle are not captured by this assessment. For example, the species expert mentioned potential impacts on marine foraging areas as well as potential impacts of ocean acidification on prey. There is no way to capture these dependencies in the current version of the CCVI. Where possible, we tried to capture additional impacts, such as altered sex ratios, by adjusting the scores for the most closely related factor (e.g., *physiological thermal niche*). Alternatively, the algorithm could be adjusted to incorporate these factors explicitly. In addition, we found that it was somewhat challenging to apply the CCVI to species with complex life histories. In many cases, different factors scores applied to different life portions of the life cycle. As noted, we adjusted a few of the species expert's responses in order to score each factor relative to the most vulnerable life history stage (e.g., factor C4a, *dependence on other species to generate habitat*). Despite the fact that the index does not account for many of the vulnerabilities specific to marine environments, this species still scored in the highest category for vulnerability to climate change.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for loggerhead turtle is G5. The species is ranked S4 in Florida.

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A8. Salt Marsh Snake *(Nerodia clarkii)*

Species Expert(s): Pierson Hill, Paul Moler

Salt marsh snakes occur in brackish coastal habitats along the northern Gulf of Mexico and are most commonly found in coastal brackish and salt marshes, mangrove swamps, and saline offshore islands (NatureServe 2011). Three subspecies (or races) occur in Florida. The Gulf race occurs in southern Texas east into Florida south of Cedar Key. The mangrove race occurs in southern Florida and north to Merritt Island, and the Atlantic race occurs on the Atlantic coast of Florida in coastal areas of Volusia County (Hipes et al. 2011).

Initially, the analysis was considered at the species level. However, after consulting with the species experts, it became apparent that the three races occurring in Florida have distinct sensitivity and exposure factors related to climate change that might not be captured in a species-level analysis. In order to explore this issue, we ran two separate analyses, one based on the reviewers inputs considered at the species level, and a separate analysis in which we pulled out those responses specific to the Atlantic race (*Nerodia clarckii taeniata*), which merits special consideration due to its federally threatened status.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A8-1) included a range map published by NatureServe (NatureServe 2011) and potential habitat models (phm) developed by FWC (Endries et al. 2009). FWC potential habitat models were available for the Atlantic (*Nerodia clarkii taeniata*) and Gulf (*N. c. clarkii*) races only. Both species experts felt that the NatureServe range overestimated the actual distribution for the species. The data set was included in the analysis in order to examine sensitivity of the CCVI to differences in resolution and accuracy of the distribution inputs. In the species-level analysis using the potential habitat models, the mangrove swamp habitat layer from the Florida Comprehensive Wildlife Conservation Strategy (FWC 2005) was used as a proxy for the mangrove race (*N. c. compressicauda*) as a potential habitat model was not available for this subspecies. For the analysis focused on the Atlantic race, the potential habitat model was used to estimate distribution. FNAI element occurrences (FNAI 2011)

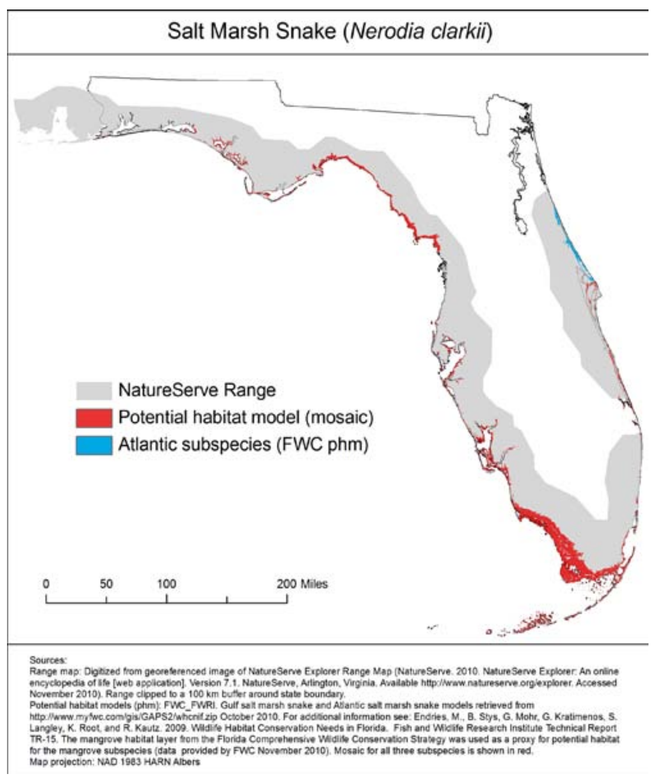

Figure A8-1. Distribution inputs considered for the CCVI analysis. (FNAI element occurrences not shown).

were available for the Atlantic and Gulf races, however they were not used in this analysis.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A8-1 and A8-2).

Table A8-1. Projected temperature exposure for salt marsh snake and Atlantic salt marsh snake in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	*Species* NatureServe range	*Species* FWC phm	*Atlantic race* FWC phm
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	24%	7%	0%
< 3.9°F warmer	76%	93%	100%
(E_T)	*0.8*	*0.4*	*0.4*

Table A8-2. Projected moisture exposure (based on the Hamon Index) for salt marsh snake (species) and Atlantic salt marsh snake in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	*Species* NatureServe range	*Species* FWC phm	*Atlantic race* FWC phm
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	6%	15%	0%
-0.096 - -0.074	41%	59%	0%
-0.073 - -0.051	50%	25%	100%
-0.050 - -0.028	3%	1%	0%
> -0.028 (No change)	0%	0%	0%
(E_M)	*1.0*	*1.3*	*1.0*

Indirect Exposure

Sea level rise (B1). Both species experts estimated that approximately 90% of the species' habitat is expected to be impacted by a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. The species experts indicated that the species' habitat consists of tidally influenced shallow creeks and mudflats within salt marshes on the northern Gulf Coast and Atlantic Coast or shallow red and black mangrove swamps along the peninsula coast. Both species experts considered these habitats to be vulnerable to climate change (see sea level rise above). Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). The species experts indicated that expanses of high-energy coastlines and sandy dunes prevent salt marsh snakes from spreading along the coast, particularly along the Atlantic Coast and Panhandle. However salt marsh habitat tends to be behind these barriers, and so they potentially have less of an impact on inland shifts precipitated by sea level rise. Lack of foraging habitat within inland freshwater systems was considered a barrier by one species expert. We addressed this as unsuitable habitat in factor C1 (*dispersal and movement*) and so adjusted this reviewer's score from "increases" vulnerability to *neutral*. This score was applied to both the species-level analysis and the Atlantic race.

Anthropogenic barriers (B2b). Large areas of urban development were considered anthropogenic barriers. Estimates of the percentage of the range boundary impacted by these barriers ranged from 10-15% but there was a high degree of uncertainty associated with these estimates. Furthermore, the subspecies are differentially impacted by the presence of anthropogenic barriers. The Atlantic coastal portions of the species' range were considered much more highly impacted by anthropogenic barriers than populations along the Gulf coast. For the species-level analysis, this factor was scored as *somewhat* *increases* vulnerability. For Atlantic salt marsh snake, this factor was scored as *greatly increases* vulnerability.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species experts identified coastal armoring as a direct threat to mangrove and salt marsh habitat as well as a blockage to the natural movement of these habitats inland with rising sea level. Water control impoundments, which alter local tidal hydrologic cycles, were identified as an additional threat, particularly for Atlantic and Gulf races. Associated scores for this factor ranged from *neutral* to *somewhat increases* vulnerability. We included both scores for the species-level analysis and assigned the higher score for Atlantic salt marsh snake.

Sensitivity

Dispersal and movement (C1). Both species experts characterized the species as having moderate dispersal, indicating that individuals would be physically capable of dispersing over distances of up to 1 km (although movement in salt marsh snakes is largely unstudied). This factor was scored as *neutral.*

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases,* and *somewhat increases* vulnerability for the species, and *increases* vulnerability for Atlantic salt marsh snake.

Physiological thermal niche (*C2a*ii*).* One species expert characterized the species as having "no association with a particular thermal environment" and the other indicated that the species prefers "relatively warmer" environments. The corresponding scores of *neutral* and *somewhat decreases* vulnerability were assigned to this factor for both the species and Atlantic salt marsh snake.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated values for variation in precipitation corresponded to *somewhat increases* vulnerability for the species-level analysis and *increases* vulnerability for Atlantic salt marsh snake due to a narrower range of exposure for the subspecies.

Historical precipitation exposure
Species-level: NatureServe range: 49 - 67 inches
FWC phm: 49 - 67 inches
Atlantic salt marsh snake: FWC phm: 50 - 55 inches

*Physiological hydrologic niche (C2b*ii). Both reviewers agreed that salt marsh snake is dependent on habitats associated with a specific hydrological regime, however there was a large amount of uncertainty in whether climate change will result in significant disruption of the hydrologic requirements in a major portion of the range. One expert scored this factor as "neutral" whereas the other assigned scores of "increases" and "greatly increases" vulnerability. The latter expert suggested that sea level rise would increase the amount and duration of standing water within currently existing salt marshes, greatly reducing the availability of refugia and foraging microhabitats, although this may be a more significant problem for the Atlantic and Gulf races. We included the entire range of responses (from *greatly increases* vulnerability to *neutral*) for the species-level analysis, but used the two highest scores for Atlantic salt marsh snake, assuming that the subspecies might be somewhat more vulnerable than the species overall.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species experts suggested that hurricanes have a larger impact on formation of salt marsh than mangroves. Furthermore, coastal flooding caused by tidal surges associated with hurricanes can displace salt marsh snakes inland, increasing extrinsic mortality and increasing the chance of hybridization with the southern watersnake (*N. fasciata*). We address the former impacts associated with hurricanes in the scoring for this factor, but addressed the risk of hybridization in factor C4e. We used both reviewers' scores of *neutral* and *somewhat increases* vulnerability at the species level and used the higher score for the Atlantic subspecies.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). This factor was scored as *somewhat decreases* vulnerability, which applies to species for which the idea of specificity to a particular geologic feature or derivative is not relevant.

Dependence on other species to generate habitat (C4a). Species experts indicated that the northern races of salt marsh snake rely heavily on smooth cordgrass (*Spartina alterniflora*) and black needlerush (*Juncus roemeriana*) for cover from predators when basking and foraging. The mangrove race relies on black mangrove (*Avicenna germinans*) and red mangrove (*Rhizopora mangle*). All races will seek shelter in the burrow networks provided by fiddler crabs (*Uca* spp.) when inactive. Both reviewers scored this factor as *somewhat increases* vulnerability, which corresponds to required habitat that is generated by not more than a few species.

Dietary versatility (C4b). Salt marsh snakes are strict piscivores, feeding almost exclusively on a variety of small brackish marsh fish. Both reviewers selected the description associated with a score of "somewhat increases" vulnerability. However, they commented that there was a big jump between the descriptions corresponding this score (diet is "dependent on a few species from a single guild") and "neutral" (diet is "flexible"), indicating that salt marsh snake fell somewhere in between. As a result, we included both scores of *neutral* and *somewhat increases* vulnerability for this factor.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). The species experts initially scored this factor as "neutral." However, we felt it appropriate to capture the increased risk of hybridization with *N. faciata* mentioned in factor C2c, as well as potential introgression between the mangrove race and other races resulting from northern migration of mangroves. The latter would not present a vulnerability at the species level, but would potentially impact the Atlantic race. We assigned scores of *neutral* and *somewhat increases* vulnerability for the species-level analysis and used the higher score of *somewhat increases* vulnerability for Atlantic salt marsh snake.

Measured genetic variation (C5a). The species experts categorized genetic variation as "average" to "high" for this species compared to related taxa. We included the corresponding scores of *neutral* and *somewhat decreases* vulnerability for this factor. A single genetic study of mangrove salt marsh snakes was referenced, which showed relatively high levels of genetic variation within and among populations. In addition, localized genetic exchange between the salt marsh snake and southern watersnake may also increase genetic diversity.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Table A8-3. Scores assigned to factors associated with vulnerability to climate change for salt marsh snake (species-level analysis) in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers (see text for details). Not all scores can be assigned to all factors as indicated by dashes.

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: hybridization	--		•	•	--	--	
Genetic variation	--			•	•	--	
Phenological response	--					--	•

Table A8-4. Scores assigned to factors associated with vulnerability to climate change for Atlantic salt marsh snake in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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: hybridization	--		•		--	--	
Genetic variation	--			•	•	--	
Phenological response	--					--	•

Results

Salt marsh snake ranked as "Highly Vulnerable" to climate change in Florida when both the potential habitat model and NatureServe range were used as estimates for the distribution. The federally endangered Atlantic subspecies (*N. c. taeniata*) rated higher, with a rank of "Extremely Vulnerable." The primary factors contributing to vulnerability for this species included sea level rise and the impact of potential changes in hydrology on mangroves and salt marsh (Table A8-3), although there was a great deal of uncertainty associated with projected impacts on hydrology. The factor was scored higher for the Atlantic race (Table A8-4) than for the species as a whole. Additionally, the Atlantic salt marsh snake was considered to be more heavily impacted by anthropogenic barriers. A number of other factors contributed to vulnerability to a lesser extent, such as the impact of changes in disturbance regime (i.e., more intense hurricanes), associations with a limited number of species for habitat, and the potential for hybridization. For both the species-level and subspecies analysis, only one sensitivity factor was scored as unknown. However, several factors were assigned multiple scores, indicating fairly high uncertainty as to how these factors are expected to influence vulnerability to climate change.

The index score for the species based on the FWC potential habitat model was 8.7 (range [4.3, 13.1], Figure A8-2), with 56% of the Monte Carlo simulations within the "Highly Vulnerable" range[3]. The output was not particularly sensitive to the choice of distribution data. Even though the NatureServe

[3] Since the Monte Carlo algorithm can only handle up to three scores per factor, we ran multiple MC simulations to generate the distributions for factors assigned more than three scores.

range was considered an overestimate for the interior distribution of this species, there was little difference in index scores calculated using the NatureServe range (8.9, range [4.0, 13.7], Figure A8-2) compared to the the FWC phm. This is not surprising given that the resolution of the exposure data is fairly coarse (approximately 15 km) and the relatively narrow distribution of this species along the Florida coast. The wide range of scores produced by the Monte Carlo simulation reflects the large number of factors that were assigned multiple scores. Results based on the FWC potential habitat models are shown in Figure 6 in the main report.

The species-level analysis indicated the potential for range expansion within the assessment area. This result is based on the low scores assigned to barriers combined with relatively high exposure and dispersal ability, while also taking the orientation of the assessment area relative to the species' range in to account. However, any potential range expansion would be dependent on the availability of suitable habitat under climate change, and whether habitat migration will be able to outpace losses due to sea level rise.

For Atlantic salt marsh snake, the index score was considerably higher (11.7, range [10.4, 13.0], Figure A8-2), with all of the Monte Carlo simulations falling within the "Extremely Vulnerable" range. The increase was due to higher scores assigned the subspecies' distribution relative to anthropogenic barriers, as well as somewhat higher vulnerability to altered hydrology and disturbance regime.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for salt marsh snake is G4. *N. c. clarkii* and *N. c. taeniata* are ranked as S3 and S1 respectively in Florida.

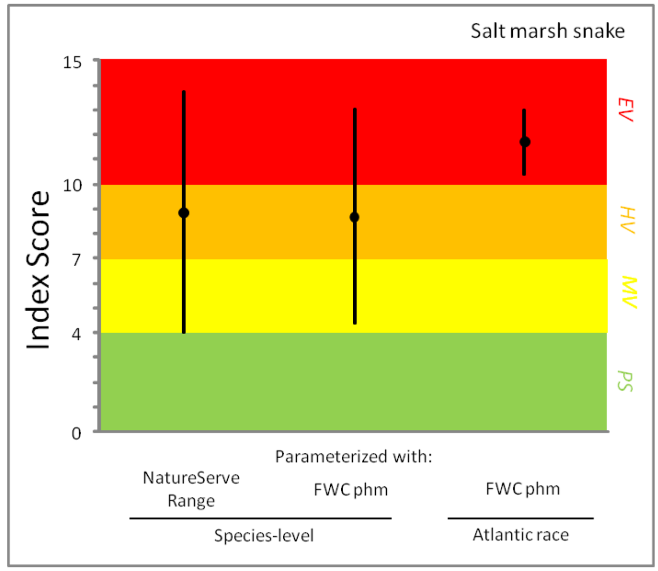

Figure A8-2. CCVI output for salt marsh snake and Atlantic salt marsh snake in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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A9. AMERICAN CROCODILE *(Crocodylus acutus)*

Species Expert(s): Michael Cherkiss, Kristen Hart, Paul Moler, Joe Waselewski

American crocodiles are found mainly in the coastal waters in the southern portion of the Florida peninsula (Hipes et al. 2001). The species' larger distribution spreads from Mexico through Central and South America. Their habitat includes coastal estuarine marshes, tidal swamps, and creeks along edges of mainland and islands. American crocodiles most often locate their nests on beaches, stream banks, and levees (Hipes et al. 2001).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A9-1) included a potential habitat model (phm) developed by FWC (Endries et al. 2009) and the USFWS American Crocodile Consultation Area (USFWS 2003). We did not utilize FNAI element occurrence data (FNAI 2011) as only five records were available for this species.

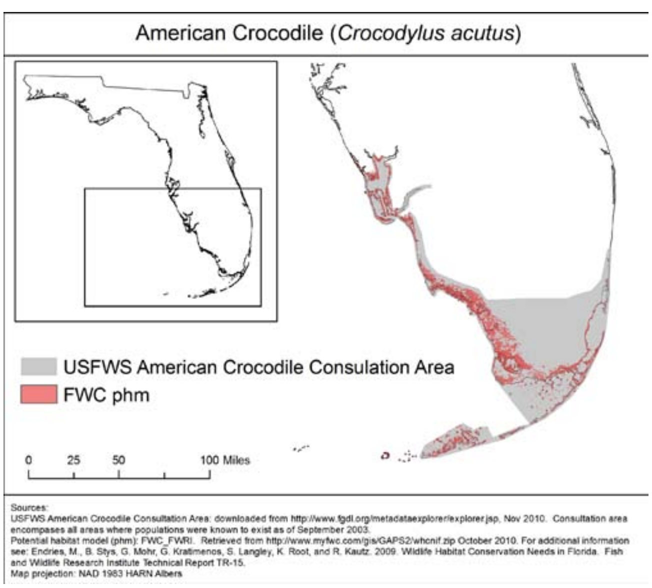

Figure A9-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Exposure

We obtained downscaled data from Climate Wizard for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric, were downloaded from NatureServe and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A9-1 and A9-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). All species experts estimated that approximately 90% of the species' nesting habitat is expected to be impacted by a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. Experts described the species' habitat as mangrove along the

Table A9-1. Projected temperature exposure American crocodile in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm	USFWS Consult. Area
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	0%	0%
< 3.9°F warmer	100%	100%
(E_T)	*0.4*	*0.4*

Table A9-2. Projected moisture exposure (based on the Hamon Index) for American crocodile in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	FWC phm	USFWS Consult. Area
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	21%	22%
-0.096 - -0.074	76%	75%
-0.073 - -0.051	3%	3%
-0.050 - -0.028	0%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.3*	*1.3*

coast and inland, coastal shoreline and beaches, and back country estuaries and flooded mangrove swamps. Two of the reviewers considered the species' habitat to be vulnerable to climate change, whereas one reviewer did not think that climate change would significantly reduce habitat or decrease the area of occupancy in the assessment area, presumably because the habitat would shift. The fourth reviewer did not provide this information. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Significant natural barriers that would inhibit the ability of the species to track climatic shifts were not identified. This factor was scored as *neutral.*

Anthropogenic barriers (B2b). The species experts considered developed areas, such as Miami, Fort Lauderdale, and Naples, and roads as anthropogenic barriers impacting this species. Three species experts selected the category describing barriers as "completely or almost completely surround[ing] the current distribution" (corresponding to "greatly increases" vulnerability). However, when asked to describe the distribution of these barriers relative to the species' range, one of the experts estimated that 40% of the range boundary was impacted by these barriers (mainly northward movement along the east and west coasts). The fourth species expert originally selected the description corresponding to "somewhat increases" vulnerability, but increased his score based on follow up discussion. Taking into account that the majority of the current range occurs in protected areas that are unlikely to be developed, we adjusted the score for this factor to *increases* vulnerability.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species experts identified shoreline hardening as a potential factor having a negative impact on the availability of nesting habitat, however a wide range of scores were assigned to this factor depending on the individual reviewers' assumptions of how likely it was that coastal armoring would occur in areas affecting American crocodile. Most species experts selected descriptions associated with scores of "increases" and/or "somewhat increases" vulnerability. One reviewer also indicated that shoreline protection could possibly create nesting habitat, as crocodiles readily use man-made habitat, and included "somewhat decreases" vulnerability in the score. We captured the uncertainty associated with this factor by included all of these scores (*increases*, *somewhat increases*, and *somewhat decreases* vulnerability) as well as the additional score of *neutral*, based on the large amount of protected area occurring in the species' current range.

Sensitivity

Dispersal and movement (C1). The species experts characterized the species as having "moderate," "good," or "excellent" dispersal or movement capability, indicating that dispersal differs by gender and life stage. Nesting females may move tens of kilometers. Relocated animals have also moved back to the original site (distances of 100 km or more). However, nest site fidelity may functionally limit movement to new nesting locations between nesting seasons. We included scores associated with the range of categories selected by the reviewers: *neutral*, *somewhat decreases,* and *decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases* and *increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* Most species experts indicated that the species is associated with warm environments, corresponding to a score of *somewhat decreases* vulnerability. We considered this score appropriate in cases in which the current range may be limited by temperature, such that warmer temperatures might promote range expansion. In addition, the species is sensitive to changes in temperatures affecting nest substrate through impacts on offspring sex ratios. The factor does not explicitly address indirect effects on the species through temperature-dependent sex determination. However, we captured this uncertainty by also including a score of *somewhat increases* vulnerability.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was the same for both distribution inputs, ranging 50 - 60 inches, which corresponds to a score of *increases* vulnerability.

*Physiological hydrologic niche (C2b*ii). The species experts considered the dependence on estuarine/coastal habitats for this factor, however there was uncertainty in whether these hydrologic requirements were likely to be significantly disrupted in a major portion of the range as a result of climate change. Written comments indicated that a major source of uncertainty was related to the impact of higher salinities on juveniles in nursery habitat. Decreased soil moisture was also mentioned as having a potential negative impact on egg incubation and development. The species experts selected descriptions associated with scores of *greatly increases* and *somewhat increases* vulnerability for this factor. We also included the intermediate score of *increases* vulnerability to capture the uncertainty associated with the reviewers' responses.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species experts considered the impacts of increased hurricane intensity on wind and overwash erosion of nesting sites. The potential for increased frequency of cold snaps resulting in direct mortality was also mentioned here. Scores for this factor included *increases* and *somewhat increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Species experts indicated that American crocodiles use beaches for nesting but will adapt to manmade habitats for nesting. Scores for this factor ranged from *neutral* to *somewhat decreases* vulnerability.

Dependence on other species to generate habitat (C4a). Initially, two species experts scored this factor as "neutral." One of the species experts selected the category describing the required habitat as "generated primarily by a single species that is at most moderately vulnerable to climate change" (corresponding to "increases" vulnerability) based on the species association with red mangrove. The species is associated with mangroves and salt marsh for part of its life cycle. Based on our follow up discussion, the score for this factor was adjusted to *neutral* (i.e., habitat generated by more than a few species).

Dietary versatility (C4b). Species experts categorized the diet as "flexible," consisting of mammals, birds, reptiles, fish, and invertebrates. This factor was scored as *neutral*

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). The species experts scored this factor as *neutral*. One reviewer indicated that habitat loss resulting from sea level rise might increase competition with other species, such as sea turtles, for nesting habitat. Not all of the species experts agreed that this potential interaction warranted an increase in the scoring for this factor. We decided to include both scores of *neutral* and *somewhat increases* vulnerability for this factor to maintain consistency across the scores applied to other reptiles (e.g., loggerhead turtle). In doing so, we have expanded the types of interspecific interactions addressed by this category relative to those listed in the NatureServe guidance.

Measured genetic variation (C5a). This factor was scored as *unknown*. Reviewers were more confident assessing the occurrence of a population bottleneck, so addressed genetic factors under factor C5b.

Occurrence of bottlenecks in recent evolutionary history (C5b). Species experts indicated that the breeding population in the late 1970s included fewer than 30 females, but that the population had increased to about 100 known nesting females prior to the January 2009 freeze. This factor was assigned a score of *increases* vulnerability, which applies to population bottlenecks of fewer than 250 individuals.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

American crocodile ranked as "Extremely Vulnerable" to climate change in Florida according to our analysis. Both of the data sets used to estimate the distribution produced the same exposure parameters, resulting in identical CCVI outputs regardless of the distribution used. This is not surprising given that the resolution of the exposure data is fairly coarse (approximately 15 km) and the relatively narrow distribution of this species in south Florida.

Table A9-3. Scores assigned to factors associated with vulnerability to climate change for American crocodile in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

The major factors identified as contributing to vulnerability to climate change for this species included sea level rise, anthropogenic barriers that may inhibit the species ability to track climatic shifts, changes in the timing/intensity of hurricanes that might impact nest success, changes to hydrology that might affect salinity, and the potential for lower than average genetic variability (Table A9-3).

Only one sensitivity factor was scored as unknown, however three or more scores were assigned to several factors, indicating fairly high uncertainty as to how these factors influence vulnerability to climate change. Despite the high number of factors assigned multiple scores, the Monte Carlo simulation consistently produced index scores falling in the "Extremely Vulnerable" range (index score: 12.9, range [8.1, 17.2]; Figure A9-2). Less than 3% of Monte Carlo simulations[4] produced scores <10.0, corresponding to a rank of "Highly Vulnerable." There was some disagreement about whether to include the potential for increased competition for nest sites in the scoring of factor C4e. Scoring this factor as neutral had only minor effects on the resulting index score (12.5, range [8.1, 16.5]) and did not affect the categorical rank.

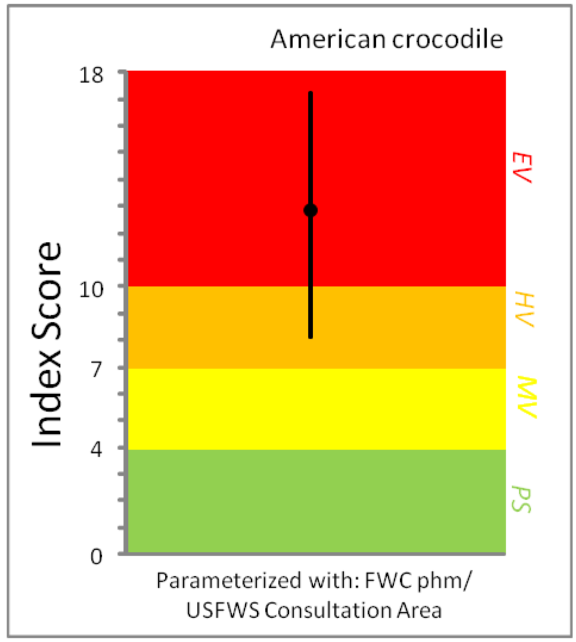

Figure A9-2. CCVI output for American crocodile in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for American crocodile is G2. The species is ranked S2 in Florida.

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[4] Since the Monte Carlo algorithm can only handle up to three scores per factor, we ran multiple MC simulations to generate the distributions for factors assigned more than three scores.

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A10. RETICULATED FLATWOODS SALAMANDER *(Ambystoma cingulatum)*

Species Expert(s): Kelly Jones, Paul Moler

Reticulated flatwoods salamander is endemic to a small portion of the Coastal Plain in the United States (NatureServe 2011). The historical range extended from the western part of the Florida Panhandle to extreme southwestern Alabama. Surveys completed since 1990 indicate that a large majority of the historical local breeding populations has been extirpated. Adults inhabit mesic longleaf pine-wiregrass flatwoods and savannas. Breeding occurs between October and January in acidic ephemeral wetlands lacking large predatory fishes (NatureServe 2011). Reticulated flatwoods salamander is listed as endangered.

Distribution Data

Distribution data are used to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A10-1) included a range map available from NatureServe (IUCN et al. 2004) and a potential habitat model (phm) developed by FWC (Endries et al. 2009). The potential habitat model was developed prior to the reclassification of *A. bishopi* and *A. cingulatum* as separate species, so we extracted the portion of the range relevant to *A. bishopi*. The species expert indicated that the NatureServe range presents a broad view of the historic distribution of the species, but that the known extant populations are much more narrowly distributed. FNAI element occurrence data (FNAI 2011) consisted of a single record and were not used in the analysis.

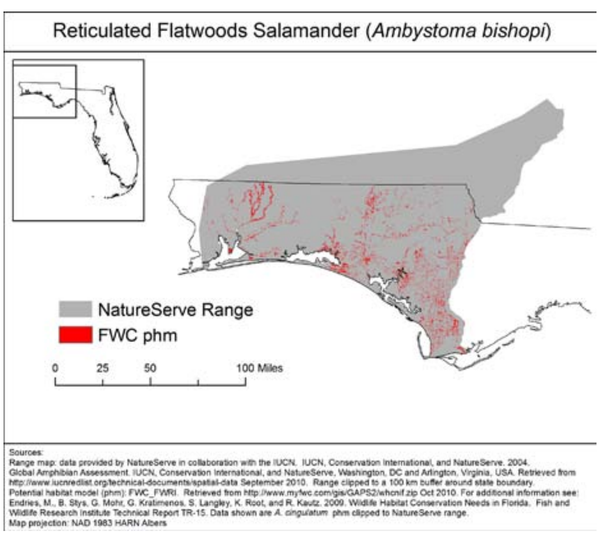

Figure A10-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the

Table A10-1. Projected temperature exposure for reticulated flatwoods salamander in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range	FWC phm
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	96%	89%
< 3.9°F warmer	4%	11%
(E_T)	0.8	0.8

Table A10-2. Projected moisture exposure (based on the Hamon Index) for reticulated flatwoods salamander in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range	FWC phm
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	0%	0%
-0.096 - -0.074	52%	45%
-0.073 - -0.051	48%	55%
-0.050 - -0.028	0%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.3*	*1.0*

percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A10-1 and A10-2).

Indirect Exposure

Sea level rise (B1). One reviewer initially based his response on the map provided in the worksheet, which showed the distribution of historic breeding sites. Follow up discussion with the species experts revealed that a much higher proportion of extant localities are considered to be at risk. Reviewers estimated that up to 70% of extant localities could be impacted by a 1-meter sea level rise, corresponding to a score of *increases* vulnerability.

Potential impact of barriers on range shifts. The species experts indicated that the species' breeding habitat includes hydrologically isolated cypress or gum swamps, marsh pasture ponds, roadside ditches, and shallow borrow pits. Adult habitat includes longleaf pine flatwoods and savannas. Both habitats are potentially vulnerable to climate change. The majority of the known populations occur in lowlands near the coast and are vulnerable to sea level rise. In addition, seasonal and annual mean changes in temperature and moisture may affect area of occupancy or habitat reduction if ephemeral breeding sites experience reduced hydroperiod. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Large rivers and streams were identified as natural barriers that may prevent movement. The historic range spans multiple large rivers, but not enough is known to determine what size river effectively blocks movement. The primary sites (Elgin Air Force Base and Garnier Landing, Santa Rosa County) are bordered by steep gradient sandhills, which function as natural barriers to movement. After consulting with the species experts, this factor was scored as *greatly increases* vulnerability, based primarily on natural barriers impacting the core extant populations.

Anthropogenic barriers (B2b). The species experts indicated that extensive intermix of urban areas in close proximity to several historic breeding sites may limit movement, however species' movement limitations are not well known. Populations on Garcon Point were identified as being bordered to the north by the city of Milton. Both reviewers indicated uncertainty in the impact that these barriers would have on climate change-caused distributional shifts. This uncertainty was captured in the range of scores selected by the reviewers: *neutral* or *somewhat increases* vulnerability.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species experts did not identify any mitigation/adaptation-related land use changes that might occur within the species' current or potential future range. One reviewer scored this factor as "neutral" with moderate to low confidence and the other species expert indicated that there were insufficient data for assessment. This factor was scored as *unknown*.

Sensitivity

Dispersal and movement (C1). The species experts indicated that this species will move hundreds of meters between breeding and non-breeding habitat, corresponding to a score of n*eutral*.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor relative to the species' range in within Florida using the maps provided by NatureServe, which corresponded to a score of *somewhat increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* This species was characterized as having no association with a particular thermal environment by one species expert, and the other species expert indicated an association with cool environments (i.e., exposed on surface for breeding during cool times of year and retreats to moist and cool sub-surface environs during daylight hours and warm parts of the year) but the availability of these environments was not considered likely to be affected by climate change. This factor was scored as *neutral*.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was identical for both distribution inputs, ranging from 53 - 67 inches, which corresponds to a score of *somewhat increases* vulnerability.

*Physiological hydrologic niche (C2b*ii). The species' reproduction is entirely dependent on seasonally-specific inundation of ephemeral wetlands with current hyrdoperiod trends limiting reproductive success in many breeding sites. Species experts suggested that additional decreases in hydroperiod could lead to increased local extirpations. Both species experts scored this factor as *greatly increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). Species experts considered multiple factors related to disturbance regime. Both experts agreed that the species would benefit from increased fire, but there was uncertainty regarding whether climate change would be expected to increase fire frequency and/or intensity. Increased storm intensity in conjunction with sea level rise was also mentioned as potentially increasing frequency of overwash events. We captured the range of potential impacts through multiple scores, *decreases* vulnerability (reflecting changes in fire regime that would benefit the species), *neutral* (reflecting a scenario in which climate change is unlikely to change fire regime), and *somewhat increases* vulnerability (reflecting increased probabilities of overwash associated with storm events).

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Species experts indicated that this species utilizes pine flatwoods, much of which is sandhill or clayhill, which is not one of the "dominant" physical habitat types. This factor was scored as *somewhat increases* vulnerability.

Dependence on other species to generate habitat (C4a). One species expert considered the required habitat to be generated by "not more than a few" species based on the species' association with a fire-dependent habitat based primarily on wiregreass and longleaf pine. The second expert considered the required habitat to be generated by "more than a few" species, noting the types of ephemeral wetlands used for breeding and the association with longleaf pine flatwoods and savannas for adult habitat. We retained the scores associated with both of their responses: *somewhat increases vulnerability and neutral.*

Dietary versatility (C4b). Both species experts categorized the species diet as flexible, corresponding to a score of *neutral.*

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species experts indicated that the species disperses on its own. This factor was scored as *neutral.*

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral.*

Measured genetic variation (C5a). Reviewers did not feel that there was enough information available to assess this factor. This factor was scored as *unknown.* A study was available providing genetic evidence (mtDNA) supporting the recognition of two species of flatwoods salamander (*A. bishopi* and *A. cingulatum*) but did not address the issue of genetic variation relative to related taxa.

Occurrence of bottlenecks in recent evolutionary history (C5b). Reviewers did not feel that there was enough information available to assess this factor. This factor was scored as *unknown.* Based on information available from NatureServe indicating that extensive surveys of historical breeding ponds have recorded the species at only a small minority of formerly inhabited sites, we included scores of *neutral* (equivalent to unknown in the CCVI calculations) and *increases vulnerability* for this factor.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. However, they indicated that the species has not adjusted behaviorally to drought years, which might suggest scoring this factor as "somewhat increasing" vulnerability. The rain events that trigger migration to ponds do not determine the length of hydroperiod. As a result, there is no known mechanism by which the species could adjust its behavior to match changes in hydroperiod. We included scores of *neutral* (equivalent to unknown in the CCVI calculations) and *somewhat increases* vulnerability for this factor.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Reticulated flatwoods salamander ranked as "Extremely Vulnerable" to climate change in Florida regardless of which spatial input was used to parameterize the exposure metrics. The primary

Table A10-3. Scores assigned to factors associated with vulnerability to climate change for reticulated flatwoods salamander in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

Vulnerability factor	GI	I	SI	N	SD	D	*unknown or n/a*
Sea level rise		•				--	
Natural barriers	•				--	--	
Anthropogenic barriers			•	•	--	--	
***Human responses to CC*[1]**	--						•
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[2]	--		•	•		--	(•)
Phenological response[2]	--		•	•		--	(•)

[1] Species experts expressed low confidence in assigning a score to this factor. We initially ran the model with their score of unknown and then adjusted the scores to capture additional uncertainty by including scores of SI, N, and SD.

[2] Scoring a factor as neutral is equivalent to unknown in the CCVI algorithm.

factors contributing to vulnerability to climate change for this species were sea level rise, natural barriers that may inhibit the species ability to track habitat shifts, and the impact of potential changes in hydrology on breeding ponds (Table A10-3). These three factors accounted for approximately half of the of the calculated index score. As a result the output was not very sensitive to small adjustments (or multiple selections) in the other factors. Two sensitivity factors (C5b and C6) were scored as unknown, but with some evidence that the factor would "somewhat increase" vulnerability. In order to capture both scores, these factors were scored as "somewhat increases" vulnerability and "neutral" (which is equivalent to a score of unknown for the purposes of calculating the summed index score).

Moisture stress was somewhat higher based on the NatureServe range (Table A10-2), resulting in higher index scores based on the NatureServe range (13.7, range [11.1, 16.9]) versus the FWC potential habitat model (11.7, range [9.4, 14.6]) as the distribution input (Figure A10-2). These index scores were generated using a score of unknown for factor B3 (*human responses to climate change*). Adjusting this factor to capture the uncertainty associated with the potential for future climate-related land use change had little effect on the model output, changing the range but not the calculated index score (13.7, range [10.1, 17.8]. Results based on the potential habitat model are shown in Figure 6 in the main report.

The outputs shown in Figure A10-2 incorporate the uncertainty associated with the impact of altered disturbance regimes (C2c) on this species, including scores of "somewhat increases," "neutral," and "decreases" vulnerability for this factor. Although there was a large range of responses included for this factor, the vulnerability rank was insensitive to changes in this parameter. Index scores shifted a bit higher when a single score of "somewhat increases" vulnerability was assigned to this factor and a bit lower with a single score of "decreases" vulnerability, but consistently ranked as "Extremely Vulnerable" in both cases.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation

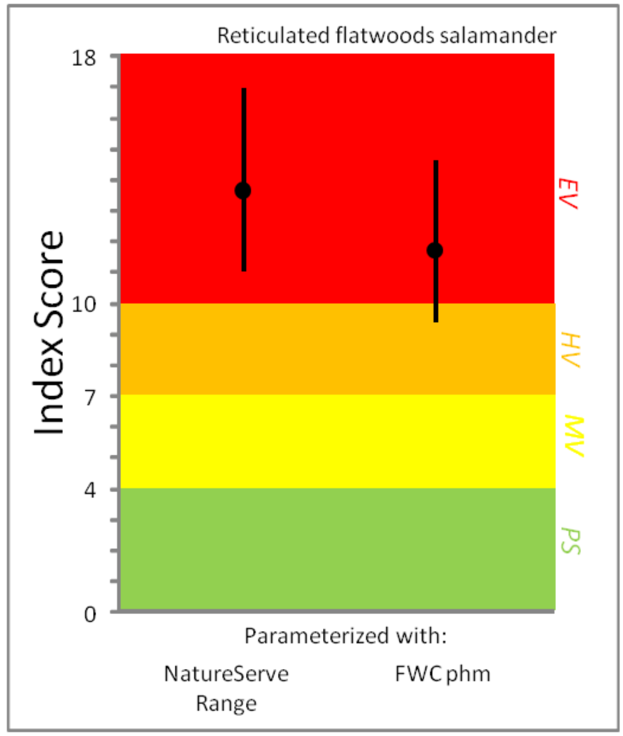

Figure A10-2. CCVI output for reticulated flatwoods salamander in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

status rank for reticulated flatwoods salamander is G2. The species' rank is S2 in Florida.

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A11. SQUIRREL TREEFROG *(Hyla squirella)*

Species Expert(s): Paul Moler

Squirrel treefrogs occur throughout Florida in a wide range of terrestrial habitats including open woods, cities and towns (NatureServe 2011). The range extends throughout the Coastal Plain from southeastern Virginia to the Florida Keys and west to southeastern Texas. Adults migrate to ephemeral water bodies to breed in spring and summer, including flooded roadside ditches, flatwoods ponds, swamps and other shallow, temporary pools. The adult diet includes a variety of small arthropods; larvae eat organic matter, algae, and plant tissue.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A11-1) included a range map available from NatureServe (IUCN et al. 2004). This species is widely distributed across the state. FNAI element occurrence data were not available.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric, were downloaded from NatureServe and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A11-1 and A11-2).

Indirect Exposure

Sea level rise (B1). The species expert indicated that less than 1% of the species' range is expected to be

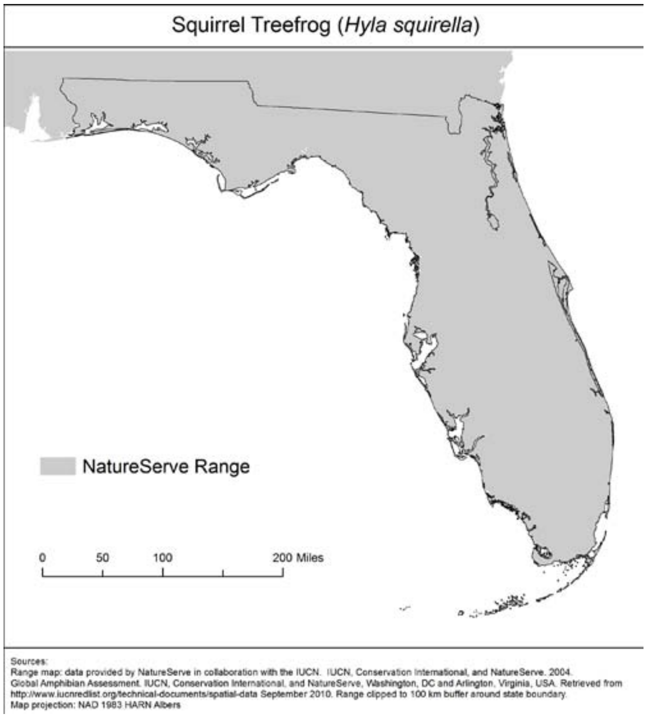

Figure A11-1. Distribution inputs considered for the CCVI analysis

impacted by a 1-meter sea level rise. This factor was scored having a *neutral* effect on vulnerability.

Potential impact of barriers on range shifts. The species expert indicated that this species breeds in ephemeral wetlands and that adults use a variety of upland habitats. He did not consider these habitats to be particularly vulnerable to climate change, although the location of available breeding ponds might shift. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Squirrel treefrog is a widely distributed species. The species expert did not consider this species to be significantly impacted by natural barriers, corresponding to a score of *neutral* for this factor.

Anthropogenic barriers (B2b). The species expert did not consider this species to be significantly impacted by anthropogenic barriers, corresponding to a score of *neutral* for this factor.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert considered the species unlikely to be significantly affected by mitigation/adaptation-related land use changes, corresponding to a score of *neutral* for this factor. In other species assessments, reviewers considered increased interior land conversion in response to inland migration of human populations in response to sea level rise. To maintain consistency across the species assessments, we also included a score of *somewhat increases* vulnerability for this factor.

Sensitivity

Dispersal and movement (C1). The species expert indicated that individuals regularly disperse more than 100 meters from their natal ponds and occasionally "hitchhike" much greater distances on vehicles. This species was scored as having "good" dispersal capability, corresponding to *somewhat decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor relative to the species' range within Florida using the maps provided by NatureServe. We included scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases* and *somewhat increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* The species expert indicated that the species has no association with a particular thermal environment, corresponding to a score of *neutral*.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for

Table A11-1. Projected temperature exposure for squirrel treefrog in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range
> 5.5°F warmer	0%
5.1 - 5.5 °F	0%
4.5 - 5.0 °F	0%
3.9 - 4.4 °F	35%
< 3.9°F warmer	65%
(E_T)	*0.8*

Table A11-2. Projected moisture exposure (based on the Hamon Index) as estimated in the CCVI for each of the data sets used as a proxy for the species' distribution. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range
< -0.119 (Driest)	0%
-0.119 - -0.097	2%
-0.096 - -0.074	35%
-0.073 - -0.051	61%
-0.050 - -0.028	2%
> -0.028 (No change)	0%
(E_M)	*1.0*

the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Precipitation values range from 46 to 67 inches across the species' distribution in Florida, corresponding to a score of *neutral*.

*Physiological hydrologic niche (C2b*ii). The categorical descriptions associated with this factor require evaluation of both the dependence on a particular wetland habitat as well as the vulnerability of that habitat to climate change. The species expert considered the dependence on ephemeral water bodies for breeding (such as flooded roadside ditches or flatwoods ponds) for this factor, however, there was uncertainty in whether these hydrologic requirements were likely to be significantly disrupted in a major portion of the range as a result of climate change. The reviewer suggested that, although many of the ephemeral water bodies used for breeding may be lost with climate change, the impact could potentially be offset by previously permanent water bodies that become ephemeral. This factor was scored as *neutral*. In order to address sensitivity to the assumption that the availability of breeding habitat would not be significantly reduced under climate change, we included a separate model run in which we scored this factor as *greatly increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). Significant impacts of altered disturbance regimes, such as fires, floods, or hurricanes, were not identified. This factor was scored as *neutral*.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The species expert indicated that this species was highly generalized in its dependence on geologic features and derivatives, corresponding to a score of *decreases* vulnerability. We also included a score of *somewhat decreases* vulnerability, which applies to species that are "flexible" in dependence on geologic features or derivatives or to species for which the idea of specificity to a particular geologic feature or derivative is not relevant.

Dependence on other species to generate habitat (C4a). The required habitat is generated by more than a few species, corresponding to a score of *neutral*.

Dietary versatility (C4b). The species' diet was considered flexible, corresponding to a score of *neutral*.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species expert indicated that the species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). The species expert did not feel that other interspecific interactions were required. This factor was scored as *neutral*.

Measured genetic variation (C5a). The species expert indicated that insufficient data were available for assessment of this factor. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). The species expert indicated that there is no evidence that a population bottleneck has occurred in the past 500 years, corresponding to a score of *neutral*.

Phenological response (C6). The reviewer was not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Table A11-3. Scores assigned to factors associated with vulnerability to climate change for squirrel treefrog in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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[1]				•		--	
Disturbance regimes	--			•			
Ice and snow				•	--	--	
Physical habitat specificity	--				•	•	
Biotic habitat dependence				•	--	--	
Dietary versatility	--			•		--	
Biotic dispersal dependence	--			•	--	--	
Other interactions: none	--			•	--	--	
Genetic variation	--			•		--	
Phenological response	--					--	•

[1] We also ran an alternative scenario with this factor scored as GI to assess sensitivity to the scoring of this factor

Results

Squirrel treefrog ranked as "Not Vulnerable/ Presumed Stable" to climate change in Florida. The species is widely distributed with few key sensitivities (Table A11-3). Even though this species requires ephemeral water bodies for breeding, it uses a wide array of temporary water bodies, and its relatively good dispersal ability and a lack of significant barriers suggest that the species will be able to track potential shifts in the availability of breeding habitat. Only one sensitivity factor was scored as unknown.

The index score was -0.1 (range [-1.8, 1.53], Figure A11-2) with 100% of the Monte Carlo simulations falling within the "Presumed Stable" category. When we considered an alternative scenario in which breeding habitat might become limiting under climate change (by adjusting the score for factor C2b*ii* from "neutral" to "greatly increases" vulnerability), the

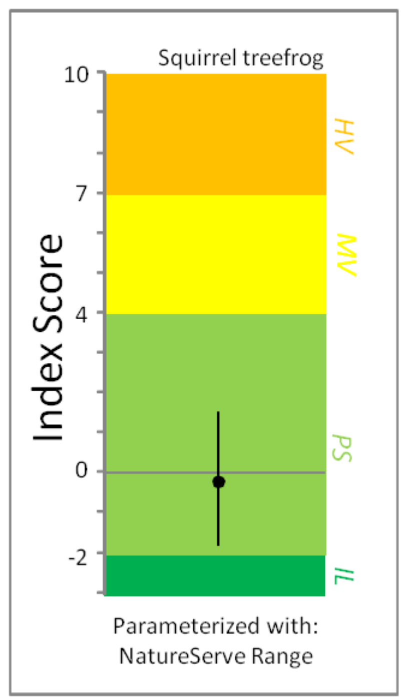

Figure A11-2. CCVI output for squirrel treefrog in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green), "Increase Likely" (dark green).

index score increased to 2.9 (range [1.2, 4.5]), with approximately 92% of the simulation runs producing scores in the "Presumed Stable" category and the remainder falling in the "Moderately Vulnerable" range. The large number of factors scored as neutral for this species buffered the impact of changing the score for a single factor, even if the magnitude of increase was quite large.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for squirrel treefrog is G5 (not ranked in Florida).

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Supporting References <none provided>

A12. Gopher Frog *(Lithobates capito)*

Species Expert(s): Boyd Blihovde, Steve Johnson

Gopher frogs are distributed throughout most of the state of Florida with the exception of the Everglades and the Keys (Hipes et al. 2001). Outside of Florida they can be found in the Southeastern Gulf and Atlantic Coastal Plains. Gopher frogs migrate to ponds for breeding between October and April, although breeding can occur during the summer in central and southern Florida. Their preferred habitat is dry, sandy uplands that include isolated wetlands or large ponds nearby. Gopher frogs breed primarily in seasonally flooded, temporary ponds (FNAI 2001).

Distribution Data

Distribution data are used to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A12-1) included a range map available from NatureServe (IUCN et al. 2004), a potential habitat model (phm) developed by FWC (Endries et al. 2009), and FNAI element occurrence data (FNAI 2011). We also included counties with known occurrences based on the National Amphibian Atlas (NAA 2010). FNAI occurrence data included 189 records distributed throughout the NatureServe range. Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

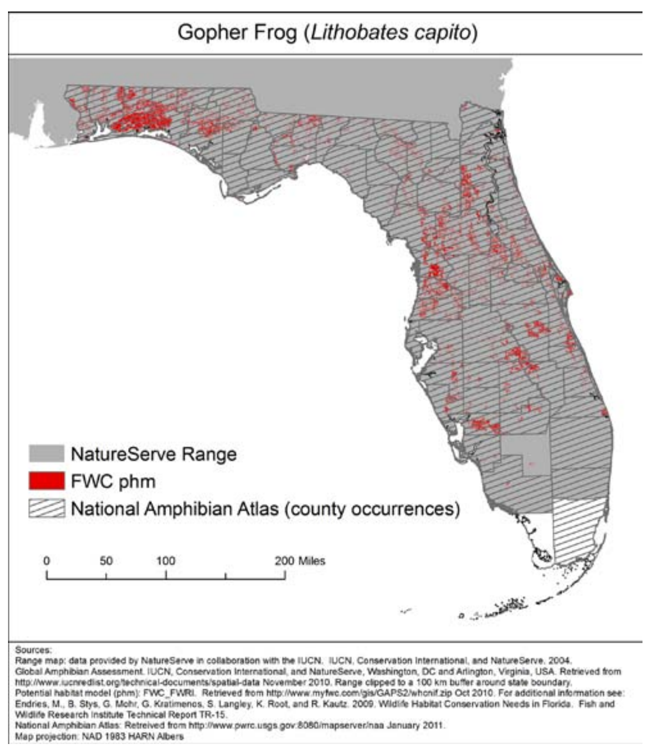

Figure A12-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A12-1 and A12-2).

Table A12-1. Projected temperature exposure for gopher frog in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range	NAA Counties	FWC phm	FNAI Occur.
> 5.5°F warmer	0%	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%	0%
3.9 - 4.4 °F	37%	28%	41%	20%
< 3.9°F warmer	63%	72%	59%	80%
(E_T)	*0.8*	*0.8*	*0.8*	*0.8*

Table A12-2. Projected moisture exposure (based on the Hamon Index) for gopher frog in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range	NAA Counties	FWC phm	FNAI Occur.
< -0.119 (Driest)	0%	0%	0%	0%
-0.119 - -0.097	0%	2%	0%	0%
-0.096 - -0.074	34%	35%	42%	28%
-0.073 - -0.051	63%	60%	57%	70%
-0.050 - -0.028	3%	3%	1%	2%
> -0.028 (No change)	0%	0%	0%	0%
(E_M)	*1.0*	*1.0*	*1.0*	*1.0*

Indirect Exposure

Sea level rise (B1). The species experts indicated that less than 2% of the species' range is expected to be impacted by a 1-meter sea level rise. This factor was scored having a *neutral* effect on vulnerability.

Potential impact of barriers on range shifts. The species experts considered the breeding habitat, which consists of ephemeral wetlands devoid of predatory fish, to be vulnerable to climate change. The species is also an inhabitant of well-drained uplands including sandhill and scrub habitats. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). The species experts identified a number of features that would function as natural barriers to movement, including large rivers, salt water habitats, large expanses of unfavorable habitat such as unmanaged scrub, and large expanses of agriculture (including pine plantations). They indicated that these natural habitat barriers occur throughout the species' range and that the distribution of the species is naturally patchy. The experts did not feel that existing barriers would be likely to significantly impair distributional shifts or contribute significantly to habitat loss with climate change, scoring this factor as *neutral.* In the Everglades, some of the barrier islands have small gopher frog populations that are completely surrounded by natural barriers, however these barriers impact < 10% of the species' range.

Anthropogenic barriers (B2b). The species experts differed somewhat in their assessment of the impact of anthropogenic barriers on distribution shifts under climate change. Both indicated that urban development is a significant barrier to gopher frog movements, and that these barriers are dispersed throughout the species' range. Estimates for the percentage of the distribution thought to be impacted by anthropogenic barriers ranged from 20-40%. Initial score selections diverged, with one reviewer considering barriers not likely to significantly impair distributional shifts ("neutral") and the other considering barriers to greatly impair climate change-caused distributional shifts ("increases" vulnerability). This reviewer noted that many protected areas in Florida are surrounded by urban infrastructure that will make source-sink dynamics in the overall population of gopher frogs nearly impossible, and that if large areas of exceptional habitat are impacted by climate change the gopher frog would not be able to move to neighboring areas because of these barriers. The estimates that reviewers provided for the percentage of the range likely to be impacted by anthropogenic barriers align more closely with the description corresponding to a score of "somewhat increases" vulnerability. However, the isolation of large populations occurring in protected areas could justify a higher score. We included scores of *neutral*, *somewhat increases* and *increases* vulnerability in the model to test the sensitivity of the outcome to a range of inputs for this factor.

Land Use Changes Resulting from Human Responses to Climate Change (B3). Experts indicated significant uncertainty regarding the probability that mitigation/adaptation-related land use changes would occur. However, they considered the possibility that areas bordering urban development might be used to mitigate climate change, including biofuel production or other alternative energy projects. Increased groundwater pumping to support energy development could negatively impact breeding sites, as would potential filling of wetlands in response to increased demand for interior development associated with sea level rise. Scores for this factor ranged from *neutral* to *somewhat increases* vulnerability.

Sensitivity

Dispersal and movement (C1). Both species experts indicated that habitat patcHipess limits dispersal. Experts indicated that the species can disperse 1-2 km through good habitat. Estimates for the distance that individual generally move per dispersal event ranged from 10-215 meters, corresponding to scores of *somewhat increases* vulnerability and *neutral*.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the map provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases* and *somewhat increases* vulnerability.

Physiological thermal niche (C2aii). Both species experts characterized the species as showing a preference for environments towards the warmer end of the spectrum, based on the association with dry upland habitat. (However, gopher frogs behaviorally select relatively cooler environments, being active on the surface mainly at night and remaining in underground retreats during the day.) This factor was scored as *somewhat decreases* vulnerability.

Historical hydrologic niche (C2bi). This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated values for variation in precipitation corresponded to *somewhat increases* vulnerability based on the FNAI occurrences and *neutral* for all other proxies for the species' distribution.

Historical precipitation exposure
NatureServe range/NAA counties/
FWC phm: 46 - 67 inches
FNAI occurrences: 47-65 inches

Physiological hydrologic niche (C2bii). Due to the species dependence on ephemeral wetlands for breeding, both reviewers assigned this factor a score of *greatly increases* vulnerability. Drier conditions are projected to occur under climate change, which could have a negative impact on pond hydroperiod in the ponds these frogs use for breeding.

Impacts of Changes to Specific Disturbance Regimes (C2c). Species experts indicated that fire was a major disturbance regime that impacts habitat suitability. More frequent fires associated with increased temperatures could improve habitat conditions, however the experts also considered the possibility that natural fire would become hotter and more severe to plant life, causing habitat to become less suitable to gopher frog and making prescribe fire more difficult to implement. Reflecting the uncertainty in the projected impact of more frequent and/or more intense fires on gopher frog habitat, one expert selected *increases* vulnerability for this factor and the other selected *somewhat decreases* vulnerability. We ran these divergent responses as two separate scenarios, holding all other factor scores constant.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Species experts indicated that the species occurs in upland habitats associated with deep, well-drained soils. One species expert selected the description associated with a score of "neutral," indicating that the species has a "clear preference for a particular geologic derivative that is among the dominant types within the species' range. " The other expert initially selected a less restrictive description, but agreed in follow up discussion that this factor should be scored as *neutral.*

Dependence on other species to generate habitat (C4a). Species experts confirmed that gopher frog requires underground burrows, primarily created by gopher tortoise, but will also use the burrows of small mammals and stump holes. Survivorship of young frogs is greatly enhanced by their ability to quickly find an underground retreat. Scores for this factor ranged from "somewhat increases" vulnerability to "greatly increases" vulnerability due to uncertainty regarding how vulnerable the associated species were to climate change and the strength of dependence on a single species. In subsequent discussion, species experts clarified that if gopher tortoises were not on the landscape, populations of gopher frog would likely decline significantly. Based on this information, we adjusted scores for this factor to *increases* or *greatly increases* vulnerability.

Dietary versatility (C4b). Both species experts categorized the species diet as "flexible," corresponding to a score of *neutral.*

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species experts indicated that the species disperses on its own. This factor was scored as *neutral.*

Other interspecific interactions (C4e). One species expert scored this factor as "increases" or "greatly increases" vulnerability, however this score reflected the dependence already captured in factor C4a. We adjusted the score to match that of the second species expert and considered this factor to have a *neutral* effect on vulnerability.

Measured genetic variation (C5a). One species expert categorized the genetic variation in gopher frog as "average," citing a recent study comparing genetic variation to the closely related dusky gopher frog and crawfish frog. The second reviewer did not assess this factor. We used the score associated with a characterization of average genetic variation (*neutral).*

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a.

Phenological response (C6). One species expert indicated that the gopher frog has been reported breeding at odd seasons as well as staying at upland shelters during extreme seasons of drought. In follow up discussion, experts hypothesized there may be indirect effects associated with shifts in the timing of breeding. For example, if breeding shifts earlier towards summer there is a chance that individuals could be impacted by fire while migrating to breeding sites. Shifts in the timing of breeding could also affect which predatory species are in the ponds at the time of breeding. Selections for this factor ranged from *neutral* to *somewhat increases* vulnerability. However, the reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. We ran the model including both experts' scores and also ran the model with this factor scored as *unknown.*

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Due to uncertainty in the projected impact of altered fire regimes, we ran two separate scenarios for gopher frog. In one scenario, we assumed that changes to fire regime under climate change would be beneficial to gopher frog. In the second scenario, we assumed that altered fire regimes would have a negative effect on gopher frog. Gopher frog ranked as "Highly Vulnerable" to climate change in Florida under both scenarios, but the range of scores generated by the Monte Carlo simulations differed considerably. In addition to altered fire regimes, the primary factors contributing to vulnerability to climate change for this species were the impact of potential changes in hydrology on breeding ponds and the dependence on a small number of species for habitat (Table A12-3). Scores were assigned to all of the sensitivity factors, although we did run a separate analysis with factor C6 (*phenological response*) scored as unknown to address uncertainty in the scoring of this factor.

There were no differences in the calculated exposure weights across the data sets used to represent the species' distribution (Tables A12-1 and A12-2). As a result, the index score was not sensitive to the choice of input for distribution, except in the case of the FNAI occurrence data. Under a scenario in which changes to the fire regime were considered beneficial to gopher frog, the index score was 7.27 (range [3.9, 10.6], Figure A12-2) based on exposure parameters derived from the NatureServe range, NAA counties or potential habitat model. This score corresponds to a rank of "Highly Vulnerable" but with moderate confidence in discriminating between "Highly Vulnerable" and "Moderately Vulnerable." Approximately 33% of the Monte Carlo simulations produced scores falling within the "Moderately Vulnerable" range. Changing the score for just one factor (C6, *phenological response*) from "somewhat increases" or "neutral" to unknown was enough to drop the index score into the "Moderately Vulnerable" range (6.8, range [3.9, 9.8]), with the resulting Monte Carlo simulations evenly split between "Highly Vulnerable" and "Moderately Vulnerable."

The index score was slightly higher based on parameters derived from the FNAI occurrence data (index score: 8.3, range [4.9, 11.6]). The higher index score under the FNAI occurrence data was due to a higher score assigned to factor C2b*i (historical hydrologic niche)*. If this factor is scored as neutral, the parameters are identical to those based on the other distributions.

Table A12-3. Scores assigned to factors associated with vulnerability to climate change for gopher frog in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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)[1]				•		--	
Physiological hydrologic niche	•					--	
Disturbance regimes[2]	--	•			•		
Ice and snow				•	--	--	
Physical habitat specificity	--			•			
Biotic habitat dependence	•	•			--	--	
Dietary versatility	--			•		--	
Biotic dispersal dependence	--			•	--	--	
Other interactions: none	--			•	--	--	
Genetic variation	--			•		--	
Phenological response[3]	--		•	•		--	(•)

[1] This factor was scored as SI using the FNAI occurrence data to estimate distribution.

[2] We ran separate scenarios in which we assumed that changes in fire regime would benefit gopher frog (factor scored as SD) or that changes in fire regime would be detrimental to gopher frog (factor scored as I).

[3] We also ran an alternate scenario in which we scored this factor as unknown (not shown in Figure 1).

When we assumed that altered fire regimes would have a detrimental impact on gopher frog, the index score rose to 9.87 (range [6.5, 13.2], Figure A12-2) still within the "Highly Vulnerable" category, but with moderate confidence in discriminating between "Extremely Vulnerable" and "Highly Vulnerable." Approximately 38% of the Monte Carlo simulations produced scores in the "Extremely Vulnerable" category. These scores are based on parameter values of "somewhat increases" vulnerability and "neutral" for factor C6.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for gopher frog is G3. The species' rank is S3 in Florida.

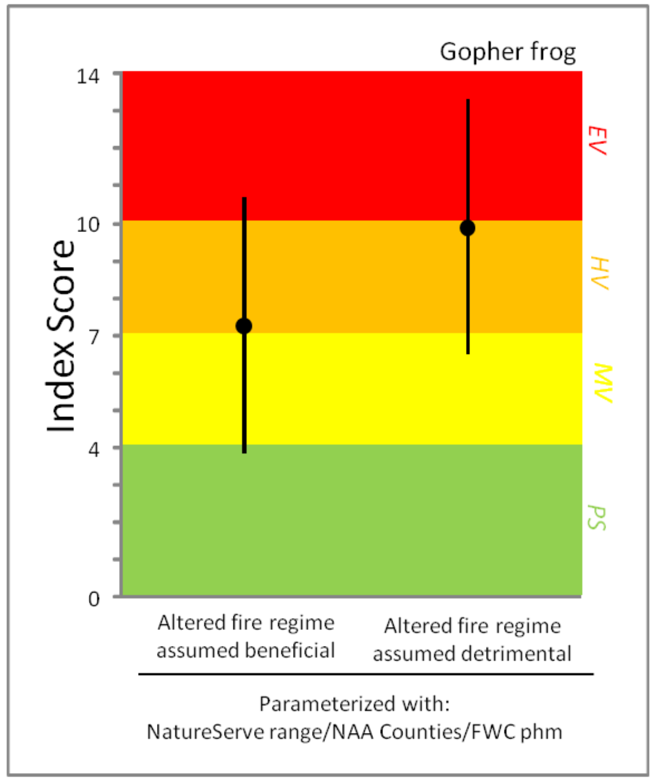

Figure A12-1. CCVI output for gopher frog in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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A13. Bonneted Bat (*Eumops floridanus*)

Species Expert(s): Jeff Gore, Kathleen Smith

Bonneted bat is found only in southern Florida where much of its natural habitat has been lost, but the species may use artificial structures and other alternative roosting sites (NatureServe 2011). Known roost sites include palms and hollow trees as well as buildings (Hipes et al. 2001). Bonneted bats may be more abundant in urban areas due to the availability of roosts, but there is little information available on the distribution and abundance of this species.

Below we document the information provided to us by the species experts. However, based on the lack of information available regarding many aspects of the biology of this species, both species experts expressed concern regarding the validity of the results generated from an assessment of this type. This species account is included as a case study to examine performance of the tool. The results of the CCVI analysis should <u>not</u> be used in ranking the vulnerability of this species without further review and assessment.

Distribution Data

Distribution data are used to calculate estimates of relative exposure for each species. Data considered as part of this assessment included a potential habitat model (phm) developed by FWC (provided by Beth Stys, FWC, October 2010) and a "range" map available from NatureServe (Patterson et al. 2003) that consisted of four approximate point locations in Florida. The species experts did not think that either map accurately represented the distribution of bonneted bat, indicating that the distribution of the species and its habitat are poorly understood. FNAI

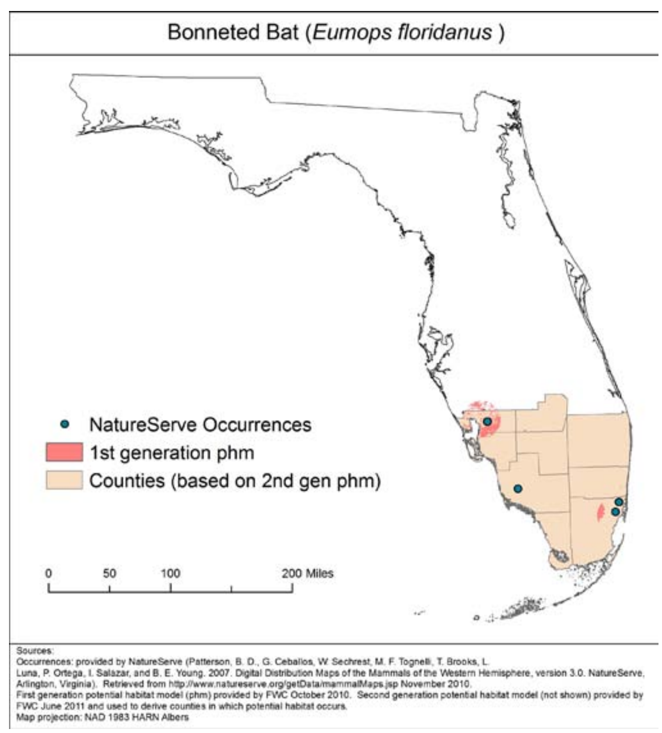

Figure A13-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences and 2nd generation potential habitat model not shown). Counties in which potential habitat for bonneted bat occurs are based on the second element occurrence data (FNAI 2011) were also available and included 14 records, the majority of which occur in Charlotte and Miami-Dade counties. Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

A second generation potential habitat map is currently in development by FWC (for more information contact Beth Stys, FWC), but the species experts qualified that the updated potential habitat model is still limited by a lack of data. The experts expressed concern that bonneted bat was unlikely to be an appropriate species for this type of assessment due in large part to a lack of information about the distribution of the species and its habitat requirements.

Due to these limitations, we decided to use the information available for this species to evaluate the sensitivity of the CCVI to differences in the resolution of the input data sets. As such, we caution that the results should not be taken to reflect the vulnerability of bonneted bat. We looked at three nested scales of data: (1) We selected data points from the FNAI element occurrences that fell within 15 km, the approximate scale of the exposure data–of the second generation potential habitat model, resulting in 10 occurrence records; (2) we used the second generation potential habitat model (version 1, provided by Beth Stys, FWC, June 2011), and (3) we selected those counties in which potential habitat occurred based on the second generation potential habitat model (Figure A13-1).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A13-1 and A13-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Climate Wizard data were only available for the Florida peninsula, so we extrapolated values from the southern tip of the Florida peninsula into the Keys (see the methodology in the main report). Due to the small area occupied by this species, the entire distribution was contained within a single category for both temperature and moisture exposure (Tables A13-1 and A13-2).

Table A13-1. Projected temperature exposure for bonneted bat in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	(1) Selected points	(2) 2nd gen phm	(3) Counties
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	0%	0%	0%
< 3.9°F warmer	100%	100%	100%
(E_T)	*0.4*	*0.4*	*0.4*

Table A13-2. Projected moisture exposure (based on the Hamon Index) for bonneted bat in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	(1) Selected points	(2) 2nd gen phm	(3) Counties
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	20%	5%	13%
-0.096 - -0.074	70%	92%	85%
-0.073 - -0.051	10%	3%	2%
-0.050 - -0.028	0%	0%	0%
> -0.028 (No change)	0%	0%	0%
Weight (E_M)	*1.3*	*1.3*	*1.3*

Indirect Exposure

Sea level rise (B1). The species experts provided estimates of < 10% and 20% of the species' range being impacted by a 1-meter sea level rise, corresponding to scores of *neutral* and *somewhat increases* vulnerability for this factor. The uncertainty associated with these estimates was captured in these multiple scores.

Potential impact of barriers on range shifts. Relatively little is known of the ecology of the Florida bonneted bat and its long-term habitat are poorly understood. Open freshwater and wetlands are used for foraging.

Roosting colonies have been found in longleaf pine, royal palm and adjacent to tropical hardwood

hammocks. Scoring for factors B2a and B2b depends on whether the species' habitat is considered vulnerable to climate change. Species occurring in habitats that are likely to persist despite climate change are scored as "neutral" because, in these situations, barriers do not contribute to vulnerability in the absence of climate-induced range shifts. Neither expert indicated that these habitats were thought to be particularly vulnerable to climate change and in any case, few barriers were thought to exist for this species. In the following sections, we indicate any barriers identified by the species experts, but in both cases these factors have been scored as *neutral.*

Natural barriers (B2a). Extensive grassland or very large bodies of water were mentioned as potential natural barriers by one expert.

Anthropogenic barriers (B2b). Neither species expert felt that anthropogenic barriers were likely to significantly impact this species. Abundance and productivity within urban areas is unknown, but most occurrence records are from urban areas.

Land Use Changes Resulting from Human Responses to Climate Change (B3). Wind farms could affect bonneted bat, but reviewers felt that habitat use is too poorly known to assess the potential scale of harm to the species. However, at least one wind farm project has been proposed in an area that could affect bonneted bat. Based on the experts written comments, it seemed unlikely that bonneted bat would benefit from mitigation or adaptation land-use changes that may occur in its range. We captured the uncertainty associated with the scoring of this factor by assigning scores of *neutral*, *somewhat increases* and *increases* vulnerability for this factor. We also ran the model with this factor scored as unknown.

Sensitivity

Dispersal and movement (C1). Both experts characterized the species as having "excellent" dispersal capability, corresponding to a score of *decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases* or *increases* vulnerability.

Physiological thermal niche (C2aii). Both experts selected the description associated with preferences for "warmer" environments, but indicated moderate to low confidence regarding the preferred thermal climate for this species. Their selection corresponds to a score of *somewhat decreases* vulnerability, but we also included a score of *neutral* to capture the uncertainty regarding the species' thermal requirements.

Historical hydrologic niche (C2bi). This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated values for variation in precipitation were similar across the distribution inputs, but generated different scores, with *increases* vulnerability applying to the selected points and *somewhat increases* vulnerability applying to the 2nd generation potential habitat model and counties.

Historical precipitation exposure
Selected points (occurrences): 50 - 60 inches
Potential habitat model: 47-60 inches
Counties: 47 - 60 inches

*Physiological hydrologic niche (C2b*ii). Both reviewers indicated reliance on hydric habitats for foraging areas, but there was less confidence in the impact of climate change on those habitats. For example, drier conditions could potentially limit insect production in foraging habitats. This factor was scored as *somewhat increases* vulnerability or *neutral*. The latter score would apply if wetland habitats were not expected to be significantly disrupted in a major portion of the range.

Impacts of Changes to Specific Disturbance Regimes (C2c). With limited data on bonneted bat ecology, the reviewers found it difficult to assess how changes to disturbance regimes would affect the species. One reviewer did not select a score, indicating that insufficient data was available for assessment. The second reviewer suggested potential impacts from fire (temporary limits on roosting habitat) and floods and severe winds associated with hurricanes that could impact movement, foraging, and insect abundance, selecting descriptions associated with *neutral* and *somewhat increases* vulnerability. We retained both of these responses in the scoring for this factor.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). One of the reviewers indicated that bonneted bats have been found in limestone outcroppings, but data are lacking to say whether this is truly a preferred habitat. Initial scores from the species experts included "somewhat decreases" or "decreases" vulnerability. Based on the information provided by the reviewers, we decided to score this factor as *somewhat decreases* vulnerability, which applies to species that are "somewhat flexible" or for which the idea of "specificity to a particular geologic feature" is not relevant.

Dependence on other species to generate habitat (C4a). One of the reviewers indicated that a bonneted bat had been found using a woodpecker category, but generally the reviewers' comments indicated that the required habitat does not require species-specific processes. We assigned this factor a score of *neutral*.

Dietary versatility (C4b). Experts indicated that the species is strictly insectivorous but consumes a variety of flying insects (e.g. Coleoptera, Diptera, Hemiptera). Even with this information one of the reviewers did not feel that there was enough data available to categorize the diet as "restricted," "flexible," or "omnivorous." The second reviewer selected the description of "flexible" There is an apparent discontinuity between the descriptions corresponding to scores of "somewhat increases" vulnerability (diet is dependent on a "few species from a single guild") and "neutral" (diet is "flexible"). The description of diet provided by the species experts indicates that the score for bonneted bat may fall somewhere between these two descriptions. As a result, we included scores of both *neutral* and *somewhat increases* vulnerability for this factor.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Some information is available in the Federal Register regarding the genetic distinction (or lack thereof) between E. floridanus and E. glaucinus, which are morphologically and ecologically distinct. However neither reviewer felt confident in assigning a score to this factor, either because this was outside their area of expertise or due to a lack of information. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). One reviewer selected descriptions associated with "somewhat increases" or "increases" vulnerability for this factor based on apparent decreases in populations since the mid 1950s. Information from the Federal Register indicates that accurate estimates of population size are unavailable, but the population of Florida bonneted bats may number less than a few hundred individuals. It is interesting to note that NatureServe guidance suggests that only species that suffered population reductions and then subsequently rebounded should qualify for scores of "increases" or "somewhat increases" vulnerability, presumably because factors related to small population size are already captured in conservation status rankings. However, we consider that the risk factors associated with low genetic variation will be exacerbated under rapid climate change, regardless of whether the population has rebounded or not, and therefore included scores of *increases* and *somewhat increases* vulnerability for this factor.

Phenological response (C6). According to the species experts, long term data sets for this species date back to the 1950s, but are patchy and are unlikely to provide much information about phenological variables. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Most factors were assigned scores of "neutral" or "somewhat increases" vulnerability for this species (Table A13-3). Both species experts cautioned that the distribution and ecology for this species is very poorly understood. The CCVI output is simply a reflection of the values assigned to the input parameters. If these are not known, or are highly uncertain, the resulting index score should be interpreted with the same uncertainty. These caveats should be considered in relation to the vulnerability ranks for this species, which ranged from "Moderately Vulnerable" to "Not Vulnerable/Presumed Stable" within Florida, depending on the distribution data used to parameterize the CCVI.

The scores assigned to the input parameters suggest that bonneted bat is somewhat of a habitat generalist (at least among forested areas), that it can readily move long distances to new areas, and may show a preference for warmer climates that may increase in

Table A13-3. Scores assigned to factors associated with vulnerability to climate change for bonneted bat in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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)[1]		(•)	•			--	
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	--					--	•

[1] Scoring for this factor differed based on the data set used to approximate distribution. The point data set generated the higher score.

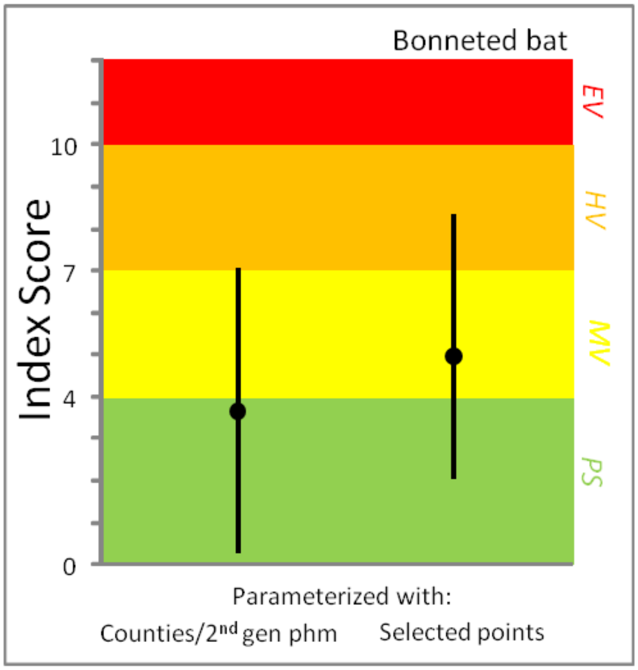

Figure A13-2. CCVI output for bonneted bat. Index scores are shown with the range of outputs based on the Monte Carlo simulation. Scores are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

availability with climate change. The CCVI flagged this species as potentially shifting its range. This result is based on the low scores assigned to barriers combined with relatively high exposure (at least for moisture) and fairly good dispersal while also taking into account the orientation of the assessment area relative to the species' range. However, it does not address other factors that may limit habitat availability or dispersal ability.

The calculated exposure values did not differ among the three spatial inputs (Tables A13-1 and A13-2). However, the choice of spatial input did affect the scoring for factor C2b*i* (*historical hydrologic niche*). Changing the score for this factor from "somewhat increases" vulnerability (which applied to the counties and 2nd generation phm) to "increases" vulnerability (for the selected points) increased the index score from 3.7 (range [0.31, 6.99]), corresponding to a rank of "Presumed Stable," to 5.0 (range [2.0, 8.3], corresponding to a rank of "Moderately Vulnerable" (Figure A13-2). We also ran the model with factor B3 (*human responses to climate change*) scored as unknown, however doing so had only moderate impacts on the resulting index scores (2.9, range [0.3, 5.5] and 4.3, range [1.6, 6.9] for the counties/2nd generation phm and selected points respectively) and did not impact the category assignments.

Overall, the CCVI was relatively insensitive to the choice of spatial input. Although there was some variation in exposure based on the three data sets, the differences had no effect on the calculated exposure metrics used to weight sensitivity. However, in the case of historical hydrologic niche (C2b*i*), the values sampled with the point data set produced a narrower range than the other spatial inputs, affecting scoring of this factor. In many cases, the sensitivity of the model is limited by the fairly coarse resolution of the downscaled exposure data rather than the finer resolution of many occurrence and distribution data sets. However, point data sets may not always capture a representative sample of the distribution, resulting in potential biases that may be captured in the resultant exposure or factor scores.

The CCVI is intended to be used in combination with conservation status ranks. However, in this case, both species experts expressed concern regarding the validity of the results generated from an assessment of this type due to the lack of information available regarding many aspects of the species' biology. As a result, we did not include the index scores for bonneted bat in the main report. The global conservation status rank for bonneted bat is G1. The species' rank is S1 in Florida.

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A14. MARSH RABBIT *(Sylvilagus palustris)*

Species Expert(s): Craig Faulhaber, Beth Forys, Phillip Hughes, Roel Lopez

Marsh rabbits are found in marsh habitats along the Atlantic and Gulf coasts, including most of the Florida peninsula (NatureServe 2011). Marsh rabbits prefer relatively undisturbed marshes but may also be found along inland lakes. Water availability is probably the most important factor limiting the species' distribution. The species likely breeds year-round in Florida, nesting in grassy vegetation near water bodies (NatureServe 2011). The federally listed Lower Keys Marsh rabbit (*Sylvilagus palustris hefneri*) is limited to small populations on just a few Keys, occurring at higher elevations within salt marsh or freshwater marsh communities (Hipes et al. 2001).

Initially, the analysis was considered at the species-level. However, after consulting with the species experts, it became apparent that a species-level would not adequately capture differences in exposure and demography between the mainland marsh rabbit and the endangered Lower Keys marsh rabbit. In order to explore this issue, we ran two separate analyses, one based on the reviewers' inputs as applied to the mainland populations within the assessment area and a separate analysis in which we pulled out the responses from those reviewers who gave input specific to the subspecies in the Keys.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. A range map was available from NatureServe (Patterson et al. 2004; Figure A14-1), but the species experts indicated that it omitted areas of known occurrence. The recommendation was to include the entire Florida peninsula, expanding the existing map west to Mobile Bay and including the full extent of the eastern counties. As a result we ended up using a map of the state boundary to estimate the species' distribution in peninsular Florida. FNAI element occurrence data (FNAI 2011) were available for the Lower Keys rabbit (16 records). FNAI does not track marsh rabbits within the Florida peninsula.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A14-1 and A14-2).

Climate Wizard data were only available for the Florida peninsula, so we extrapolated values from the southern tip of the Florida peninsula into the Keys

Figure A14-1. Distribution input considered for the CCVI analysis (FNAI element occurrences not shown). See text for actual distribution used in the analyses.

Table A14-1. Projected temperature exposure for marsh rabbit and Lower Keys marsh rabbit in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	Peninsular range	Lower Keys subspecies
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	28%	0%
< 3.9°F warmer	72%	100%
(E_T)	*0.8*	*0.4*

Table A14-2. Projected moisture exposure (based on the Hamon Index) for marsh rabbit and Lower Keys marsh rabbit in the assessment area in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	Peninsula range	Lower Keys subspecies
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	3%	0%
-0.096 - -0.074	37%	100%
-0.073 - -0.051	57%	0%
-0.050 - -0.028	3%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.0*	*1.3*

(see the methodology in the main report). The result was that the entire distribution of the Lower Keys subspecies was contained within a single category for both temperature and moisture exposure (Tables A14-1 and A14-2). Therefore, any subset of points within the Keys will generate identical exposure variables under these conditions.

Indirect Exposure

Sea level rise (B1). In the initial scoring, reviewer responses ranged from "neutral" to "greatly increases" vulnerability for this factor depending on whether they had scored the factor for the Lower Keys rabbit or the species as a whole. We scored this factor as *neutral* to *somewhat increases* vulnerability in the peninsular range, as reviewers indicated uncertainty about the relative importance of coastal habitat versus interior habitat for this species. We used the highest score for Lower Keys marsh rabbit: *greatly increases* vulnerability.

Potential impact of barriers on range shifts. The species experts indicated that marsh rabbits are found in close proximity to water in a variety of habitats, including salt marsh, freshwater marsh, wet prairie, coastal beach berms, mangrove swamps, hammocks, sugarcane and other agricultural fields, lake margins and vegetation along canals, ditches, and roadsides. Coastal and low lying freshwater marsh ecosystems will be vulnerable to sea level rise. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Large expanses of uplands and large expanses of water were identified as natural barriers for this species. One of the reviewers identified major jumps in elevation as a potential natural barrier, presumably due to dependence on low lying habitats that may be unable to migrate to higher ground. Although the marsh rabbit is widely distributed, the exact distribution is unknown, which made estimating the impact of barriers on the species difficult. This factor was scored as *neutral* or *somewhat increases* vulnerability for peninsular populations where the species occurs in suitable habitat throughout the assessment area and as *greatly increases* vulnerability for the Lower Keys rabbit where it is surrounded by water.

Anthropogenic barriers (B2b). Urban areas were identified as anthropogenic barriers for this species. Estimates of the species' range that would be impacted by anthropogenic barriers ranged from 10 to 30% with low to moderate confidence in these estimates. This factor was scored as *neutral* or *somewhat increases* vulnerability for peninsular populations and as *neutral* for the Lower Keys marsh rabbit.

Land Use Changes Resulting from Human Responses to Climate Change (B3). Reviewers considered the possibility that shoreline hardening and sea walls could potentially have negative impacts on salt marshes and mangroves. High uncertainty was captured in the range of scores selected by the reviewers, which included *neutral*, *somewhat increases* and *increases* vulnerability. This range of responses was used in both analyses.

Sensitivity

Dispersal and movement (C1). Experts characterized the species as having "moderate" to "good" dispersal capabilities (up to 2,000 meters) although the average dispersal distance of the species is unknown. This factor was scored as *neutral* or *somewhat decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases* vulnerability, *increases* vulnerability, and *somewhat increases* vulnerability for the peninsular populations and *greatly increases* vulnerability for the Lower Keys marsh rabbit.

*Physiological thermal niche (C2a*ii*).* The species was characterized as not having an association with a particular thermal environment. This factor was scored as *neutral.*

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. Since data were not available for the Florida Keys, we based this calculation for the Lower Keys marsh rabbit on the range of cell values occurring in the southern tip of the Florida peninsula. The calculated values for variation in precipitation corresponded to *neutral* for peninsular populations and *increases* vulnerability for the Lower Keys marsh rabbit due to a narrower range of exposure for the subspecies.

Historical precipitation exposure
Peninsula: 46 - 67 inches
Lower Keys: 50 - 59 inches

*Physiological hydrologic niche (C2b*ii). The species experts considered the association with marsh habitats in assessing this factor, indicating that drier conditions could reduce the availability of suitable habitat and food. However, they noted that there is a large amount of uncertainty in precipitation projections. The descriptions associated with this factor are somewhat confusing, asking reviewers to evaluate the species' dependence on a highly vulnerable wetland habitat. However, the uncertainty lies in how vulnerable the habitat is, not in whether the species in dependent on wetland habitats. This factor was scored as *somewhat increases* or *increases* vulnerability. We also ran the assessment with a wider range of scores (adding *neutral* and *greatly increases* vulnerability) to assess the sensitivity to the scores assigned to this factor.

Impacts of Changes to Specific Disturbance Regimes (C2c). Both fire and storm surges were mentioned by the species experts. Increased fire could potentially increase habitat availability by promoting herbaceous growth and limiting woody encroachment, provided there was sufficient moisture to support regrowth and sufficient unburned habitat to provide cover. Storm surges associated with climate-related changes in hurricane intensity and/or frequency were mentioned as having a potentially negative impact on marsh rabbits. Depending on which disturbance regime was considered, scores for this factor included *somewhat increases* vulnerability, *neutral*, and *somewhat decreases* vulnerability for mainland populations. For Lower Keys marsh rabbit, small local populations could be quite vulnerable to increased storm surges, so we assigned scores of *increases* and *somewhat increases* vulnerability for the subspecies.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). We did not consider features related to hydrology in scoring this factor as they have already been captured in factor *C2*b*ii*. We adjusted the score for this factor to *somewhat decreases* vulnerability, which applies to species that are not considered to be highly dependent on a particular geologic feature or derivative.

Dependence on other species to generate habitat (C4a). The required habitat was not considered to be dependent on a small number of species. This factor was assigned a score of *neutral*.

Dietary versatility (C4b). Species experts characterized the diet as "flexible" (consuming a wide variety of plants), corresponding to a score of *neutral*.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Species experts considered genetic variation "low" for the Lower Keys marsh rabbit relative to related taxa, corresponding to a score of *somewhat increases* vulnerability. Genetic factors were scored in factor C5b for the mainland population.

Table A14-3. Scores assigned to factors associated with vulnerability to climate change for marsh rabbit in Florida (peninsular populations). Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

Table A14-4. Scores assigned to factors associated with vulnerability to climate change for Lower Key marsh rabbit in Florida. Scores assigned to bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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							•

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a. For the mainland population, this factor was scored as *neutral* (no evidence of a population bottleneck) as specific information on measured genetic variation was not available.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown.*

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Marsh rabbit ranked as "Moderately Vulnerable" within peninsular Florida, and the Lower Keys marsh rabbit ranked as "Extremely Vulnerable." Overall, the reviewers' scores suggest that factors related to indirect exposure are likely to have a much larger impact on Lower Keys marsh rabbit compared to peninsular populations (Tables A14-3 and A14-4). Other factors thought to increase vulnerability to climate change included potential changes in hydrology that could affect habitat availability, and changes to disturbance regimes, some of which may have positive impacts on habitat (increased fire frequency) and others with potentially negative impacts (increased hurricane intensity and storm surges). Only one sensitivity factor was scored as unknown.

The index score for the Lower Keys marsh rabbit was much higher than that of peninsular populations of marsh rabbit in Florida (12.8, range [11.0, 14.4] vs. 4.5, range [0.1, 8.1]; Figure A14-2). The Monte Carlo simulations indicate that the index score is fairly sensitive to the range of parameter inputs assigned in the peninsular analysis, producing scores ranging from "Not Vulnerable/Presumed Stable" to "Highly Vulnerable." In the peninsular analysis, approximately 35% of the Monte Carlo simulations produced scores in the "Presumed Stable" range. Fewer factors were assigned multiple scores for Lower Keys marsh rabbit, resulting in a much narrower range of index scores. It is important to note that the entire range of this subspecies is highly threatened by sea level rise under the projections used for this assessment. According to expert opinion, sea level rise and natural barriers alone should probably qualify the Lower Keys marsh rabbit as "Extremely Vulnerable" to climate change.

The peninsular population was flagged as potentially shifting range within the assessment area in response to climate change, indicating that the species may have the potential to track changing climate. Species that are exposed to few barriers and have good to moderate dispersal capability generally fall into this category, but will be limited by the ability of the

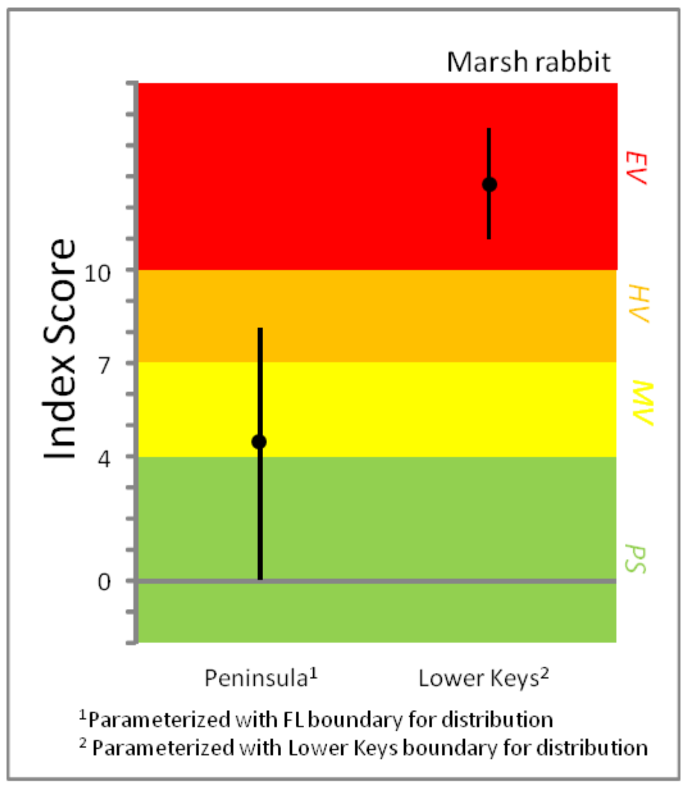

Figure A14-2. CCVI output for marsh rabbit (peninsular populations and Lower Keys subspecies) in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

associated habitat to shift. Natural barriers surrounding the Lower Keys marsh rabbit limit the potential for the subspecies to shift in response to climate change.

Finally, we explored sensitivity of the index score to the scores assigned to factor C2b*ii* (*physiological hydrological niche*), which was scored with relatively low confidence, by expanding the range of scores to include all values from "neutral" to "greatly increases" vulnerability. Incorporating this additional uncertainty had no effect on the value of the index scores, but did increase the range of outputs generated by the Monte Carlo simulations (ranges [-0.9, 9.8] and [9.7, 15.82] for the peninsular analysis and the Keys respectively.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for marsh rabbit is G5 (not ranked in Florida). The global conservation status rank for Lower Keys marsh rabbit is G5T1. The subspecies' rank is S1 in Florida.

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A15. RIVER OTTER *(Lontra canadensis)*

Species Expert(s): Robert Brooks, Bob McCleery

River otters can be found in freshwater and, less commonly, in brackish habitats, including streams, lakes, ponds, swamps, marshes and estuaries near sufficient cover (NatureServe 2011). Their historic range included most of North America north of Mexico. However, following European colonization, river otters were extirpated from large portions of the interior U.S. The species has since been reintroduced to some parts of its range. River otters feed opportunistically on aquatic animals, primarily fishes, but also other vertebrates and invertebrates. When inactive, river otters inhabit burrows on the banks of the water body, particularly under the roots of trees (NatureServe 2011).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. The range map available from NatureServe (Patterson et al. 2004; Map A15-1), indicates that river otters occur throughout the state of Florida. Species experts noted that the species is concentrated around freshwater resources but utilizes most aquatic habitats, which is not captured in the range map. We received a potential habitat model (phm) developed by FWC after the worksheets module had been developed (provided by B. Stys, FWC, December 2010). As a result, the potential habitat model was not evaluated by the species experts as part of this assessment, but we did use it for comparison in calculating exposure. FNAI element occurrence data were not available for this species.

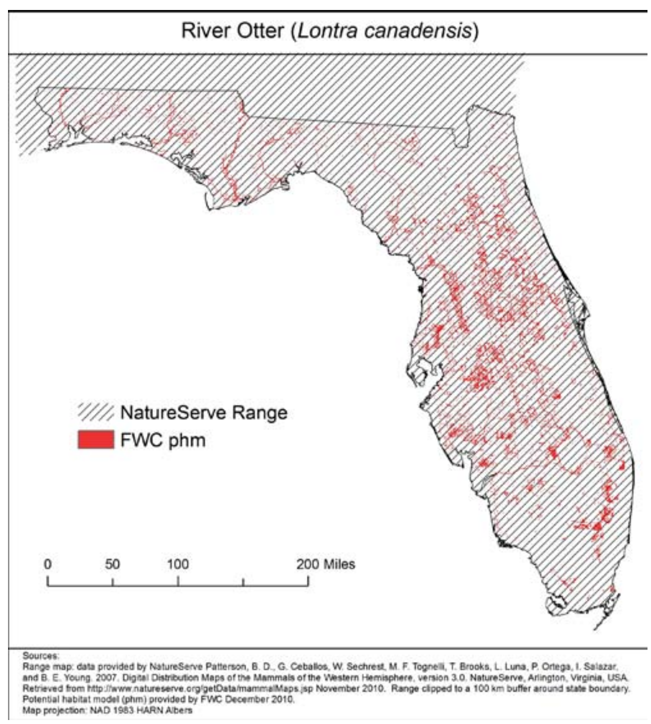

Figure A15-1. Distribution inputs considered for the CCVI analysis.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture

Table A15-1. Projected temperature exposure for river otter in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range	FWC phm
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	35%	15%
< 3.9°F warmer	65%	85%
(E_T)	*0.8*	*0.4*

Table A15-2. Projected moisture exposure (based on the Hamon Index) for river otter in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	NatureServe Range	FWC phm
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	2%	1%
-0.096 - -0.074	34%	35%
-0.073 - -0.051	61%	62%
-0.050 - -0.028	3%	2%
> -0.028 (No change)	0%	0%
(E_M)	*1.0*	*1.0*

data, in the form of the Hamon AET: PET moisture metric was downloaded from NatureServe, and is derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A15-1 and A15-2).

Indirect Exposure

Sea level rise (B1). Both experts assigned scores corresponding to "somewhat increases" vulnerability for this factor based on estimates that 10-49% of the species' range is expected to be impacted by a 1-meter sea level rise. One of the experts also indicated that the species occurs in an intertidal habitat that is expected to increase in extent with a rising sea level. However, the associated score ("somewhat decreases" vulnerability) was not supported by the written comments provided by reviewers. As sea level rises, estuarine habitats will move inland, but it is unclear whether this will create additional habitat or simply result in habitat shifts. Furthermore, species experts indicated that otters are less common in brackish water, so not only is habitat being lost, but some areas would become more brackish. We assigned a score of *somewhat increases* vulnerability to this factor.

Potential impact of barriers on range shifts. The species experts indicated that river otters use most aquatic habitats, usually foraging in the water and resting or denning along riparian areas. Both experts considered these habitats vulnerable to climate change, both as a result of sea level rise due to projected drier conditions which could affect aquatic habitats. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Uplands that do not convert to aquatic habitats following sea encroachment were mentioned as a possible natural barrier. Genetic differences between coastal and inland populations of otters along the Gulf Coast also suggest that some natural barriers exist, caused by habitat or feeding preferences. Both species experts selected the description stating that "small barriers exist but are not likely to significantly impair distributional shifts with climate change," corresponding to a score of *neutral* for this factor. We also included a score of *somewhat increases* vulnerability to capture the uncertainty associated with their scores.

Anthropogenic barriers (B2b). Urban areas were identified as anthropogenic barriers affecting this species. Estimates of the species' range that would be impacted by anthropogenic barriers ranged from 10 to 20% with moderate confidence in these estimates. This factor was scored as *neutral* or *somewhat increases* vulnerability.

Land Use Changes Resulting from Human Responses to Climate Change (B3). Reviewers considered the possibility that shoreline hardening and sea walls could potentially reduce or eliminate access to foraging and denning areas. We captured the uncertainty associated with this factor by including scores of *neutral* and *somewhat increases* vulnerability.

Sensitivity

Dispersal and movement (C1). Experts characterized the species as having "good" to "excellent" dispersal capabilities, up to 30-60 km in the western U.S., however in the Gulf states dispersal distances appear to be less (up to 7 km). This factor was scored as *somewhat decreases* or *decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases*, and *somewhat increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* The species was characterized as not having an association with a particular thermal environment. River otters can tolerate a wide range of thermal regimes, and given the wide array of aquatic habitats that are used in the assessment area, river otter was considered unlikely to be restricted to particular thermal environments in Florida. This factor was scored as *neutral*.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was identical for both distribution inputs, ranging from 46-67 inches, which corresponds to a score of *neutral*.

*Physiological hydrologic niche (C2b*ii). The species experts considered the association with aquatic habitats in assessing this factor, indicating that drier conditions could reduce the availability of suitable habitat. Both reviewers selected the description associated with "increases" vulnerability for this factor, although there was moderate confidence attributed to the degree to which habitat will be impacted by climate change. We also included a score of *somewhat increases* and *increases* vulnerability to capture this uncertainty.

Impacts of Changes to Specific Disturbance Regimes (C2c). One species expert mentioned that changes in fire and flooding regimes could have moderate negative impacts on the species, corresponding to a score of "somewhat increases" vulnerability. Otters use emergent wetlands that may experience increased fire frequency and intensity, and excessive flooding along river changes could destabilize bands used for denning and resting. We included scores of *somewhat increases* vulnerability and *neutral*, capturing both reviewer's scores.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Both species experts considered this species to be highly generalized relative to dependence on geological features or derivatives, corresponding to a score of *decreases* vulnerability. We also included a score of *somewhat decreases* vulnerability, which applies to species "not strongly tied" to any specific geologic feature or derivative.

Dependence on other species to generate habitat (C4a). The required habitat was not considered to be dependent on a small number of species. This factor was assigned a score of *neutral*.

Dietary versatility (C4b). Species experts characterized the diet as "flexible," corresponding to a score of *neutral*. However, river otters do exhibit preferences among fishes, crustaceans, and amphibians, and warming could shift prey availability or abundance.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Species experts characterized the genetic variation as "average" to "high" based on published information. This factor was scored as *neutral* to *somewhat decreases* vulnerability.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

River otter ranked as "Not Vulnerable/Presumed Stable" in Florida using both the NatureServe range and FWC potential habitat to estimate exposure. The variation in index scores under both exposure estimates reflects the large number of parameters that were assigned multiple scores. The primary factor contributing to vulnerability was the species' dependence on aquatic habitats, captured in the factor associated with physiological hydrologic niche (Table A15-3). A number of other factors, particularly those related to indirect exposure and potential changes to disturbance regimes, also contributed to vulnerability, but to a lesser degree. Several factors contribute to adaptive capacity in this species, such as good dispersal ability and relatively high genetic variation. Only one sensitivity factor was scored as unknown.

The NatureServe range and FWC potential habitat generated slightly different exposure metrics (Tables A15-1 and A15-2), accounting for the higher index score based on the NatureServe range compared to the potential habitat model (2.8, range [-1.5, 7.1] vs. 2.4, range [-0.6, 5.4], Figure A15-2). In both cases, a majority of the Monte Carlo simulations produced scores falling in the "Not Vulnerable/Presumed Stable" category. Only 17% and 5% of the Monte Carlo simulations produced scores in the "Moderately Vulnerable" category for the NatureServe range and potential habitat model respectively.

River otter is a wide ranging species and different factor scores would likely apply to different parts of the species' range. For example, one of the reviewers

Table A15-3. Scores assigned to factors associated with vulnerability to climate change for river otter in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

suggested that warming temperatures might have a greater effect on prey ability or competition on river otters occurring in cooler climates in the northern part of their continental range, but would be unlikely to have much of an effect in warmer portions of the range (e.g., Florida) where river otters use an array of aquatic habitats and might be more likely to be able to adapt to projected increases in temperature.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for river otter is G5 (not ranked in Florida).

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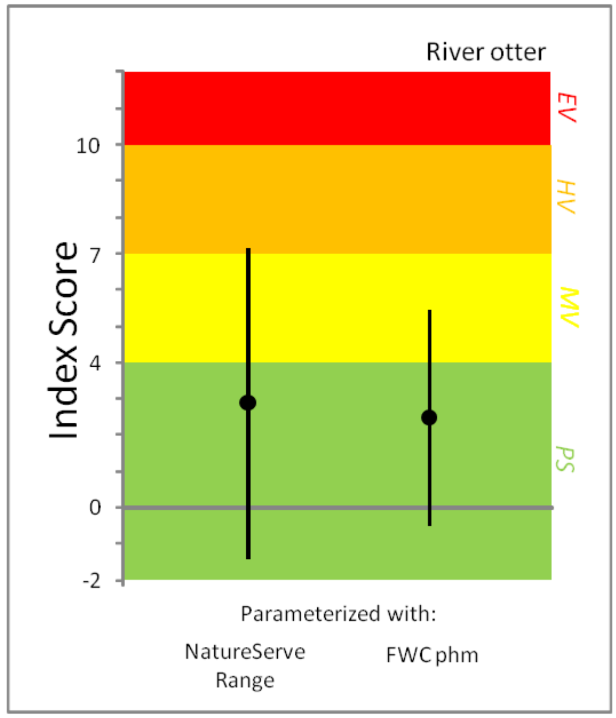

Figure A15-2. CCVI output for river otter in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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A16. FLORIDA PANTHER *(Puma concolor coryi)*

Species Expert(s): Darrell Land, Chris Belden

This subspecies of the North American cougar was formerly found throughout the southeastern U.S., extending from Arkansas and Louisiana south to Florida (Hipes et al. 2001). However, the current distribution of Florida panther is limited to a few counties in southern Florida. Florida panthers occur in Collier, Glades, and Lee counties as well as Miami-Dade and Monroe counties, although individuals may disperse north of these areas. Florida panthers require large blocks of mostly forested land, most often lowlands and swamps, but also upland forests in some parts of the range. Large wetlands are used during the day for denning daytime resting sites (Hipes et al. 2001, NatureServe 2011). The Florida panther is listed as endangered.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A16-1) included a range map available from NatureServe (Patterson et al. 2004), a potential habitat model (phm) developed by FWC (Endries et al. 2009), and a map of USFWS primary habitat provided by one of the reviewers (C. Belden, pers. comm.). The species experts indicated that the NatureServe range and FWC phm did not accurately reflect the current area of occupancy for this species, the latter significantly overestimating the current extent of occurrence. We included it in our analysis in order to examine how sensitive the index scores were to the distribution data set used to estimate exposure. We did not include the NatureServe range map in our analysis. FNAI occurrence data (FNAI 2011) consisted of 5 records and were not used in this assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A16-1 and A16-2).

Indirect Exposure

Sea level rise (B1). The species experts estimated that approximately 5-10% of the species' existing habitat is expected to be impacted by a 1-meter sea level rise. This factor was scored as *neutral.*

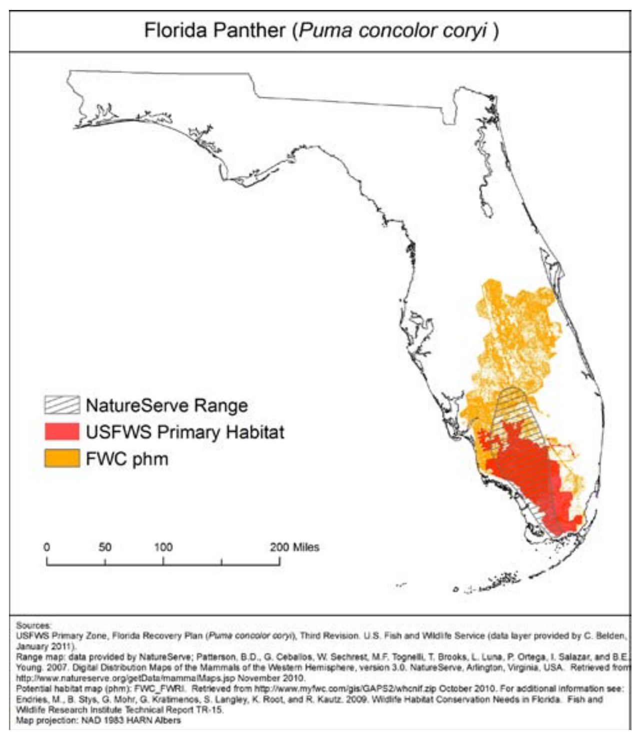

Figure A16-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Table A16-1. Projected temperature exposure for Florida panther in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	USFWS primary habitat	FWC phm
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	0%	0%
< 3.9°F warmer	100%	100%
(E_T)	*0.4*	*0.4*

Table A16-2. Projected moisture exposure (based on the Hamon Index) for Florida panther in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	USFWS primary habitat	FWC phm
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	22%	8%
-0.096 - -0.074	78%	80%
-0.073 - -0.051	0%	12%
-0.050 - -0.028	0%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.3*	*1.3*

Potential impact of barriers on range shifts. Factors B2a and B2b are relevant for habitats expected to be vulnerable to climate change. Species occurring in habitats that are likely to persist despite climate change are scored as "neutral" because, in these situations, barriers do not contribute to vulnerability in the absence of climate-induced range shifts. The species experts considered this to be the case for Florida panther, which uses an array of forested as well as other non-urban habitats in proportion to availability. As a result, even though natural and anthropogenic barriers negatively affect panther movement in its current area of occupancy, climate change will not necessarily increase the negative impact imposed by these barriers. We have described the natural and anthropogenic barriers identified by the species experts, but scored these factors as "neutral." We also ran the CCVI with higher scores assigned to natural and anthropogenic barriers in order to look at the sensitivity of the CCVI ranks to the scoring for these factors.

Natural barriers (B2a). Experts identified Shark River Slough and other Everglades habitats to the south and east of the occupied range and the Caloosahatchee River to the north as natural barriers. The river presents a barrier mainly to females. Dispersing males cross this area.

Anthropogenic barriers (B2b). Experts identified intensive urban development on the east and west coasts of Florida as anthropogenic barriers.

Land Use Changes Resulting from Human Responses to Climate Change (B3). One reviewer mentioned in written comments that the area of occupancy may be reduced due to a shift of the human population further inland in response to sea level rise and scored this factor as "somewhat increases" vulnerability. The second reviewer provided a score of "neutral" for this factor. We included scores of *somewhat increases* vulnerability and *neutral* in order to capture the uncertainty associated with this factor.

Sensitivity

Dispersal and movement (C1). Both experts characterized the species as having "excellent" dispersal, with dispersal distances averaging 20 km for females and 60 km for males. This factor was scored as *decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases* and *increases* vulnerability.

Physiological thermal niche (C2aii). One expert indicated that the species has no association with a particular thermal environment, corresponding to a score of neutral. The second expert mentioned requirements for shady understory vegetation for daytime resting sites and den sites. As these microhabitats were not considered to be particularly vulnerable to climate change, his response also corresponded to a score of *neutral*.

Historical hydrologic niche (C2bi). This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was similar for both distribution inputs, corresponding to a score of *increases* vulnerability in both cases.

Historical precipitation exposure
USFWS primary zone: 50-59 inches
FWC phm: 47 - 57 inches

Physiological hydrologic niche (C2bii). The species experts indicated that drier conditions could potentially increase the availability of denning habitat for females, although they expressed uncertainty in the impact this would have on Florida panther. They considered the species to have little dependence on a specific wetland habitat and/or broad moisture regime tolerances. This factor was scored as *neutral* or *somewhat decreases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species experts considered the impacts of changes to fire regimes on Florida panther. Increased fire could increase forage for deer, thereby increasing prey availability. However, fire may also reduce the availability of daytime resting sites and available den sites in thick vegetation. Both experts scored this factor as "neutral" with moderate uncertainty regarding the expected change in frequency, severity, and/or extent of the disturbance regime. We examined the sensitivity of this factor to alternative score selections by expanding their score selections to include *somewhat increases*, *neutral*, *somewhat decreases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Reviewers did not feel that the idea of specificity to a particular geologic feature or derivative was particularly relevant to this species, corresponding to score of *somewhat decrease* vulnerability.

Dependence on other species to generate habitat (C4a). The required habitat was not considered to be dependent on a small number of species. Both reviewers assigned a score of *neutral* to this factor.

Dietary versatility (C4b). The species experts selected scores corresponding to "neutral" and "somewhat increases" vulnerability for this factor, indicating that large mammals such as white-tailed deer and wild hog are required, but smaller animals such as raccoon and armadillo may be taken opportunistically. There appears to be a big jump between the descriptions corresponding to scores of "somewhat increases" vulnerability (i.e., diet is dependent on a "few species from a single guild") and neutral (i.e., diet is "flexible"). Based on their written descriptions of diet, Florida panther appears to follow somewhere in between these two categories, so we included scores of both *neutral* and *somewhat increases* vulnerability for this factor.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). The reviewers cited studies indicating that the number of polymorphic microsatellite loci and amount of genetic variation are lower than for other related subspecies. However average heterozygosity has increased following the introduction of eight female Texas pumas to the population. One species expert described genetic variation in this species as "very low" and the other selected "low" compared to related taxa. In follow up discussion, these differences in response primarily reflected differences in pre- and post-augmentation variation. We included both scores, corresponding to *increases* and *somewhat increases* vulnerability.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a.The species experts indicated that this species was down to as few as 20-30 individuals in the early 1980's, increasing to 100-160 adult panthers today, which would correspond to a score of "increases" vulnerability. This score is already captured in factor C5a.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown.*

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Florida panther ranked as "Not Vulnerable/Presumed Stable" to climate change in Florida. None of the factors examined were scored as greatly increasing vulnerability (Table A16-3). Factors that were identified as contributing to vulnerability included potentially incompatible human responses to climate change, changes in fire regime that might reduce the availability of resting and denning sites, and genetic variability. Only one sensitivity factor was scored as unknown.

Both of the distribution data sets used in this analysis produced equivalent exposure metrics (Tables A16-1 and A16-2), even though the potential habitat was much larger than the species current extent of occurrence. The index score was 2.6 (range [0, 5.28]; Figure A16-2) regardless of the distribution data set used. Low sensitivity to the differences in the distribution inputs is not surprising given that the resolution of the exposure data is fairly coarse (approximately 15 km) and the relatively narrow distribution of the species. Index scores fell within the "Presumed Stable" range in approximately 90% of the Monte Carlo simulations, with the remainder in the "Moderately Vulnerable" category.

It is important to recognize that a score of "Presumed Stable" for this species only applies to vulnerability to climate change within the species' current extent and may not adequately capture climate-related vulnerability that may impact the species in its recovered range. This species is still critically threatened by other factors, such as habitat loss and alteration, as evidenced by the species' conservation rank. The CCVI is not designed to capture factors incorporated in other conservation status assessments, such as population size, and/or demographic factors which

Table A16-3. Scores assigned to factors associated with vulnerability to climate change for Florida panther in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

may magnify species' vulnerability to climate change. In addition, the CCVI does not capture the impact of climate change on the conservation actions still needed for recovery. For example, barriers were scored as "neutral" in term of vulnerability to climate change, but barriers do pose a significant threat in terms of recovery of the species because they restrict access to potential habitat.

The CCVI flagged this species as potentially shifting its range. This result is based on the low scores assigned to barriers combined with relatively high exposure and fairly good dispersal, but does not account for the fact that substantial barriers exist. The scores assigned to barriers are based on the assumption that these barriers are not likely to contribute significantly to a reduction or loss of the species area of occupancy with projected climate change. Relaxing this assumption, by assigning scores of "greatly increases" or "increases" vulnerability for natural barriers and somewhat increases vulnerability for anthropogenic barriers, increased the vulnerability rank to "Moderately Vulnerable" (index score: 5.1, range [2.1, 8.1]).

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for Florida panther is G5T1. The species' rank is S1 in Florida.

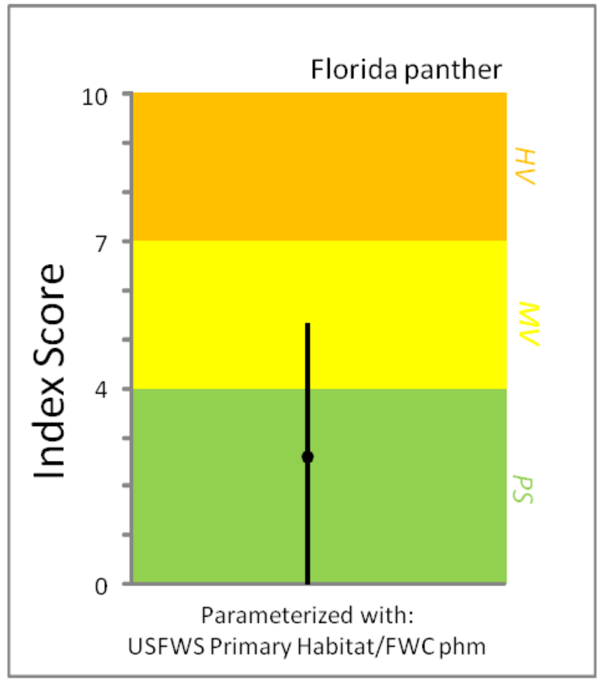

Figure A16-2. CCVI output for Florida panther in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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A17. KEY DEER *(Odocoileus virginianus clavium)*

Species Expert(s): Darrell Land, Chris Belden

This subspecies of the white-tailed deer formerly occurred throughout most of the Florida Keys, but the current range is restricted to the Lower Keys (NatureServe 2011). Key deer occupy a range of habitats, including hardwoods and pinelands with proximity to fresh water (Hipes et al. 2001). The subspecies is listed as endangered.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment (Figure A17-1) included a potential habitat model (phm) developed by FWC (Endries et al. 2009) and FNAI element occurrence data (FNAI 2011). The species experts felt that the potential model adequately represented the current distribution of Key deer. FNAI occurrence data included 15 records distributed throughout the area identified in the potential habitat model. Although we include the occurrenced data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for.mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A17-1 and A17-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Climate Wizard data were only available for the Florida peninsula, so we extrapolated values from the southern tip of the Florida peninsula into the Keys (see the methodology in the main report). Due to the small area occupied by this species, the entire distribution was contained within a single category for both temperature and moisture exposure (Tables A17-1 and A17-2).

Indirect Exposure

Sea level rise (B1). Both species experts assigned scores corresponding to *increases* vulnerability for this factor, based on estimates that approximately 50% of the species' range is expected to be impacted by a 1-meter sea level rise.

Potential impact of barriers on range shifts. The species experts indicated that the species primarily uses upland habitats in the lower Keys, including urban

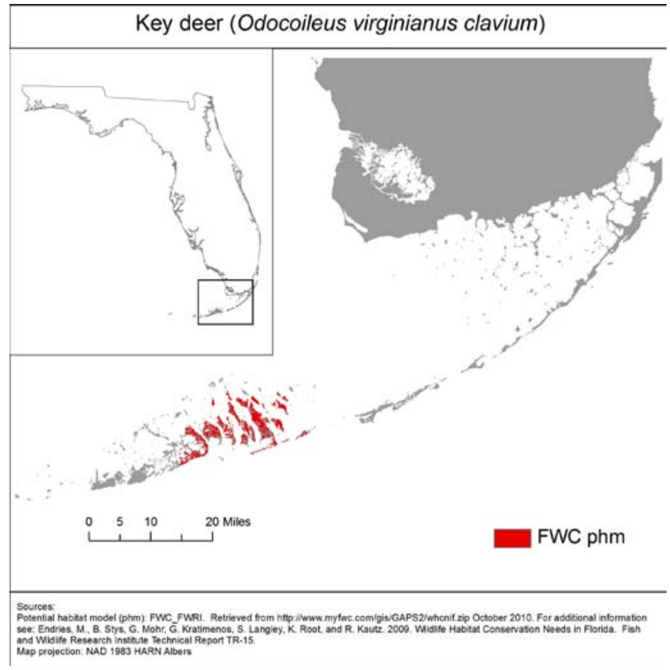

Figure A17-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

areas, and considered this habitat to be to be vulnerable to climate change. Species occurring in habitats that are considered likely to persist despite climate change would be scored as neutral for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). This species is restricted to the Florida Keys, with water surrounding the islands serving as a natural barrier to the species. Both experts scored this factor as *greatly increases* vulnerability.

Anthropogenic barriers (B2b). Neither species expert felt that anthropogenic barriers were likely to significantly impact this species. This factor was scored as *neutral.*

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species experts indicated that adaptation strategies such as sea walls could protect upland habitat. We included the range of responses selected by the reviewers in order to capture the uncertainty associated with the extent of future shoreline protection. This factor was scored as *neutral*, *somewhat decreases* and *decreases* vulnerability.

Table A17-1. Projected temperature exposure for Key deer in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set→ (Distribution	FWC phm/ FNAI occurrences
> 5.5°F warmer	0%
5.1 - 5.5 °F	0%
4.5 - 5.0 °F	0%
3.9 - 4.4 °F	0%
< 3.9°F warmer	100%
(E_T)	*0.4*

Table A17-2. Projected moisture exposure (based on the Hamon Index) for Key deer in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set→ (Distribution)	FWC phm/ FNAI occurrences
< -0.119 (Driest)	0%
-0.119 - -0.097	0%
-0.096 - -0.074	100%
-0.073 - -0.051	0%
-0.050 - -0.028	0%
> -0.028 (No change)	0%
(E_M)	*1.3*

Sensitivity

Dispersal and movement (C1). Both experts characterized the species as having "good" dispersal, estimating dispersal distance at 2-3 kilometers. This factor was scored as *somewhat decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included scores that applied to any part of the species' range in Florida (extrapolating values from the southern peninsula to the Keys), which for Key deer corresponded to a score of *greatly increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* The xperts both categorized the species as having "no association" with a particular thermal environment, corresponding to a score of *neutral*.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. Usually, the species' distribution is overlaid with the maps provided by NatureServe to assess this factor. However, since data were not available for the Florida Keys, we based this calculation on the range of cell values occurring in the southern tip of the Florida peninsula. The variation in precipitation ranged from 50 - 59 inches, which corresponds to a score of *increases* vulnerability.

*Physiological hydrologic niche (C2b*ii). Both reviewers cited reliance on freshwater for drinking. Freshwater holes and other freshwater wetlands are threatened by saltwater incursion. After discussion with the species experts, this factor was scored as *somewhat increases* or *increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species experts considered increased intensity hurricanes and associated storm surges as the major disturbance regime likely to affect Key deer under climate change. Storm surges are a source of saline incursion and hurricanes are a source of direct mortality. This factor was scored as *somewhat increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Initially one reviewer selected the description corresponding to increases vulnerability due to the association with geologic features required for water holes. However, based on follow up with this reviewer, we felt that the dependence on freshwater sources was already captured in the responses to factor C2b*ii*. The second reviewer selected the score that described the species as "highly generalized" relative to dependence upon geologic features, which corresponded to a score of decreases vulnerability. We also included a score of *somewhat decreases* vulnerability, applicable to species that are "not strongly dependent" on a particular geologic feature or derivative.

Dependence on other species to generate habitat (C4a). The species' habitat was not considered dependent on species-specific processes. Both reviewers assigned a score of *neutral* to this factor.

Dietary versatility (C4b). Experts characterized the diet as "flexible." One reviewer initially selected the description associated with a score of "somewhat decreases" vulnerability, presumably based on the species' adaptability to varied food sources, even in urban environments. Key deer are herbivorous in their natural environment. We adjusted the score for this factor to *neutral* (i.e., diet "flexible"), matching the score of the second reviewer.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Both reviewers characterized genetic variation in the species as "low," corresponding to a score of *somewhat increases* vulnerability. We also included a score of *increases* vulnerability for this factor based on the evidence provided for factor C5b.

Occurrence of bottlenecks in recent evolutionary history (C5b). The species experts cited studies suggesting that the Key deer population dropped to less than 50 individuals in the 1930s with subsequent rebound to 600-700 deer, which would correspond to a score of "increases" vulnerability. Since a score should only be reported for either factor C5a or C5b (not both), we included this higher score in the scoring for factor C5a rather than including it here.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Table A17-3. Scores assigned to factors associated with vulnerability to climate change for Key deer in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Key deer ranked as "Highly Vulnerable" to climate change in Florida. The primary factors contributing to vulnerability were sea level rise, the existence of natural barriers, and the impact of potential changes in hydrology, and disturbance regimes on freshwater drinking sources (Table A17-3). In addition, the species was identified as having relatively low genetic variation, which could impact the species' evolutionary adaptive capacity. Only one sensitivity factor was scored as unknown.

There was no difference in the exposure metrics based on the FWC potential habitat model and FNAI occurrence data, resulting in identical input parameters for both runs. This is not surprising given the small distribution for the species and the fairly coarse resolution of the data, especially in the Florida Keys where limitations in the exposure data set required us to extrapolate values for exposure and historical precipitation based on values for the southern peninsula. The index score was 9.3 (range, [7.2, 11.3]; Figure A17-2), with 78% of the Monte Carlo simulations occurring in the "Highly Vulnerable" category. Factors associated with indirect exposure (sea level rise and natural barriers) weighted heavily into the index score.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for Key deer is G5T1. The species' rank is S1 in Florida.

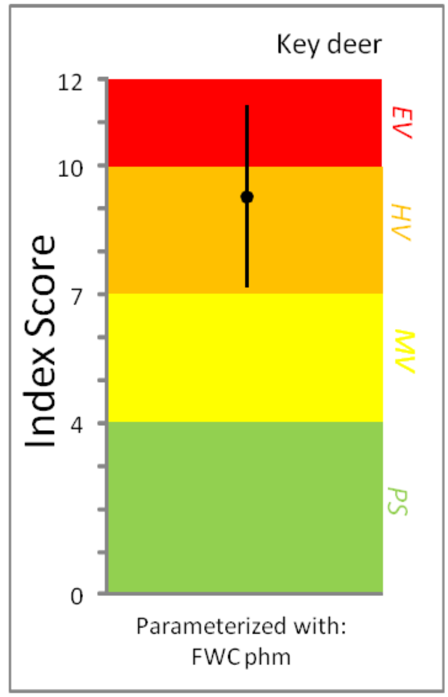

Figure A17-2. CCVI output for Key deer in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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A18. Red Widow *(Latrodectus bishopi)*

Species Expert(s): G.B. Edwards

Red widow spiders are found exclusively in central and southeastern Florida (NatureServe 2011). Their habitat is restricted to sand pine scrub, where they most commonly make their webs in scrub palmettos. The web is created by rolling a palmetto frond into a cone and tying it with silk.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. We were unable to find a range map for this species, so we mapped counties with known occurrences based on the information in NatureServe Explorer (NatureServe 2010, Figure A18-1). In addition, we received element occurrences (13 records) for this species from FNAI (FNAI 2011). Although we included the occurrence data for comparison with other distribution data, we did not specifically evaluate the how well the element occurrences approximated the range extent as part of our assessment.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a

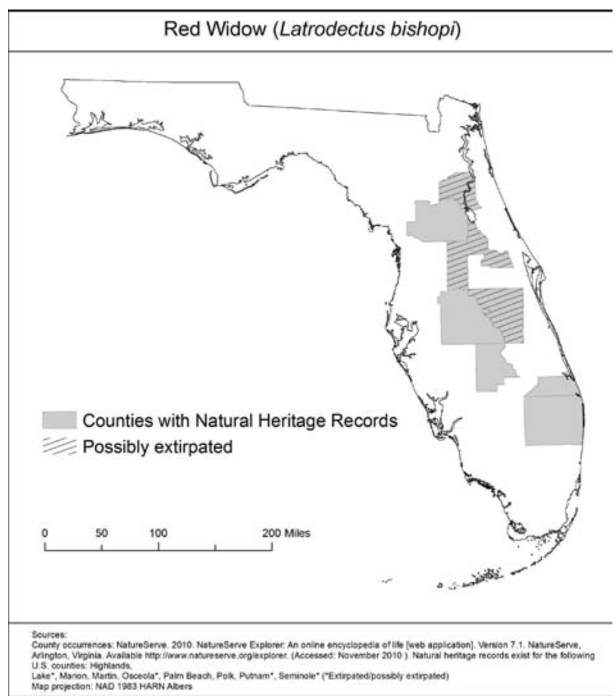

Figure A18-1. Distribution inputs considered for the CCVI analysis (FNAI element occurrences not shown).

Table A18-1. Projected temperature exposure for red widow in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	County occurrences	FNAI occurrences
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	0%	0%
< 3.9°F warmer	100%	100%
(E_T)	*0.4*	*0.4*

Table A18-2. Projected moisture exposure (based on the Hamon Index) for red widow in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	County occurrences	FNAI occurrences
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	0%	0%
-0.096 - -0.074	44%	62%
-0.073 - -0.051	56%	38%
-0.050 - -0.028	0%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.0*	*1.3*

particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A18-1 and A18-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). The species expert estimated that approximately 2% of the species' range would be impacted by a 1-meter sea level rise. This factor was scored as *neutral*.

Potential impact of barriers on range shifts. Factors B2a and B2b are relevant for habitats expected to be vulnerable to climate change. Species occurring in habitats that are likely to persist despite climate change are scored as neutral because, in these situations, barriers do not contribute to vulnerability in the absence of climate-induced range shifts. This was considered the case for red widow, which occurs primarily in xeric scrub associated with sand pine but also occurs in wooded sand dunes. We have described the natural and anthropogenic barriers identified by the species expert, but in both cases these factors have been scored as *neutral*.

Natural barriers (B2a). The species expert indicated that the species was restricted in habitat to vegetation limited by a soil type that cannot shift in location. This association is addressed in factor C3.

Anthropogenic barriers (B2b). Urban development completely divides the species' range in half and has apparently destroyed the southernmost portion of the original habitat.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert indicated that portions of current distribution occur in protected areas, but unprotected areas could potentially be exposed to increased development pressure resulting from human movement away from coasts. This factor was scored as *neutral* or *somewhat increases* vulnerability.

Sensitivity

Dispersal and movement (C1). The species expert characterized the species as having "low" to "moderate" dispersal or movement capability, corresponding to scores of *somewhat increases* vulnerability and *neutral*.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to a score of *increases* vulnerability.

*Physiological thermal niche (C2a*ii*).* The species expert indicated that the species is associated with warmer environments, corresponding to a score of *somewhat decreases* vulnerability. In follow up discussion, he indicated that excessively cold winters negatively affect red widow at the north edge of its range, which is consistent with our interpretation of this score as appropriate in cases in which the current range may be limited by temperature, such that warmer temperatures might promote range expansion.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was similar for both distribution inputs, but resulted in different scores, with *somewhat increases* vulnerability applying to the county occurrences and *increases* vulnerability applying to the point occurrence data.

Historical precipitation exposure
County occurrences: 46 - 60 inches
FNAI occurrences: 49-59 inches

*Physiological hydrologic niche (C2b*ii). The species expert was uncertain as to whether changes in moisture regime could potentially affect the plant associations providing web support structures or the availability of prey species and indicated that there was insufficient data for assessment of this factor. This factor was scored as *unknown*. We also examined the CCVI output with this factor scored as *increases*, *somewhat increases* and *neutral* to capture the uncertainty associated with this factor and to examine the sensitivity of the index score to scores for this factor.

Impacts of changes to specific disturbance regimes (C2c). The species expert considered fire regimes in scoring this factor. Depending on frequency, increased fire could affect habitat structure, thereby impacting available websites. However, he noted that the species is not affected by controlled burns. This factor was scored as *somewhat increases* vulnerability and *neutral*.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The species expert indicated that the species is associated with fossil or extant dune habitats that are highly uncommon relative to other habitat types. We adjusted the original score to reflect this dependence, assigning a score of *increases* vulnerability for this factor.

Dependence on other species to generate habitat (C4a). The species expert indicated that web support in most of range is dependent on presence of *Sabal etonia* and *Serenoa repens*. This factor was scored as *somewhat increases* vulnerability.

Dietary versatility (C4b). Diet includes assorted arthropods associated with the preferred habitat, but is not specific to a certain type. The species expert characterized the diet as "flexible," corresponding to a score of *neutral*.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species is wind-dispersed by ballooning. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). The species expert did not feel that there was enough information available to assess this factor. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). The species expert did not feel that there was enough information available to assess this factor. This factor was scored as *unknown*.

Phenological response (C6). The species expert was not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Red widow ranked as "Moderately Vulnerable" to "Highly Vulnerable" to climate change in Florida depending on the data set used to estimate the species' distribution. The main sensitivity identified for this species (Table A18-3) was its dependence on vegetation that is limited by soil type, which is captured in factor C3 (*physical habitat specificity*). Red widow is entirely restricted to a single habitat in peninsular Florida, which cannot shift in location due to its dependence on particular soils. However, this xeric habitat was not identified as being particularly vulnerable to climate change. The score for this factor should not be taken to suggest that the inability of the habitat to shift in location is not an important consideration in the conservation of this species. In fact it likely exacerbates the threat of habitat loss, which the species expert considered to be a larger threat than climate change for this species, as there is no place else the habitat can go. The species expert did not feel that the CCVI score was able to adequately capture this habitat dependence, suggesting that soil types and vegetation should be more explicitly factored in to the model. Two sensitivity factors were scored as unknown. One additional factor (*physiological hydrologic niche*) was given an alternative score of unknown.

Table A18-3. Scores assigned to factors associated with vulnerability to climate change for red widow in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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)[1]		(•)	•			--	
Physiological hydrologic niche[2]		•	•	•		--	
Disturbance regimes	--		•	•			
Ice and snow				•	--	--	
Physical habitat specificity	--	•					
Biotic habitat dependence			•		--	--	
Dietary versatility	--			•		--	
Biotic dispersal dependence	--			•	--	--	
Other interactions: none	--			•	--	--	
Genetic variation	--					--	•
Phenological response	--					--	•

[1] The higher value is assigned to this factor when using the element occurrences to estimate the species' distribution.
[2] We also ran the model with this factor scored as unknown.

The index score based on the county occurrences was 5.1 (range [3.2, 7.0], Figure A18-2). Differences in resolution between the data sets used to approximate the species' distribution affected the index score for this species. The element occurrences may underestimate the actual distribution, whereas the county data overestimate the actual distribution. The element occurrence data produced a higher moisture exposure metric (E_M) than the county occurrence data. When this higher exposure was combined with a higher value for historical hydrologic niche based on the GIS overlay, the resulting index scores were considerably higher when parameterized with the element occurrences (index score: 7.6, range [5.2, 9.9]). Results based on the county occurrences are shown in Figure 5 of the main report.

Based on the parameters associated with the county occurrence data, 85% of the Monte Carlo simulation runs fell within the "Moderately Vulnerable" range, with the remainder ranked as "Not Vulnerable/ Presumed Stable". These values shifted up by approximately one category for the parameters associated with the element occurrence data, with 65% of the scores falling in the "Highly Vulnerable" range and the remainder ranking as "Moderately Vulnerable."

When we scored factor C2b*ii* (*physiological hydrologic niche*) as unknown, the index scores dropped by approximately one unit, shifting the score based on the element occurrences down to the "Moderately Vulnerable" range (6.3, range [5.2, 7.3]). Using parameters derived from the county occurrence data, the Monte Carlo simulations were equally split between "Moderately Vulnerable" and "Presumed Stable" based parameters (score: 4.1, range [3.2, 5.0]).

Interestingly, the CCVI flagged this species as potentially shifting its range. This result is based on the low scores assigned to barriers combined with relatively high exposure and fairly good dispersal while also taking the orientation of the assessment area relative to the species' range into account. However, it clearly does not account for the physical habitat specificity captured in factor C3.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for red widow is G3/G4. The species' rank is S3/S4 in Florida.

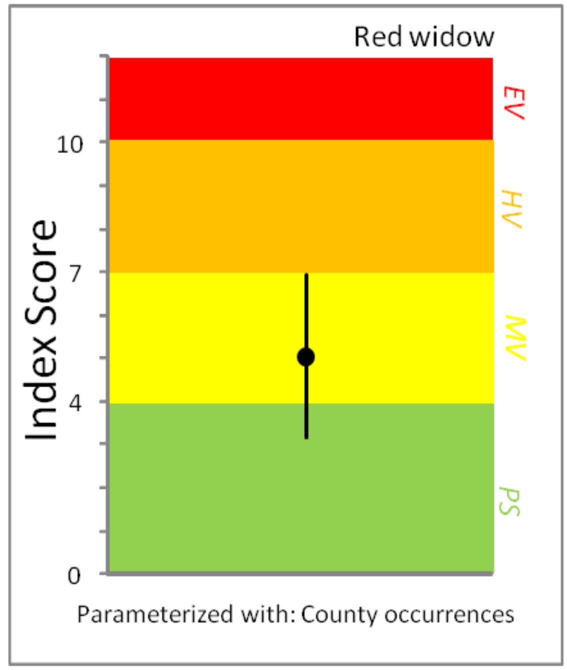

Figure A18-2. CCVI output for red widow in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

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A19. Salt Marsh Skipper *(Panoquina panoquin)*

Species Expert(s): Marc Minno

Salt marsh skipper occurs in coastal salt marshes and brackish marshes along much of the Florida coastline. The species' broader range in the U.S. spans along the Atlantic coast from New York to Florida and west along the Gulf Coast into Texas (Opler et al. 2010). The adults feed on nectar from a variety of flowers, including some upland species (M. Minno pers. comm.). The caterpillars are restricted to a few species of salt marsh grasses as host plants. Several broods are produced from February to December in Florida (Opler et al. 2011).

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. We were unable to find a distribution data set for this species, so we mapped counties with known occurrences of salt marsh skipper (Opler et al. 2011). We also used the salt marsh habitat layer from the Florida Comprehensive Wildlife Conservation Strategy (2005) as a proxy for the species' distribution (Figure A19-1). FNAI element occurrences were not available for this species.

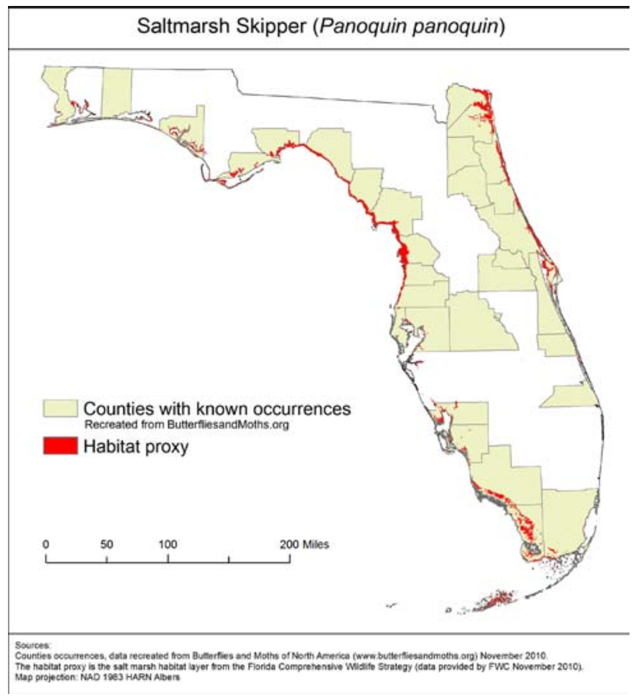

Figure A19-1. Distribution inputs considered for the CCVI analysis.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A19-1 and A19-2).

Indirect Exposure

Sea level rise (B1). The species expert estimated that approximately 99% of the species' current range is expected to be impacted by a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. The species expert described the habitat for this species as salt marshes and edges of mangrove swamps having the larval host grasses (*Spartina alterniflora*, *Sporobolus virginicus*, and *Distichalis spicata)*. Factors B2a and B2b are relevant for habitats expected to be vulnerable to climate change. Species occurring in habitats that are likely to persist despite climate change are scored as neutral because, in these situations, barriers do not contribute to vulnerability in the absence of climate-induced range shifts.

Natural barriers (B2a). The species expert noted that this species is known to disperse over long distances, but indicated moderate uncertainty regarding the impact of natural barriers on distributional shifts. The description that he selected ("barriers exist but

Table A19-1. Projected temperature exposure for salt marsh skipper in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	County occurrences	Habitat proxy
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	15%	13%
< 3.9°F warmer	85%	87%
(E_T)	*0.4*	*0.4*

Table A19-2. Projected moisture exposure (based on the Hamon Index) for salt marsh skipper within the assessment area. The percentages are used to calculate the exposure weight (E_M) that modifies the sensitivity scores. See Young et al. (In press) for details.

Data set → (Distribution)	County occurrences	Habitat proxy
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	6%	7%
-0.096 - -0.074	31%	19%
-0.073 - -0.051	60%	72%
-0.050 - -0.028	3%	2%
> -0.028 (No change)	0%	0%
(E_M)	*1.0*	*1.0*

are not likely to contribute significantly to reduced habitat or loss in the area of occupancy") corresponds to a score of *neutral*. We also assigned a score of *somewhat increases* vulnerability to capture the uncertainty associated with the response. In other assessments for species occurring in similar habitat, reviewers thought it relevant to include associations with habitat when assessing the impact of barriers and assigned higher scores to this factor. For example, coastal topography might pose a natural barrier to salt marsh migration. In order to capture the indirect threat posed by barriers through impacts on habitat availability, we also ran a separate scenario in which we scored this factor as *increases* and *somewhat increases* vulnerability.

Anthropogenic barriers (B2b). The species expert indicated that extensive urban areas along the coast likely form at least partial barriers to dispersal and highways are a source of direct mortality, but expressed moderate uncertainty regarding the impact of anthropogenic barriers on distributional shifts. He selected the description stating that "small barriers exist but are not likely to significantly impair distributional shifts," corresponding to a score of *neutral*. We also assigned a score of *somewhat increases* vulnerability to capture the uncertainty associated with the response.

In other assessments for species occurring in similar habitat, reviewers included the potential impact of highly developed areas along the coast on the associated habitat in their assessment, and assigned higher scores to this factor. In order to capture the indirect threat posed by barriers through impacts on habitat availability, we also ran a separate scenario in which we scored this factor as *increases and somewhat increases* vulnerability.

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert noted that salt water wetlands have a high degree of protection from land use changes in Florida, assigning a score of *neutral* to this factor. We also included a score of *somewhat increases* vulnerability to capture situations in which this might not be the case and coastal armoring might affect hydrology and/or habitat shifts. This mirrors the scoring indicated in other assessments for species occurring in similar habitats.

Sensitivity

Dispersal and movement (C1). The species expert characterized the species as having "moderate" to "good" dispersal capability, corresponding to a score of *somewhat decreases* vulnerability. The species is known to disperse into the Lower Florida Keys and occasionally inland.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area. This is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. We assessed this factor using the maps provided by NatureServe. We included all scores that applied to any part of the species' range in Florida, which corresponded to scores of *greatly increases*, *increases* and *somewhat increase*s vulnerability.

*Physiological thermal niche (C2a*ii*)*. The species expert noted that in Florida the species is absent from, or only transiently present, in the most tropical areas of the state and selected the description stating that the species is "somewhat restricted" to relatively cool environments that may be lost or reduced as a result of climate change. This factor was scored as *somewhat increases* vulnerability.

*Historical hydrologic niche (C2b*i*)*. This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. We overlaid the species' distribution with the maps provided by NatureServe to assess this factor. The calculated value for variation in precipitation was identical for both distribution inputs, ranging from 47-67 inches, which corresponds to a score of *somewhat increases* vulnerability.

*Physiological hydrologic niche (C2b*ii). The species expert considered the dependence on salt marshes and edges of mangrove swamps, habitats that are associated with a specific hydrologic regime. The descriptions ask for an assessment of both the dependence on a particular wetland habitat as well as the vulnerability of that habitat to climate change. The species expert selected the description associated with "greatly increases" vulnerability presumably due to the high dependence on a specific wetland habitat. However, in his written comments, he expressed uncertainty regarding how much habitat loss will occur and identified a data gap in modeling. In some areas these habitats are likely to move upslope with sea level rise, while other areas will be too deep to support salt marshes, and current areas of freshwater marsh may shift to salt marsh. We captured this uncertainty by adjusting the score for this factor to include the range of scores from *greatly increases* vulnerability to *neutral*.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species expert indicated that increased frequency and duration of flooding in salt marshes could have strong negative impacts on salt marsh skipper (direct mortality to caterpillars). This factor was scored as *increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). A response was not selected for this factor. We assigned scores of *neutral* and *somewhat decreases* vulnerability, the latter score applies to species for which the idea of specificity to a particular geologic feature or derivative is not relevant.

Dependence on other species to generate habitat (C4a). The species expert indicated that the larval stage is restricted to a few species of grasses (*Spartina alterniflora*, *Sporobolus virginicus*, and *Distichalis spicata)*. This factor was scored as *somewhat increases* vulnerability.

Dietary versatility (C4b). The species expert indicated that the caterpillars eat a few species of grasses that grow in salt marshes (see C4a). The adults sip nectar from a variety of plants and may wander into uplands. Based on the relatively narrow diet breadth for the larval stage, this factor was scored as *somewhat increases* vulnerability.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Interspecific interactions with the host plant for larvae were captured in C4a. This factor was scored as *neutral*.

Measured genetic variation (C5a). The species expert did not feel that there was enough information available to assess this factor. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). The species expert scored this factor as *neutral* (no evidence for a population bottleneck within the last 500 years).

Phenological response (C6). The species expert was not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Salt marsh skipper ranked as "Highly Vulnerable" to "Extremely Vulnerable" to climate change in Florida, depending on how natural and anthropogenic barriers were scored. Initially, we assigned the lower scores to these factors (see sections B2a and B2b above), which resulted in a rank of "Highly Vulnerable" and flagged the species as potentially shifting its range. Feedback provided by our reviewer questioned whether this rank adequately captured the vulnerability of the species' habitat to sea level rise. Range shifts are likely limited by habitat availability, which will be dependent on the availability of habitat to migrate in response to sea level rise. When we modified the scoring of factors B2a and B2b to include the potential impact of barriers on habitat shifts (i.e., assuming that barriers will prevent habitat shifts) the rank for salt marsh skipper increased to "Extremely Vulnerable." This assumes that the combination of sea level rise and barriers will significantly reduce habitat availability for salt marsh skipper in the assessment area. It does not however, address the availability of potential habitat outside of the assessment area under climate change.

The primary factors contributing to vulnerability for salt marsh skipper included sea level rise and the impact of potential changes in hydrology on the associated habitat (Table A19-3). The larval stage appeared to have higher sensitivity to several of the factors considered in the assessment, such as vulnerability to flooding and dependence on a narrow range of host species (captured in the factors for biotic habitat dependence and diet versatility). Only one factor was scored as unknown.

The projected exposure was very similar for the two data sets used as proxies for the species' distribution (Tables A19-1 and A19-2) and produced identical exposure metrics. As a result, the choice of distribution data set did not affect the index score. When barriers were assigned the lower scores (capturing the direct effects of barriers on the focal species), the index score was 9.1 (range, [6.0, 12.2], Figure A19-2), with approximately 26% of the Monte Carlo simulations in the "Extremely Vulnerable" category, 67% in the "Highly Vulnerable" category,

Table A19-3. Scores assigned to factors associated with vulnerability to climate change for salt marsh skipper in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewer. Not all scores can be assigned to all factors as indicated by dashes.

Vulnerability factor	GI	I	SI	N	SD	D	*unknown or n/a*
Sea level rise	•					--	
Natural barriers[1]		•	•		--	--	
Anthropogenic barriers[1]		•	•		--	--	
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	--					--	•

[1] Scores assigned when accounting for indirect effects of barriers on habitat. We also ran a scenario with these factors scored as SI/N, accounting only for direct effects on the species.

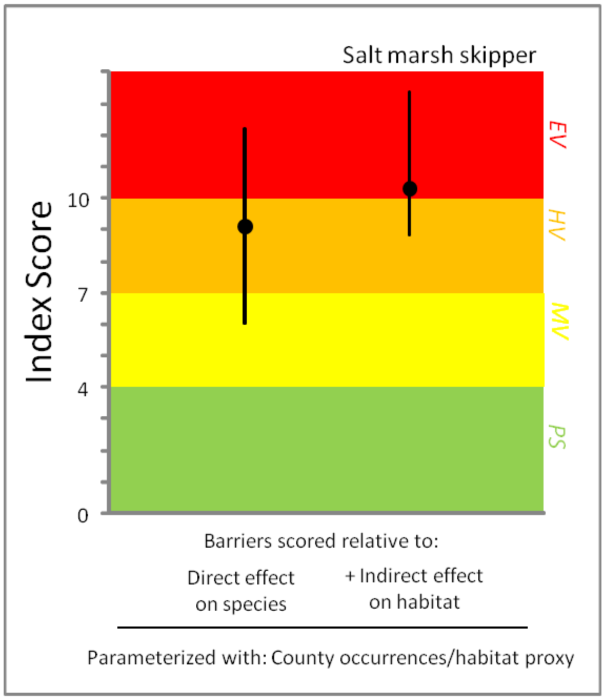

Figure A19-2. CCVI output for salt marsh skipper in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Extremely Vulnerable" (red), "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green).

and 6% in the "Moderately Vulnerable" category.[5] Like other taxa (e.g., birds), many butterflies may be able to fly over or around potential obstructions, however this assumption does not capture the indirect threat of barriers through impacts on the ability of habitat to shift, which most reviewers felt was an important consideration. When barriers were assigned higher scores to capture these indirect effects, the index score rose to 10.3 (range [8.8, 13.4], Figure A19-2) with 56% of the Monte Carlo simulations ranked as "Extremely Vulnerable" and the remainder ranked as "Highly Vulnerable". Results based on this latter set of assumptions are shown in Figure 6 in the main report.

One of the challenges in applying the CCVI to this species was addressing differences in sensitivity across the different life stages. We tried to capture the limiting life stage when considering each of the factors. For example, we scored the factors related to diet and dependence on other species for habitat relative requirements of the larval stage. One of the limitations to this approach is that it does not allow identification of which of the life stages might be more or less vulnerable to climate change, which would be important considerations when developing monitoring plans and/or conservation strategies.

The CCVI is intended to be used in combination with conservation status ranks. The global conservation status rank for salt marsh skipper is G5. The species' rank is S4 in Florida.

Literature Cited

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Opler, P. A., K. Lotts and T. Naberhaus, coordinators. 2010. Butterflies and Moths of North America. http://www.butterfliesandmoths.org (Accessed November 2010).

Zganjar, C., E. Girvetz, and G. Raber (Developers). 2009. Climate Wizard [web program] (http://www.climatewizard.org).

Supporting References *(provided by the species expert)*

Whelan, J. C., J. C. Daniels, and G. R. Gallice. Assessing the Impact of Roadway Mortality on Lepidoptera in North Florida. In prep.

[5] Since the Monte Carlo algorithm can only handle up to three scores per factor, we ran multiple MC simulations to generate the distributions for factors assigned more than three scores.

A20. PURPLE SWAMPHEN *(Porphyrio porphyrio)*

Species Expert(s): Jim Rodgers, Marsha Ward

Purple swamphen is a non-native species introduced to south Florida in the mid-1990's by escape or release from private collections (FWC 2011, Johnson and McGarrity 2009). Since that time, the population has increased and expanded from urban areas into public conservation lands despite eradication efforts (J. Rodgers, pers. comm.). Most of the individuals occurring in Florida are the gray-headed subspecies (*Porphyrio porphyrio poliocephalus*) that is native to southern Asia. As in their native range, purple swamphens inhabit a wide variety of wetlands, including artificial ponds, canal edges, marshes, and wet prairie in their introduced range (FWC 2011, Johnson and McGarrity 2009).

We were interested in exploring whether the CCVI could be applied to non-native species where a primary concern is whether climate change might be expected to make control of these species more difficult. When applied in this non-traditional way, factors that "increase vulnerability" can be thought of as beneficial from a management perspective in that they may limit population growth or range expansion, whereas factors that "decrease vulnerability" may make management of the species more difficult under climate change. In other words, "vulnerability" may be a desired condition when applied to invasive species if it suggests that future climatic conditions and/or factors related to indirect exposure may be less likely to favor increases in abundance or range expansion.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment included occurrences from the Early Detection and Distribution Mapping System (EDDMapS 2010, Figure A20-1). To estimate exposure, we used the point data directly and also used the point data to delineate an approximate range, assuming that the extent of occurrences defined the current range. The species experts reviewed the occurrence data and felt that it was reasonable, but suggested that these sporadic occurrences were not as important as known breeding and wintering areas, the majority of which occur within interior freshwater marshes of the Everglades Water Conservation Areas and Stormwater Treatment Areas. Since we lacked true distribution data, we also used the freshwater marsh habitat layer from the Florida Comprehensive Wildlife Conservation Strategy (2005) within the estimated range as a proxy for the species' distribution (Figure A20-1).

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture

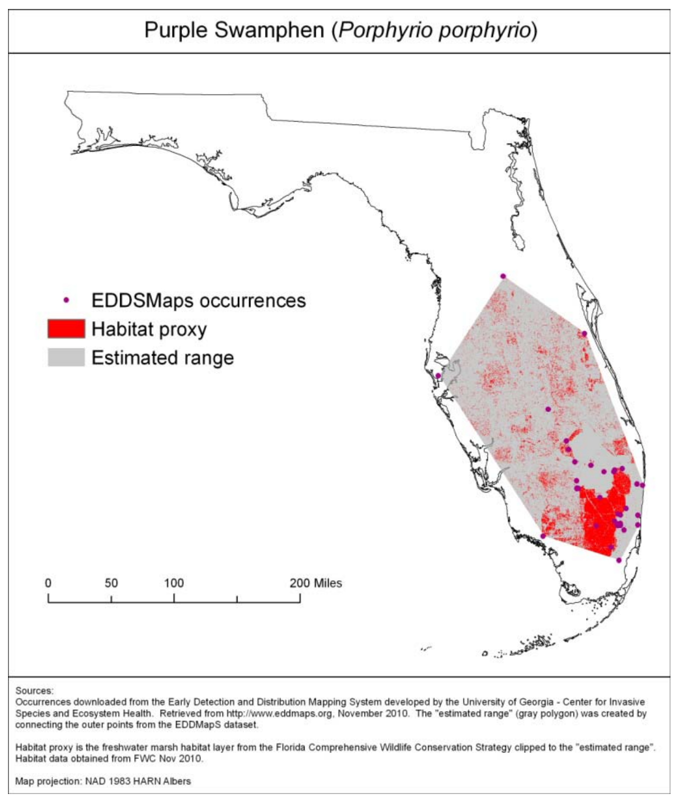

Figure A20-1. Distribution inputs considered for the CCVI analysis.

Table A20-1. Projected temperature exposure for purple swamphen in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	EDDSMapS occurrences	Estimated range	Habitat proxy
> 5.5°F warmer	0%	0%	0%
5.1 - 5.5 °F	0%	0%	0%
4.5 - 5.0 °F	0%	0%	0%
3.9 - 4.4 °F	0%	0%	0%
< 3.9°F warmer	100%	100%	100%
(E_T)	*0.4*	*0.4*	*0.4*

Table A20-2. Projected moisture exposure (based on the Hamon Index) for purple swamphen in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	EDDSMapS occurrences	Estimated range	Habitat proxy
< -0.119 (Driest)	0%	0%	0%
-0.119 - -0.097	1%	5%	16%
-0.096 - -0.074	94%	63%	70%
-0.073 - -0.051	5%	32%	14%
-0.050 - -0.028	0%	0%	0%
> -0.028 (No change)	0%	0%	0%
(E_M)	*1.3*	*1.3*	*1.3*

data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A20-1 and A20-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). The species experts estimated that less than 10% of the species' current range is expected to be impacted by a 1-meter sea level rise. They thought that some habitat in extreme south Florida may be lost as sea levels rise and mangroves move into areas that were previously freshwater marsh, but this was considered to have a minor impact. This factor was scored as *neutral.*

Potential impact of barriers on range shifts. The species experts described the species as requiring freshwater wetlands, characterized by dense emergent vegetation and interspersed with cattail, sawgrass and some willow-dominated tree islands. Currently, the species is found mainly in potions of the Everglades Water Conservation Areas and Stormwater Treatment Areas. There are also infrequent occurrences on wetlands within Lake Okeechobee and Lake Istokpoga and smaller numbers in urban wetlands in western Fort Lauderdale. Based on the projected changes in temperature and moisture in the current range, neither expert felt that the habitat for swamphen would be significantly reduced under climate change.

Factors B2a and B2b are relevant for habitats expected to be vulnerable to climate change. Species occurring in habitats that are likely to persist despite climate change are scored as neutral because, in these situations, barriers do not contribute to vulnerability in the absence of climate-induced range shifts. This was considered the case for the purple swamphen. We have described the natural and anthropogenic barriers identified by the species experts, but in both cases these factors have been scored as *neutral.*

Natural barriers (B2a). The species experts felt that few natural barriers existed. The only potential barrier that was identified was distance between adjacent marshes or wetlands. If the distance got too large, the species could have difficulty moving between wetlands.

Anthropogenic barriers (B2b). The species experts felt that few anthropogenic barriers existed, except perhaps for birds located in the urban wetlands of western Fort Lauderdale.

Land Use Changes Resulting from Human Responses to Climate Change (B3). One of the species experts thought that it was unlikely that significant land use changes would occur within the Everglades Water Conservation Areas or Stormwater Treatment Areas and scored this factor as "neutral." The second expert assigned scores of both "neutral" and "somewhat decreases" vulnerability, based on the species potential to acclimate to artificial wetlands such as canals, borrow pits, and parks. However it is unclear whether these land use changes are likely to increase in extent as a result of climate change. We conservatively scored this factor as *neutral*.

Sensitivity

Dispersal and movement (C1). The species experts characterized the species as having "good" to "excellent" dispersal or movement capability, corresponding to individuals regularly dispersing 1-10 kilometers or greater than 10 km. The species experts noted that the current population in Florida dispersed into natural areas from an urban release of captive birds, and the species is currently increasing its northern range in Florida. The experts selections corresponded to scores of *somewhat decreases* and *decreases* vulnerability.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area, and is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell (Young et al. 2010). Since this species was introduced to Florida fairly recently (within the past 20 years), we scored this factor as *unknown*.

Physiological thermal niche (*C2a*ii*).* One species expert characterized the species as having no association with a particular thermal environment and the other expert characterized the species as showing a preference for environments towards the "warmer end" of the spectrum, indicating available habitat in warmer regions further north may benefit purple swamphen. We included both scores for this factor: *neutral* and *somewhat decreases* vulnerability. We considered the latter score appropriate in cases in which the current range may be limited by temperature, such that warmer temperatures might promote range expansion.

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. Since this species was introduced to Florida fairly recently (within the past 20 years), we scored this factor as *unknown*.

*Physiological hydrologic niche (C2b*ii). Both species experts considered the dependence on freshwater marshes for this factor, however there was uncertainty in whether these hydrologic requirements were likely to be significantly disrupted in a major portion of the range as a result of climate change. One reviewer did not consider the wetlands inhabited by this species to be highly vulnerable to loss or reduction with climate change and scored this factor as "neutral" (but indicated a moderate level of uncertainty in the response). The second reviewer considered negative impacts of reduced rainfall and/or competition with humans for the remaining freshwater habitat, selecting descriptions corresponding to scores of "increases" or "somewhat increases" vulnerability. We included all three scores (*increases* vulnerability, *somewhat increases* vulnerability, and *neutral*) for this factor in order to capture the uncertainty associated with the impacts on the species.

Impacts of Changes to Specific Disturbance Regimes (C2c). One species expert did not feel there was enough information available to select a response for this factor, and the other selected the description corresponding to "neutral" but with a moderate degree of confidence. We scored this factor as *neutral*. Assigning a score of "neutral" versus "unknown" does not affect the value of the CCVI score, except in cases where the minimum number of factors required to calculate a score is not are met. In this case a score was required for this factor in order to calculate a CCVI score.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). Both species experts selected the description associated with *somewhat decreases* vulnerability for this factor, which applies to species that are flexible in dependence on geologic features or derivatives or to species for which the idea of specificity to a particular geologic feature or derivative is not relevant.

Dependence on other species to generate habitat (C4a). Both species experts considered the required habitat to be generated by more than a few species, corresponding to a score of *neutral* for this factor.

Dietary versatility (C4b). One species expert selected the description characterizing the diet as "flexible" and the other species expert selected "omnivorous," corresponding to scores of *neutral* and *somewhat decreases* vulnerability, respectively. Written comments indicated that the species is a dietary generalist, consuming a variety of invertebrate prey and plant matte. We included both scores in the analysis.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species experts indicated that the disperses on its own. This factor was scored as *neutral*.

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Both species experts indicated that there was insufficient data for assessment of this factor. This factor was scored as *unknown*.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor asks whether there is evidence that the total population was reduced to fewer than 1,000 individual during the last 500 years. The factor is intended to capture species that may be less able to adapt to climate change as a result of reduced evolutionary adaptive capacity associated with a genetic bottleneck. Neither reviewer selected a score for this factor, but written comments highlighted the difficulty in applying this factor to an introduced non-native species. Originally, the population in Florida consisted of only a few individuals, but the population has slowly increased to 400-600 individuals and there may be several times this number distributed around the central and south Florida wetlands. This factor was scored as *unknown*.

Phenological response (C6). The species experts were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown*.

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

Purple swamphen ranked as "Not Vulnerable/ Presumed Stable" to climate change in Florida regardless of which distribution data set was used to

Table A20-3. Scores assigned to factors associated with vulnerability to climate change for purple swamphen. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

parameterize the model. The only factor identified as potentially contributing to "vulnerability" for this species was the potential impact of changes in hydrology affecting freshwater marshes (Table A20-3), but there was a large amount of uncertainty associated with whether climate change would significantly disrupt the availability of freshwater wetlands within the species' range. Good dispersal ability and tolerance for warmer temperatures, in combination with few limiting barriers, suggest that the species may be able to expand its range with climate change. Four sensitivity factors were scored as unknown, including *historical thermal niche* (C2a*i*) and *historical hydrologic niche* (C2b*i*).

Not surprisingly, the EDDSMapS occurrences and the estimated range based on those occurrences generated the same exposure metrics (Tables A20-1 and A20-2), as did the habitat proxy. As a result the choice of "distribution" had no effect on the parameterization of the CCVI. The index score was -1.0 (range [-3.2, 1.2], Figure A20-2), although the species was flagged as potentially shifting its range. Approximately 25% of the Monte Carlo simulations produced scores in the "Not Vulnerable/Increase Likely" category, and the upper range fell well below the cutoff score for "Moderately Vulnerable." These results suggest that future climatic conditions may promote range expansion for this invasive species, with the potential for further impacts on native populations.

The CCVI is intended to be used in combination with conservation status ranks. However, purple swamphen is a non-native species and accordingly has no conservation status rank.

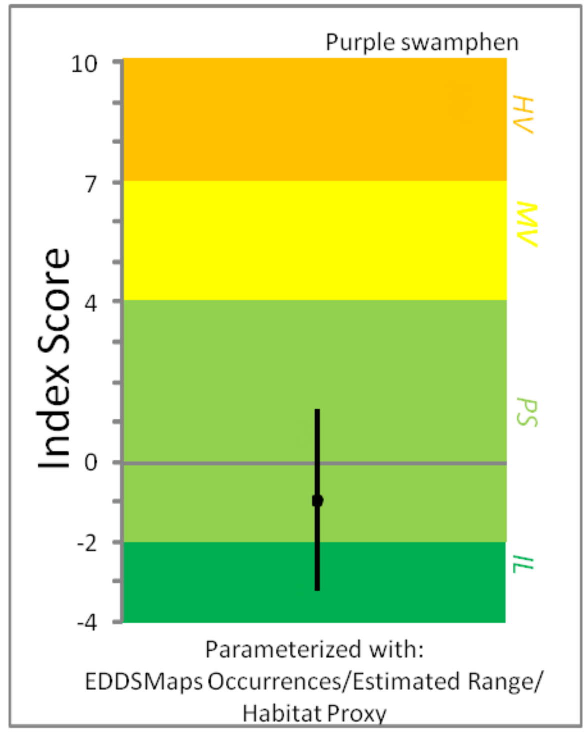

Figure A20-2. CCVI output for purple swamphen in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: highly vulnerable (orange), moderately vulnerable (yellow), presumed stable (green), increase likely (dark green).

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A21. BURMESE PYTHON *(Python bivattatus)*

Species Expert(s): Michael Cherkiss, Kristen Hart

Burmese pythons are native to Southeast Asia, but have been reported in Everglades National Park since the 1980s and are now well-established in Florida (FWC 2011). Populations in Florida have been confirmed as breeding and are apparently self-sustaining. The species is semi-aquatic but spends much of its time in trees. Burmese pythons eat mammals, birds, reptiles, amphibians, and fish, thereby posing a threat to a variety of wildlife species (FWC 2011).

We were interested in exploring whether the CCVI could be applied to non-native species where a primary concern is whether climate change might be expected to make control of these species more difficult or increase their potential to spread. When applied in this non-traditional way, factors that "increase vulnerability" can be thought of as beneficial from a management perspective in that they may limit population growth or range expansion, whereas factors that "decrease vulnerability" may make management of the species more difficult under climate change. In other words, "vulnerability" may be a desired condition when applied to invasive species if it suggests that future climatic conditions and/or factors related to indirect exposure may be less likely to favor increases in abundance or range expansion.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment included occurrences from the Early Detection and Distribution Mapping System (EDDMapS 2010). To estimate exposure, we used the point data directly and also used the point data to delineate an approximate range, assuming that the extent of occurrences defined the current range (Figure A21-1). There was one outlying point occurrence in the Panhandle which we excluded from our estimate of the range.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A21-1 and A21-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Indirect Exposure

Sea level rise (B1). The species experts estimated that approximately 50-60% of the species' range in Florida

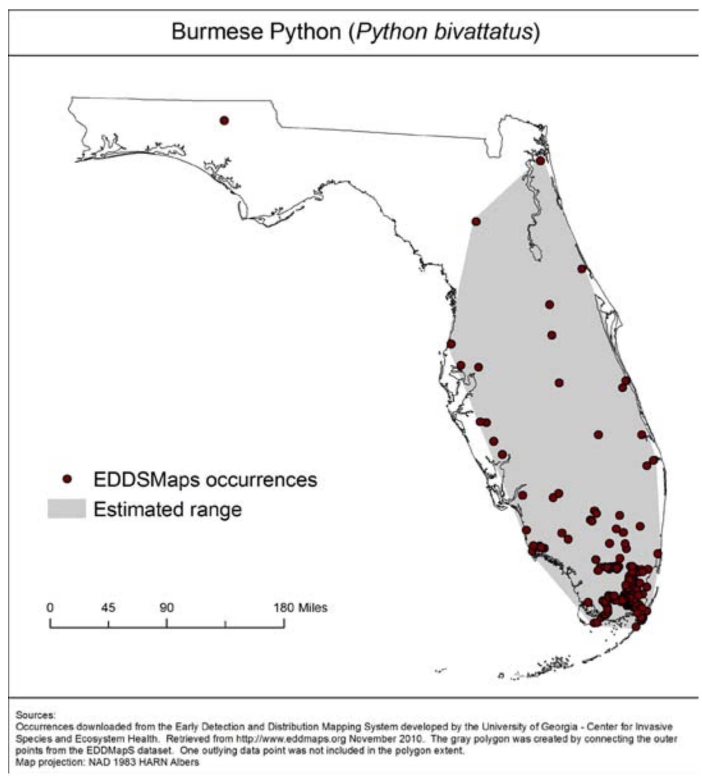

Figure A21-1. Distribution inputs considered for the CCVI analysis.

Table A21-1. Projected temperature exposure for Burmese python in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	EDDSMapS Occurrences	Estimated Range
> 5.5°F warmer	0%	0%
5.1 - 5.5 °F	0%	0%
4.5 - 5.0 °F	0%	0%
3.9 - 4.4 °F	0%	0%
< 3.9°F warmer	100%	100%
(E_T)	*0.4*	*0.4*

Table A21-2. Projected moisture exposure (based on the Hamon Index) for Burmese python in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	EDDSMaps Occurrences	Estimated Range
< -0.119 (Driest)	0%	0%
-0.119 - -0.097	17%	5%
-0.096 - -0.074	79%	48%
-0.073 - -0.051	4%	47%
-0.050 - -0.028	0%	0%
> -0.028 (No change)	0%	0%
(E_M)	*1.3*	*1.3*

would be impacted by a 1-meter sea level rise. This factor was scored as *increases* vulnerability.

Potential impact of barriers on range shifts. Experts indicated that the species occupies a range of habitats, including mangrove, uplands, tree islands, and areas near lakes and ponds, as well as man-made habitats such as levees and canals. Both reviewers considered the species' habitat to be vulnerable to climate change. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). The reviewers considered salinity and temperature as natural barriers to this species, but were uncertain in how much of an effect these barriers would have on potential distributional shifts under climate change. This uncertainty was captured across the range of scores selected by the reviewers, which corresponded to *neutral* and *somewhat increases* vulnerability. In follow up discussion, the species experts indicated that they thought that barriers were not too much of a factor as the species has successfully established in many parts of southern Florida.

Anthropogenic barriers (B2b). The species experts did not feel that any anthropogenic barriers, even urban areas, would preclude pythons from spreading as long as sufficient prey resources and microhabitats were available. Neither reviewer provided a score for this factor, but based on these written comments we assigned this factor a score of *neutral.*

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species experts indicated that some of the land uses changes that may occur in response to climate change, including shoreline hardening, new levies and roads would have a neutral impact or even benefit the species. They captured the uncertainty associated with this factor by selecting a range of responses corresponding to scores of *neutral*, *somewhat decreases* and *decreases* vulnerability

Sensitivity

Dispersal and movement (C1). The species experts characterized the species as having the ability to move many kilometers, corresponding to "good" or "excellent" movement capability. This factor was scored as *somewhat decreases* or *decreases* vulnerability.

Historical thermal niche (C2ai). This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area, and is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell. Since this species was introduced to Florida, we have scored this factor as *unknown*.

Physiological thermal niche (C2aii). Both species experts indicated that the species is associated with "warmer" environments. A cold snap in 2010 killed many pythons in southern Florida. This factor was scored as *somewhat decreases* vulnerability (the lowest score available for this factor). We considered this score appropriate in cases in which the current range may be limited by temperature, such that warmer temperatures might promote range expansion.

Historical hydrologic niche (C2bi). This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. Since this species was introduced to Florida, we scored this factor as *unknown*.

*Physiological hydrologic niche (C2b*ii). The species experts considered the species' preference for habitats such as tree islands adjacent to standing water for this factor, but also noted that Burmese pythons readily use man-made structures, such as roads near water and levees adjacent to canals, that are not likely to be vulnerable to climate change. The reviewers had some difficulty applying the standard category descriptions to an invasive species that does well in both natural and man-made habitats. They initially selected descriptions associated with "increases" or "somewhat increases" vulnerability. Both of these descriptions specify dependency on a wetland habitat. However, they also identified that habitat as being vulnerable to climate change, which may not be the case for canals and other man-made structures. In their written comments, both reviewers indicated that these habitats might be unaffected or even potentially increase. We have captured this uncertainty by including scores of *neutral* and *somewhat decreases* vulnerability in addition to their scores of *increas*es and *somewhat increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). One species experts indicated that the species has little or no response to a specific disturbance regime and scored this factor as *neutral*. The second species expert scored this factor as neutral but also indicated that hurricanes could potentially increase dispersal, corresponding to *somewhat decreases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). One species expert selected the description associated with "somewhat decreases" vulnerability for this factor, which applies to species that are "flexible" in dependence on geologic features or derivatives or to species for which the idea of specificity to a particular geologic feature or derivative is not relevant. The other species expert selected the description associated with "decreases" vulnerability, which applies to "highly generalized" species that are known to occur on substrates that represent opposite ends of the spectrum (e.g., wet and dry). We retained both scores of *somewhat decreases* and *decreases* vulnerability for this factor.

Dependence on other species to generate habitat (C4a). Neither expert considered this species to be highly dependent on other species for habitat as the species is found in habitats ranging from the Everglades to urban areas. This factor was scored as *neutral*.

Dietary versatility (C4b). Species experts categorized the diet as "flexible," consisting of various mammals, birds, and reptiles. This factor was scored as *neutral*

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. Experts noted that dispersal is facilitated by humans and higher water events. This factor was scored as *neutral* (the lowest score available for this factor).

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral*.

Measured genetic variation (C5a). Both experts characterized the genetic variation in this species as "low" based on microsatellite variation in published studies, corresponding to a score of *somewhat increases* vulnerability for this factor.

Occurrence of bottlenecks in recent evolutionary history (C5b). This factor is not applicable in cases where a score has been assigned to factor C5a.

Phenological response (C6). Reviewers were not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events. This factor was scored as *unknown.*

Documented or Modeled Response to Climate Change

Published studies on modeled potential range were available for this species, but not necessarily future ranges based on projected climate change. The available models show potential range based on areas of the U.S. that climatically match the pythons' native range. But since this is an invasive species with the potential for range expansion, we felt it appropriate to include the modeled potential range in scoring this section. We included the following scores:

Table A21-3. Scores assigned to factors associated with vulnerability to climate change for Burmese python in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

Documented changes in distribution or abundance in response to recent climate change (D1). Scored as *unknown.*

Modeled future change in range or population size (D2). Scored as *somewhat decreases* vulnerability (predicted future range represents a 20-50% increase relative to current range in assessment area) or *decreases* vulnerability (predicted future range represents >50% increase relative to current range in assessment area).

Overlap of modeled future range with current range (D3). Scored as *neutral* (predicted future range overlaps the current range by >60% within the assessment area), which is the lowest score available for this factor.

Occurrence of protected areas in modeled future distribution (D4). We felt that this factor was not applicable in the case of an invasive species which readily adapts to manmade environments. We did not provide a score (*unknown*).

Results

Burmese python ranked as "Not Vulnerable/ Presumed Stable" to climate change in Florida, regardless of which distribution data set was used to parameterize the model. Factors that potentially contribute to "vulnerability" of this species include sea level rise and the potential impact of changes in hydrology affecting the availability of suitable habitat (Table A21-3). Three factors were scored as unknown, including *historical thermal niche* (C2a*i*) and *historical hydrologic niche* (C2b*i*). An additional factor was assigned four scores (*physiologic hydrologic nich*e, C2b*ii*), indicating high uncertainty as to how the factor would influence vulnerability.

Not surprisingly, the EDDSMapS occurrences and the estimated range based on those occurrences generated the same exposure metrics (Tables A21-1 and A21-2). As a result the choice of "distribution" had no effect on the parameterization of the CCVI. The index score was 0.14 (range, [-3.9, 4.2], Figure A21-2), falling in the "Presumed Stable" category but flagged as potentially shifting in range. Approximately

9% of the Monte Carlo simulations[6] produced scores in the "Not Vulnerable/Increase Likely" category.

Modeled potential distributions were available for Burmese python. Although these were not projections based on potential climate change per se, we were able to apply these data to some of the factors in Section D. Some of the factors were difficult to apply to an invasive species. For example, we did not include a score for factor D4 which asks about the occurrence of protected areas in the modeled future distribution. The available scores for this factor range from "increases" vulnerability to "neutral," all of which seemed too high in this case. Ideally, the factor would have allowed us to address the occurrence of potential habitat in the future range, which would have "decreased vulnerability" and lowered the factor sub-score. As a result, the sub-score for Section D ("Presumed Stable") was likely higher than it would have been for an assessment designed to assess climate change impacts on invasive species.

The CCVI combines the sub-score for section D with the index score to generate an overall score, which in this case was "Presumed Stable." However, even with the limited information provided in section D, the sub-score fell on the cut-off between "Presumed Stable" and "Increase Likely" (which is calculated separately for Section D), indicating that there may be potential for the species to expand its range with climate change.

The CCVI is intended to be used in combination with conservation status ranks. However, Burmese python is a non-native species and accordingly has no conservation status rank.

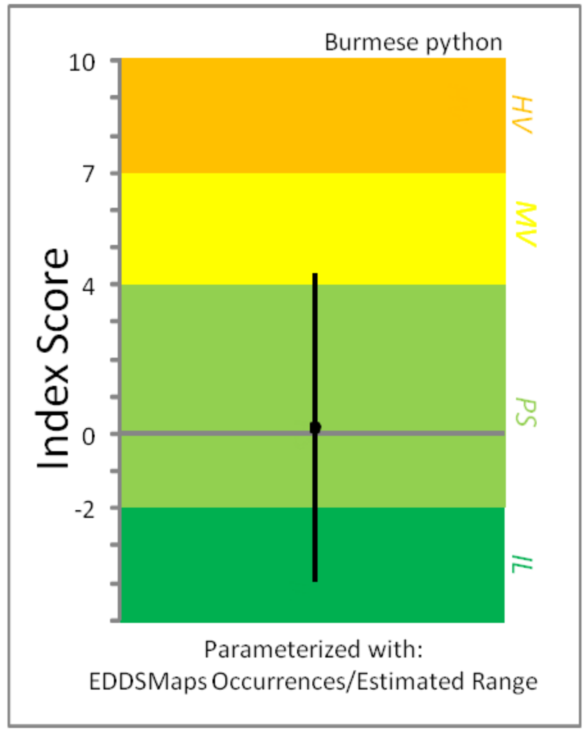

Figure A21-2. CCVI output for Burmese python in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), "Presumed Stable" (green), "Increase Likely" (dark green).

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[6] Since the Monte Carlo algorithm can only handle up to three scores per factor, we ran multiple MC simulations to generate the distributions for factors assigned more than three scores.

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A22. GAMBIAN GIANT POUCHED RAT *(Cricetomys gambianus)*

Species Expert(s): Gary Witmer

Gambian giant pouched rat (also called Gambian pouch rat) is native to parts of western, central and southern Africa (FWC 2011). It was imported as part of the pet trade until 2003, after which a brief ban on imports occurred in response to an outbreak of monkeypox disease. Around 1999, a release led to establishment of a population on Grassy Key (FWC 2011), but eradication efforts may have eliminated the species from the Keys. However occasional suspected sightings still occur (G. Witmer, pers. comm.).

We were interested in exploring whether the CCVI could be applied to non-native species where a primary concern is whether climate change might be expected to make control of these species more difficult or increase their potential to spread. When applied in this non-traditional way, factors that "increase vulnerability" can be thought of as beneficial from a management perspective in that they may limit population growth or range expansion, whereas factors that "decrease vulnerability" may make management of the species more difficult under climate change. In other words, "vulnerability" may be a desired condition when applied to invasive species if it suggests that future climatic conditions and/or factors related to indirect exposure may be less likely to favor increases in abundance or range expansion.

Distribution Data

The CCVI utilizes distribution data to calculate estimates of relative exposure for each species. Data considered as part of this assessment included occurrences from the Early Detection and Distribution Mapping System (EDDMapS 2010, Figure A22-1). Recent eradication efforts have greatly reduced, and perhaps eliminated the Gambian giant pouched rat population from Grassy Key. The occurrence on Islamorada is based on a road-killed specimen and surveys have not revealed any other Gambian giant pouched rats in the area (G. Witmer, pers. comm.).

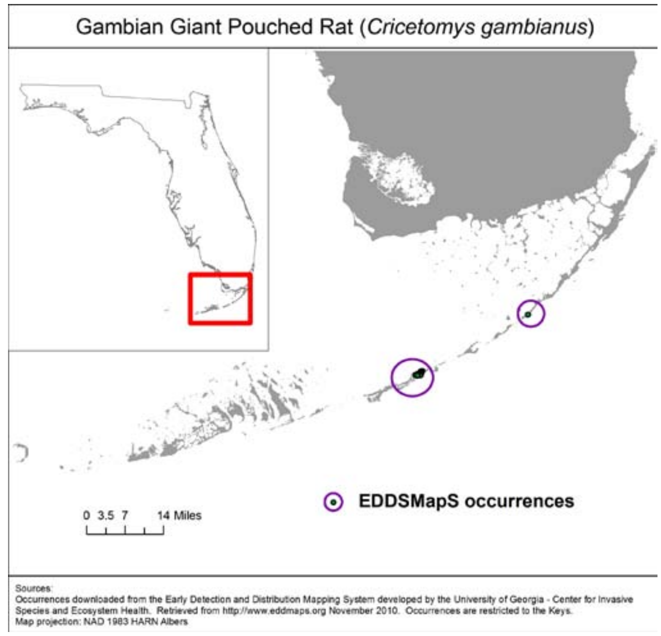

Figure A22-1. Distribution inputs considered for the CCVI analysis.

Exposure

We obtained downscaled data from Climate Wizard (Zganjar et al. 2009) for the state of Florida for mid-century projections based on the mean ensemble model under the A1B emissions scenario. Moisture data, in the form of the Hamon AET: PET moisture metric were downloaded from NatureServe, and are derived from Climate

Wizard temperature and precipitation projections for mid-century under the A1B emissions scenario. To use the CCVI, the percentage of the distribution that is exposed to a particular range of projected change in temperature or moisture is calculated in ArcGIS by overlaying the exposure data on the distribution or occurrence data (Tables A22-1 and A22-2). For point data sets, we assigned a single exposure value to each of the points based on the overlay.

Climate Wizard data were only available for the Florida peninsula, so we extrapolated values from the southern tip of the Florida peninsula into the Keys (see the methodology in the main report). Due to the small area occupied by this species, the entire distribution was contained within a single category for both temperature and moisture exposure (Tables A22-1 and A22-2).

Indirect Exposure

Sea level rise (B1). The species expert estimated greater than 90% of the range in Florida would be impacted by a 1-meter sea level rise. This factor was scored as *greatly increases* vulnerability.

Potential impact of barriers on range shifts. The species expert indicated that the species occupies variable habitats including dry woodland and grass-woodland mix as well as riverine habitats and agricultural fields. They also do well in human-dominated landscapes as evidenced in Grassy Key. Because of the impact of sea level rise (see above), the Florida habitat is vulnerable to climate change. Species occurring in habitats that are considered likely to persist despite climate change would be scored as "neutral" for factors B2a and B2b, which focus on the potential impact of barriers on climate-induced range shifts.

Natural barriers (B2a). Gambian giant pouched rat has been introduced only in the Keys. The ocean and large distances between the islands provide a natural barrier to dispersal. The ocean completely surrounds the occupied island with the exception of island-connecting bridges. This factor was scored as *increases* vulnerability (i.e., natural barriers were considered likely to "greatly impair" distributional shifts).

Anthropogenic barriers (B2b). Bridges between the islands of the Florida Keys are long, narrow, unvegetated and have considerable traffic volume, likely restricting their functionality for passage by Gambian giant pouched rats. This factor was scored as *somewhat*

Table A22-1. Projected temperature exposure for Gambian giant pouched rat in the assessment area. The percentages are used to calculate the temperature component (E_T) of the exposure metric. See Young et al. (In press) for details.

Data set → (Distribution)	EDDSMapS Occurrences
> 5.5°F warmer	0%
5.1 - 5.5 °F	0%
4.5 - 5.0 °F	0%
3.9 - 4.4 °F	0%
< 3.9°F warmer	100%
(E_T)	*0.4*

Table A22-2. Projected moisture exposure (based on the Hamon Index) for Gambian giant pouched rat in the assessment area. The percentages are used to calculate the moisture component (E_M) of the exposure stress. See Young et al. (In press) for details.

Data set → (Distribution)	EDDSMapS Occurrences
< -0.119 (Driest)	0%
-0.119 - -0.097	0%
-0.096 - -0.074	100%
-0.073 - -0.051	0%
-0.050 - -0.028	0%
> -0.028 (No change)	0%
(E_M)	*1.3*

increases vulnerability (i.e., anthropogenic barriers were considered likely to "significantly impair" distributional shifts).

Land Use Changes Resulting from Human Responses to Climate Change (B3). The species expert indicated that some of the land uses changes that may occur in response to climate change, including new seawalls and shoreline protection may prevent substantial habitat loss and could benefit this species. This factor was scored as *decreases* vulnerability (i.e., the species is likely to benefit from land use changes that are "likely or very likely" to occur). We also included a score of *somewhat decreases* vulnerability to account for the uncertainty regarding whether or not these changes will actually occur.

Sensitivity

Dispersal and movement (C1). The species expert characterized the species as having moderate dispersal ability (100 + meters), corresponding to a score of *neutral* for this factor.

*Historical thermal niche (C2a*i*).* This factor is intended to approximate the species' temperature tolerance at a broad scale by looking at large-scale temperature variation that a species has experienced in the past 50 years within the assessment area, and is calculated as the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature for each cell (Young et al. 2010). Since this species was introduced to Florida, we scored this factor as *unknown*.

*Physiological thermal niche (C2a*ii*).* The species expert indicated that the species is associated with "warm" environments. This factor was scored as *somewhat decreases* vulnerability (the lowest score available for this factor).

*Historical hydrologic niche (C2b*i*).* This factor is intended to capture the species' exposure to past variation in precipitation as a proxy for tolerance to large-scale variation in precipitation. The factor is assessed by calculating the range in mean annual precipitation for the period of 1951-2006 observed across the species' distribution in the assessment area. Since this species was introduced to Florida, we scored this factor as *unknown*.

*Physiological hydrologic niche (C2b*ii). The species expert indicated that the species is believed to need regular access to freshwater for drinking, which is already somewhat limited on the Florida Keys and may become more so with projected climate change. This factor was scored as *somewhat increases* vulnerability.

Impacts of Changes to Specific Disturbance Regimes (C2c). The species expert indicated that the species uses burrows and so is adversely affected by flooding events. This factor was scored as *somewhat increases* vulnerability.

Dependence on ice, ice-edge, or snow cover habitats (C2d). All species in Florida were scored as *neutral* for this factor.

Physical habitat specificity (C3). The species has a broad distribution in native tropical Africa, presumably across variable and diverse geologic features. This *factor was scored as decreases vulnerability.*

Dependence on other species to generate habitat (C4a). There are no known associations with other species for habitat. This factor was scored as *neutral.*

Dietary versatility (C4b). Diet was categorized as omnivorous. The species consumes a broad array of plant and invertebrate foods, including agricultural crops and ornamental plants/fruits. This factor was scored as *somewhat decreases* vulnerability.

Pollinator versatility (C4c). Not applicable.

Dependence on other species for propagule dispersal (C4d). The species disperses on its own. Experts noted that dispersal is facilitated by humans and higher water events. This factor was scored as *neutral* (the lowest score available for this factor).

Other interspecific interactions (C4e). Additional interspecific interactions that might affect vulnerability were not identified. This factor was scored as *neutral.*

Measured genetic variation (C5a). The genetic diversity of the current population is unknown, however the free-ranging population was derived from a release of approximately eight individuals. This information has been captured in the score for factor (C5b).

Occurrence of bottlenecks in recent evolutionary history (C5b). A small founding population and ongoing eradication effort has greatly reduced (and may have eliminated) the existing population. If these populations were to rebound, they would be assumed to have reduced genetic diversity. This factor was scored as *increases* vulnerability based on this assumption.

Phenological response (C6). The reviewer was not aware of any research specifically assessing the correspondence between changes in seasonal dynamics and changes in the timing of phenological events other than shifts in diet when certain types of food (i.e., seeds and fruits) become available. This factor was scored as *unknown.*

Documented or Modeled Response to Climate Change

We did not include these optional factors in the analysis.

Results

The Gambian giant pouched rat ranked as "Moderately Vulnerable" to climate change in Florida (index score: 5.0, range [4.6, 5.3]; Figure A22-2), primarily as a result of its geographical distribution. The majority of factors identified as potentially influencing "vulnerability" for this species are related to the fact that it is currently restricted to the Florida Keys (Table A22-3), suggesting that if it were to be introduced to the Florida peninsula, the species would

Table A22-3. Scores assigned to factors associated with vulnerability to climate change for Gambian giant pouched rat in Florida. Bolded factors were associated with higher levels of uncertainty by the expert reviewers. Not all scores can be assigned to all factors as indicated by dashes.

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	--					--	•

potentially be able to expand its distribution and would be either unaffected by or even potentially benefit from projected climate change. Three factors were scored as unknown, including historical thermal niche (C2a*i*) and historical hydrologic niche (C2b*i*).

When factors for which scores were dependent on the current extent of occurrences (i.e., those related to indirect exposure and hydrologic niche) were scored as "neutral," the index score dropped into the "Not Vulnerable/Presumed Stable range (1.5, range [1.2, 1.8]) and the species was flagged as potentially shifting range in the assessment area. Modeling suggests that even under current climate conditions, the potential spread of Gambian giant pouched rats would be very large if they reach mainland Florida due to the adaptability of this species, the thermal and moisture regimes in which they occur in their native range, and the variety of foods and habitat they can use.

The CCVI is intended to be used in combination with conservation status ranks. However, Gambian giant pouched rat is a non-native species and accordingly has no conservation status rank.

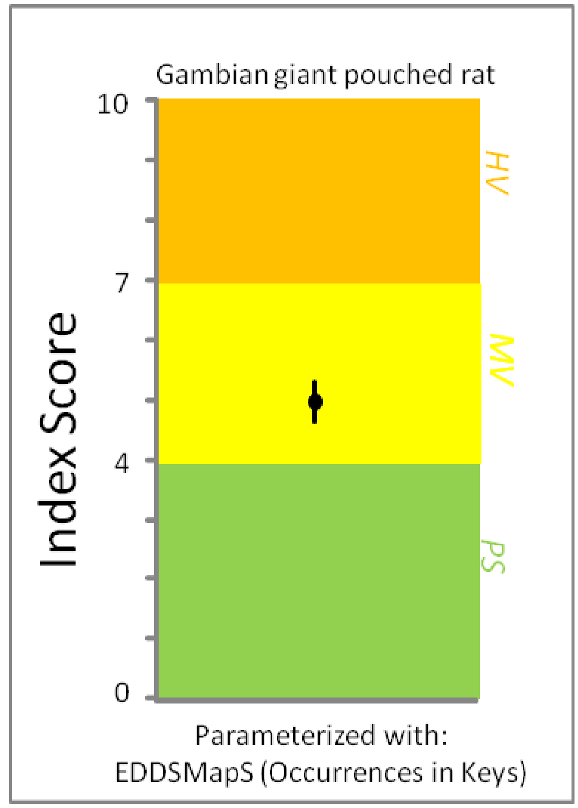

Figure A22-2. CCVI output for Gambian giant pouched rat in Florida. The index score (black circle) is shown with the range of scores produced by the Monte Carlo simulation. Categorical ranks are coded by color: "Highly Vulnerable" (orange), "Moderately Vulnerable" (yellow), and "Presumed Stable" (green).

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Supporting References *(provided by the species expert)*

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Engeman, R. M., G. W. Witmer, J. B. Bourassa, J. W. Woolard, B. Constantin, P. T. Hall, S. Hardin, and N. D. Perry. 2007. The path to eradication of the Gambian giant pouched rat in Florida. Pages 305-311 *in* Managing Vertebrate Invasive Species: Proceedings of an International Symposium (G. W. Witmer, W. C. Pitt, and K. A. Fagerstone, Eds). USDA National Wildlife Research Center, Fort Collins, CO.

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Kingdon, J. 1974. East African Mammals: Vol. II, Part B (Hares and Rodents). The University of Chicago Press, Chicago, IL.

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Peterson, A. T., M. Papes, M. G. Reynolds, N. D. Perry, B. Hanson, R. L. Regnery, C. L. Hutson, B. Muizniek, I. K. Damon, and D. S. Carroll. 2006. Native-range ecology and invasive potential of *Cricetomys* in North America. Journal of Mammalogy 87:427–432.

Rosevear, D. R. 1969. The Rodents of West Africa. British Museum of Natural History, London.

Appendix B: CCVI Worksheet Module

This worksheet module was developed by Defenders of Wildlife for use with the NatureServe Climate Change Vulnerability Index (CCVI). Individual modules were prepared for each species. The module for limpkin is provided as an example.

Species experts were identified by the Florida Fish and Wildlife Conservation Commission (FWC) and invited to participate in the CCVI assessment process. Species experts were asked to fill out the worksheet module individually. In addition to selecting a the most appropriate description for each factor, a series of follow up questions asked the experts to document the underlying information associated with each selection and provide a qualitative assessment of the uncertainty associated with each of those components.

After reviewing the responses, Defenders staff conducted a group conference call with the experts for each species to discuss the responses and interpretation of the scores. Defenders staff implemented the CCVI analysis based on the information provided by the species experts and the guidance document produced by NatureServe. Each descriptive statement corresponds to a "score" for each factor that is entered into the CCVI. Summaries of the information provided by the species experts are presented in Appendix A.

NatureServe Climate Change Vulnerability Index

Species Sensitivity Worksheets

Limpkin (*Aramus guarauna*)

This document was prepared by N. Dubois, Defenders of Wildlife, November 2010

Based on: Young et al. (2010). Guidelines for Using the NatureServe Climate Change Vulnerability Index, Release 2.0. NatureServe, Arlington VA.

The following set of worksheets is intended to help us gather the necessary information required to use the NatureServe Climate Change Vulnerability Index (CCVI). We have provided a set of starting points based on the recommendations made by NatureServe, but we encourage you to provide feedback on any component and/or suggest other data sources that may be available. The following factors are considered in the CCVI:

- Direct exposure to climate change (e.g., altered temperature and moisture regimes)
- Indirect exposure to climate change (e.g., sea level rise, natural and anthropogenic barriers)
- Sensitivity (e.g., dispersal ability, thermal tolerance, biotic interactions, etc.)
- Documented or modeled response to climate change (optional)

Defining the Assessment Area

The results of this CCVI will be used in combination with a scenario-based modeling approach developed by a team from MIT. Consider the entire state of Florida as the assessment area. However, <u>please make note of any instances in which you answers would change if the assessment area were limited to the extent utilized in the MIT models</u> (which does not include northern Florida).

Species Distribution Data

A range or distribution map is a primary input for the CCVI. Some common sources of distribution maps that have been used with the CCVI include range maps from NatureServe Explorer, the USDA Plants Database, and heritage program data. Below, we have identified one or more maps available for this species. <u>Please provide any comments on these maps in terms of your own knowledge of the distribution of the species, and provide other suggestions for sources of range or distribution maps if known.</u>

Maps:

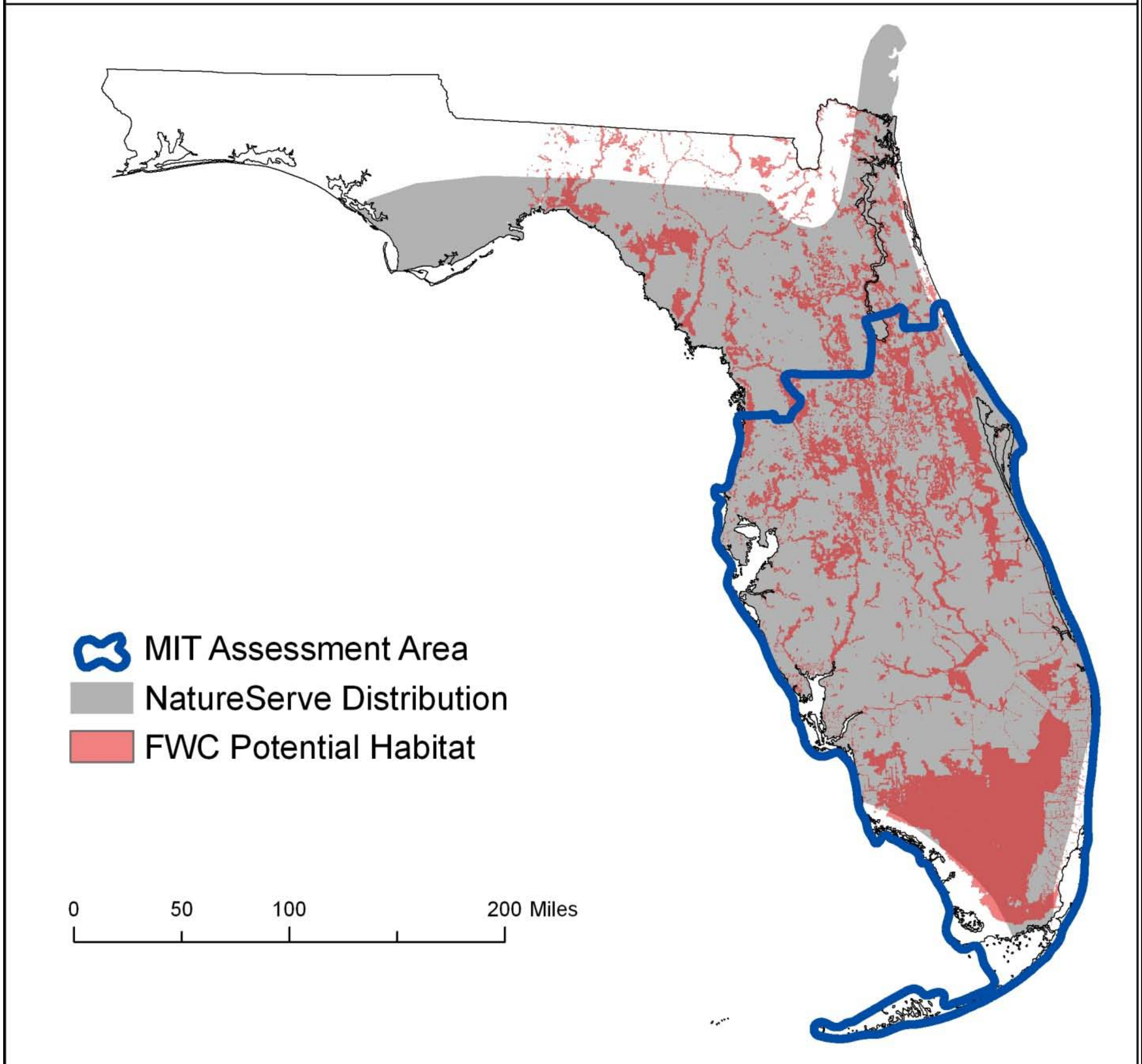
☒ Distribution Map from NatureServe Explorer

☒ FWRI Potential Habitat Model

☐ Other:

Distribution map and/or potential-habitat map

Limpkin (*Aramus guarauna*)

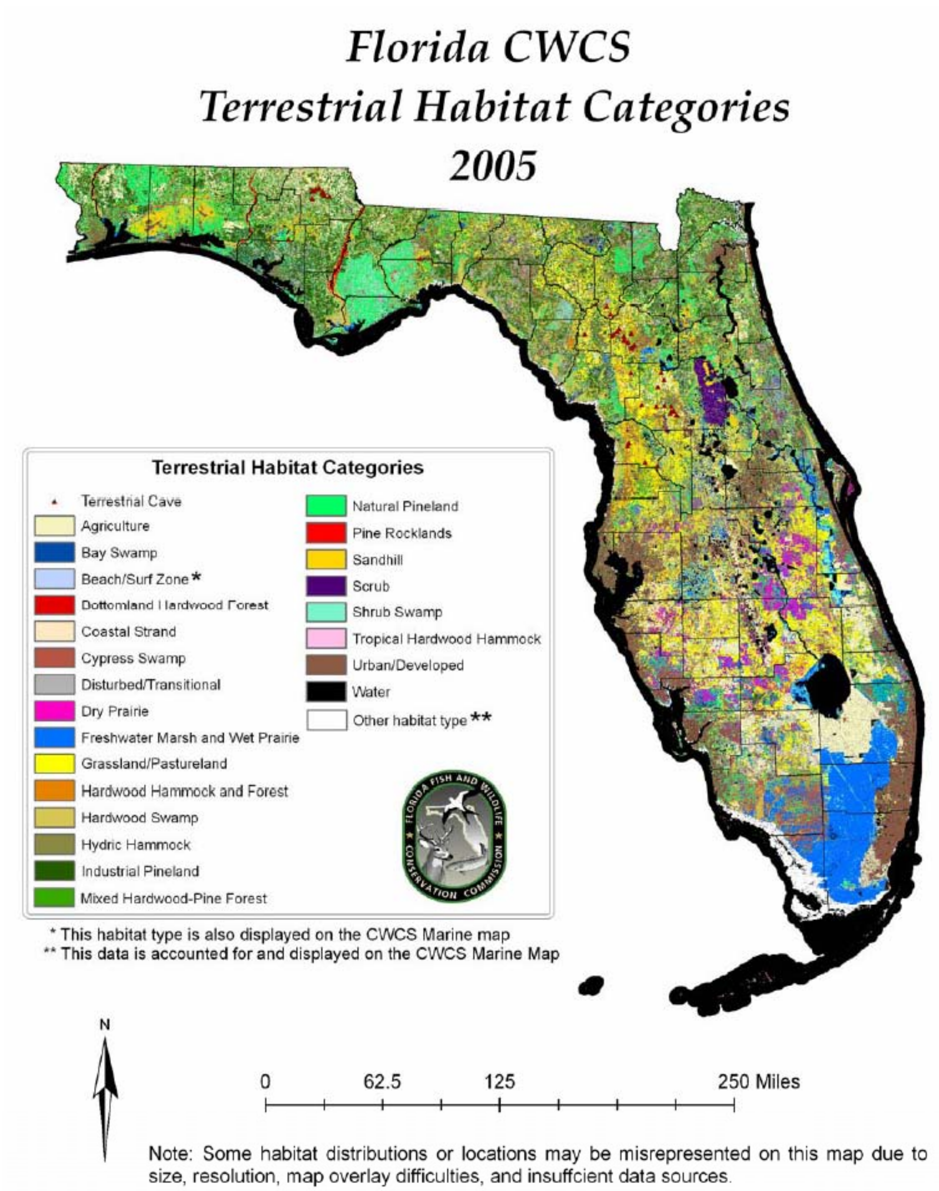


Sources:
Distribution map, data provided by NatureServe in collaboration with Robert Ridgely, James Zook, The Nature Conservancy-Migratory Bird Program, Conservation International-Center for Applied Biodiversity Science, World Wildlife Fund-US, and Environment Canada-WILDSPACE. Retrieved from http://www.natureserve.org/getData/birdMaps.jsp Sept 2010. Distribution clipped to a 100 km buffer around state boundary.
Potential habitat map, FWC_FWRI. Retrieved from http://www.myfwc.com/gis/GAPS2/whcnif.zip Oct 2010. For additional information see: Endries, M., B. Stys, G. Mohr, G. Kratimenos, S. Langley, K. Root, and R. Kautz. 2009. Wildlife Habitat Conservation Needs in Florida. Fish and Wildlife Research Institute Technical Report TR-15.
Map projection: NAD 1983 HARN Albers

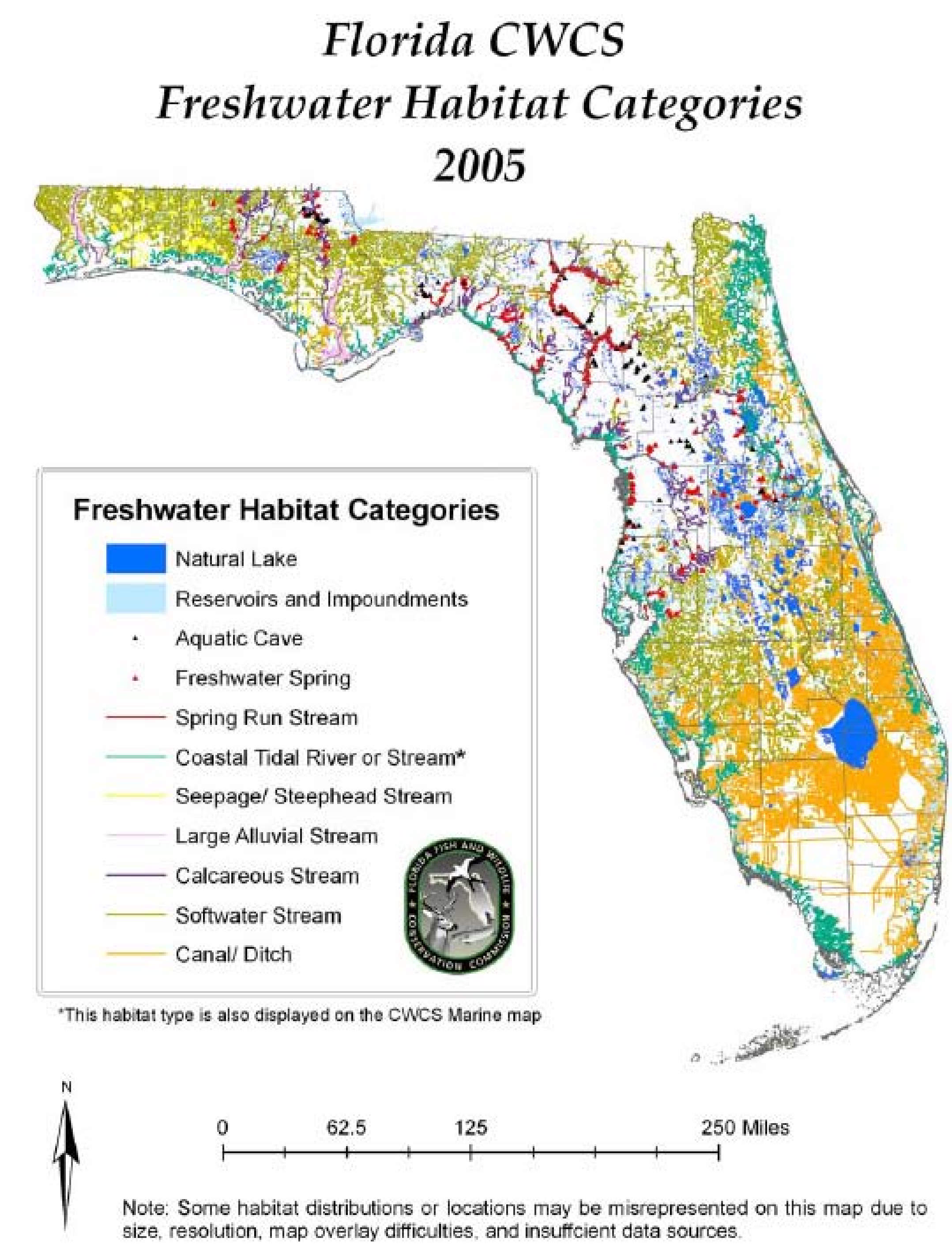
Comments on distribution and/or potential habitat map and suggestions for other sources.
Click here to enter text.

Habitat Maps

A number of factors will need to be evaluated relative to the distribution of habitat for the species, so it may be helpful to have a general habitat map for reference. The map(s) we have provided below are not species specific, but rather depict the general habitat classifications identified in the Florida Comprehensive Wildlife Conservation Strategy. Please help us by identifying and making use of other resources and information that may be available for the particular focal species.

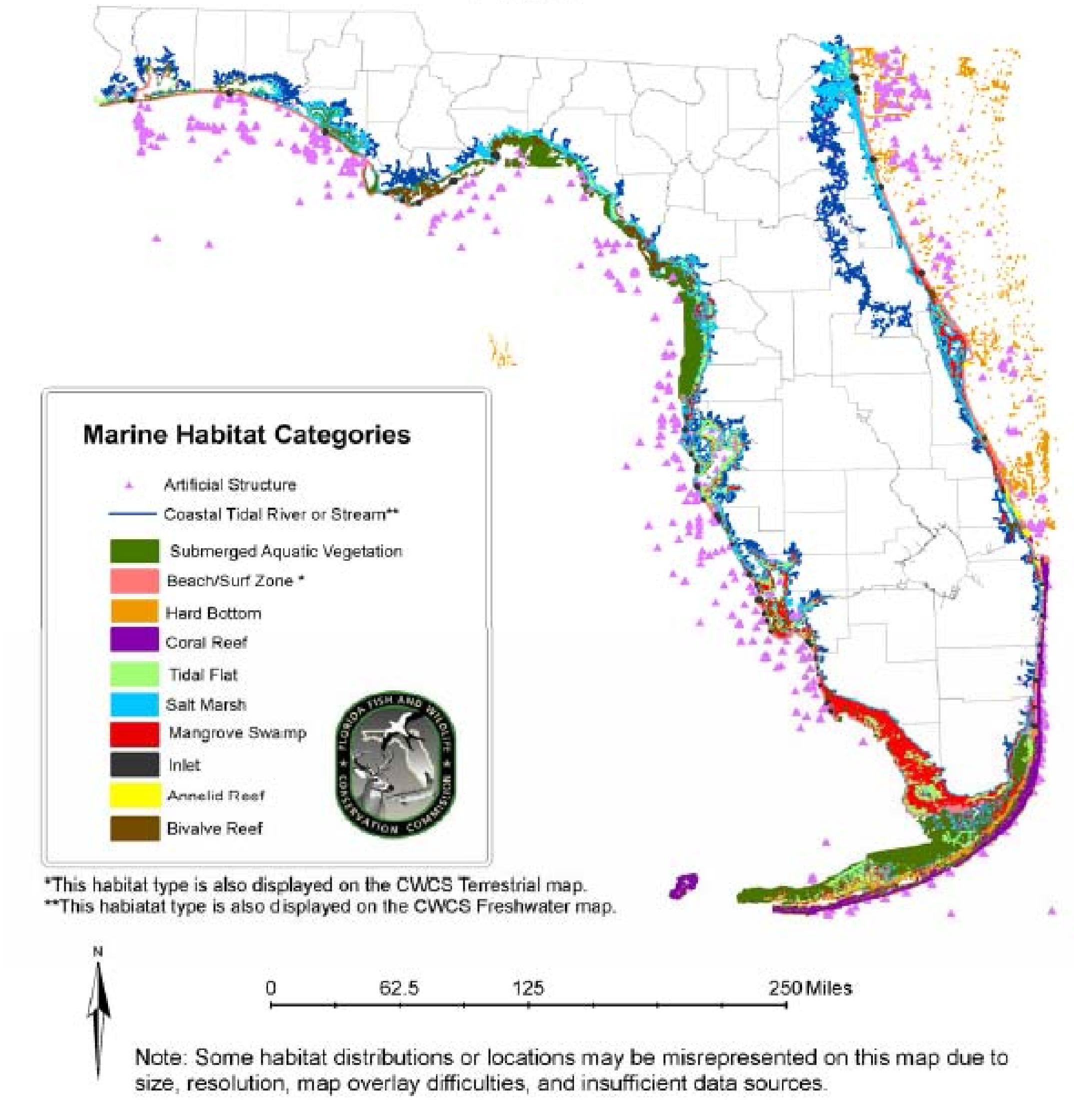


Source: Florida Fish and Wildlife Conservation Commission. 2005. Florida's Wildlife Legacy Initiative. Florida's Comprehensive Wildlife Conservation Strategy. Tallahassee, FL.



Source: Florida Fish and Wildlife Conservation Commission. 2005. Florida's Wildlife Legacy Initiative. Florida's Comprehensive Wildlife Conservation Strategy. Tallahassee, FL.

Florida CWCS
Marine Habitat Categories
2005

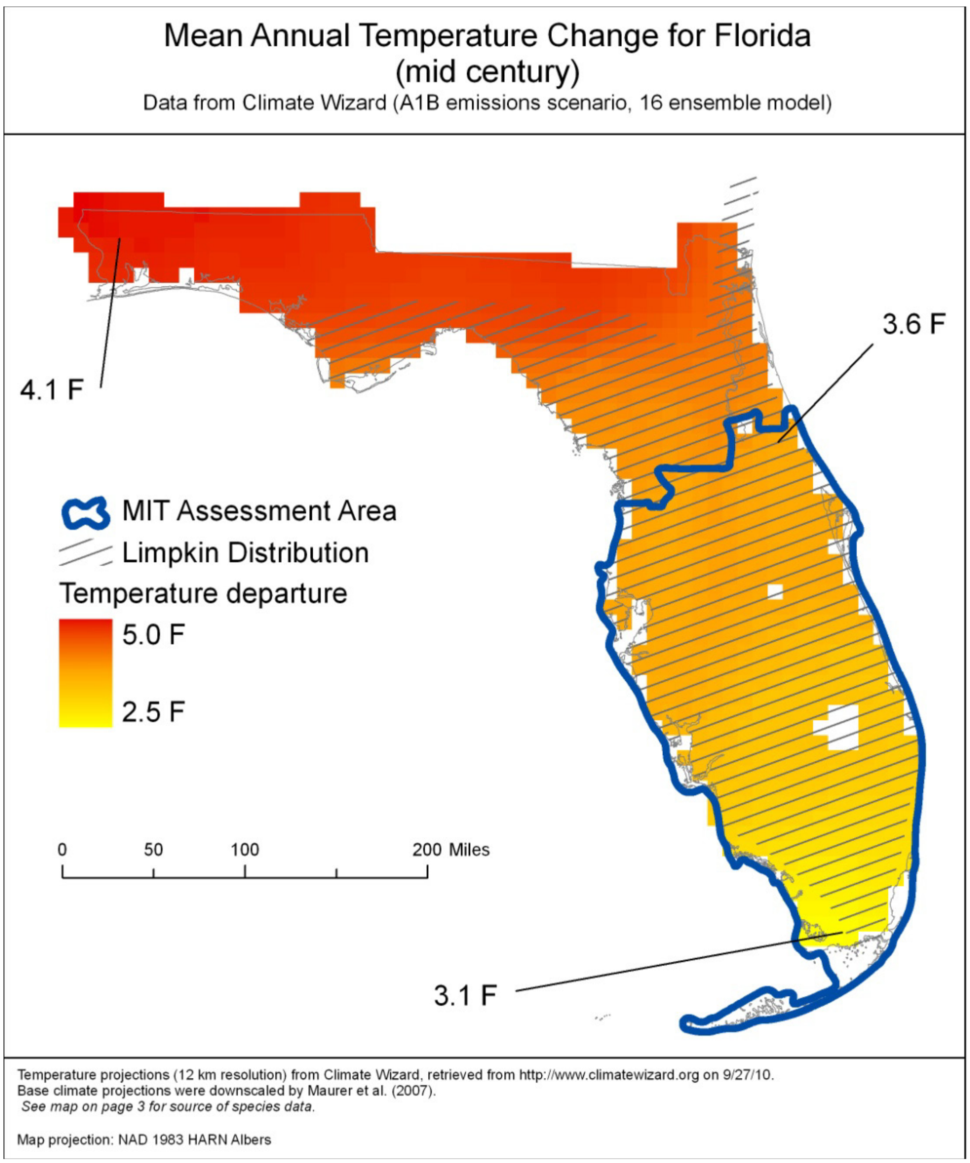


Source: Florida Fish and Wildlife Conservation Commission. 2005. Florida's Wildlife Legacy Initiative. Florida's Comprehensive Wildlife Conservation Strategy. Tallahassee, FL.

Comments on habitat map(s) and suggestions for other resources
Click here to enter text.

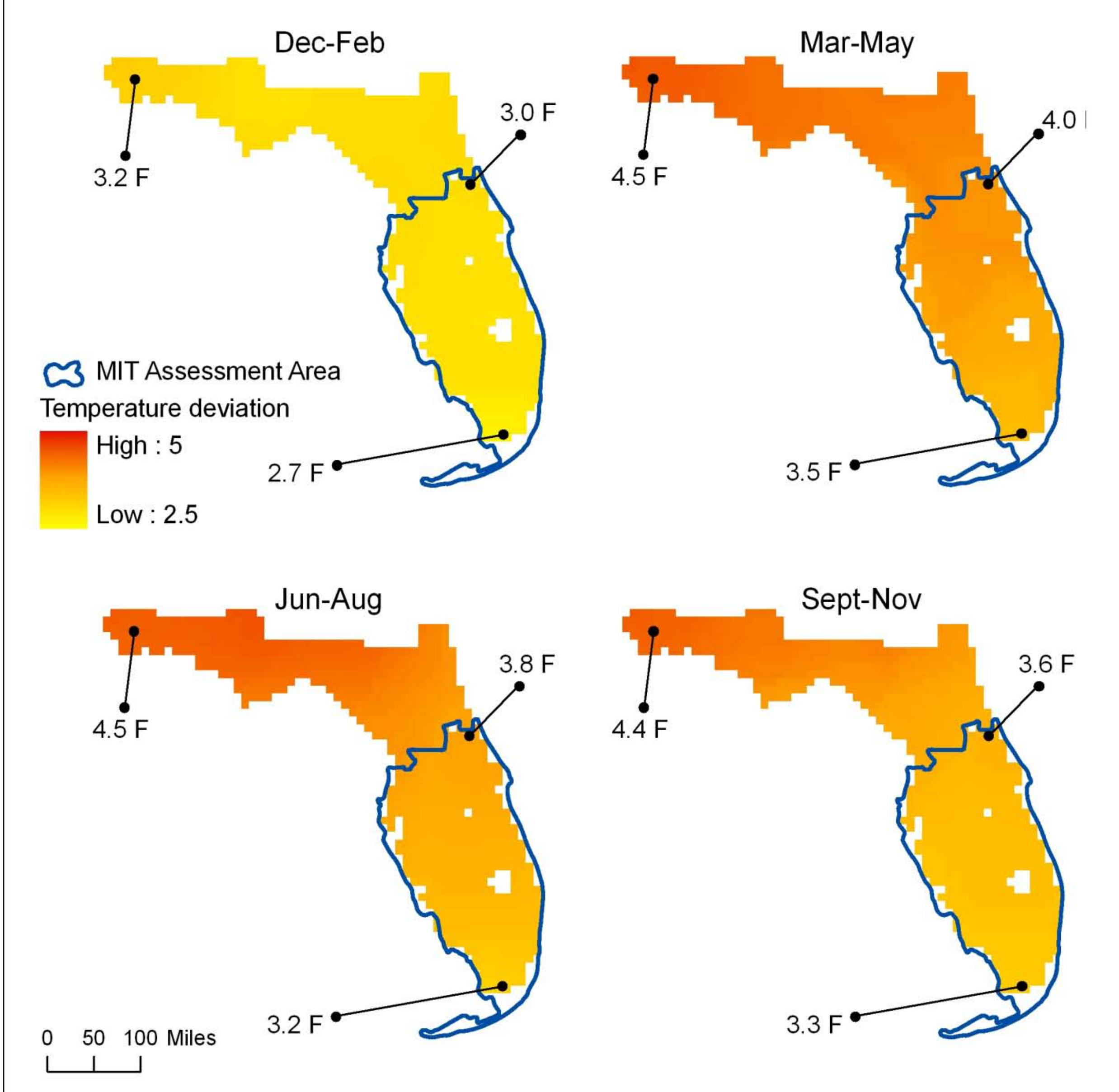
Direct Exposure to Climate Change

NatureServe recommends Climate Wizard (http://www.climatewizard.org) as an easily accessible source of downscaled climate projections. The data available through Climate Wizard are downscaled to a 12 km^2 resolution by Maurer et al. (2007) using statistical downscaling techniques. Below, we have downloaded temperature data (annual and seasonal means) from Climate Wizard for the ensemble average produced from 16 major global circulation models under the A1B scenario and projected to mid-century. These data are provided as a general baseline to use when assessing some of the sensitivity parameters. The issue of model selection will be further addressed during the workshops, however, we invite you to share any guidance regarding model selection for the assessment area. Additional downscaled models are currently in development as part of the Southeast Regional Assessment Project (SERAP) funded by the National Climate Change and Wildlife Center and should be available by the end of the year.



Mean Seasonal Temperature Change for Florida (mid century)

Data from Climate Wizard (A1B emissions scenario, 16 ensemble model)

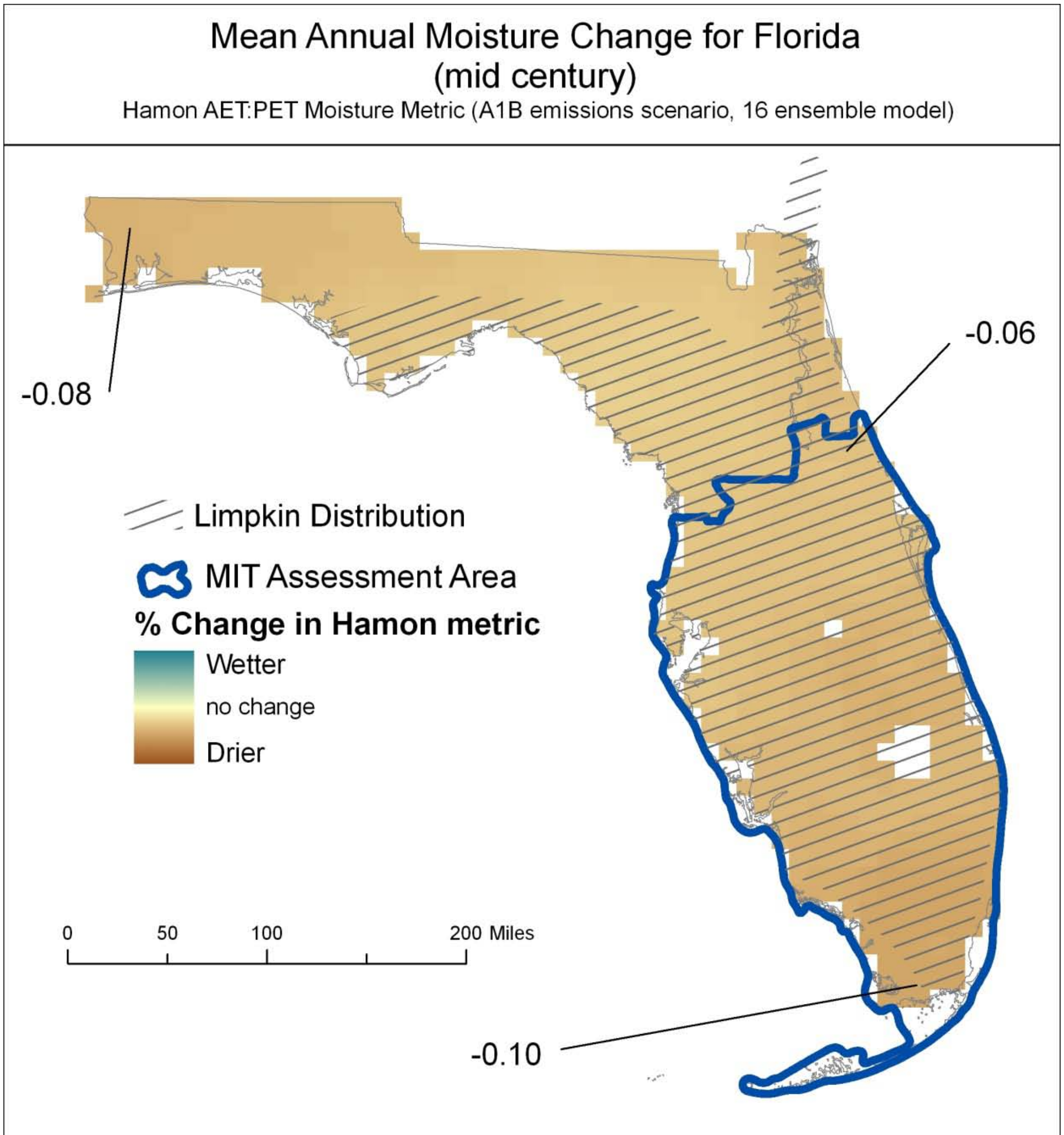


Temperature projections (12 km resolution) from Climate Wizard, retrieved from http://www.climatewizard.org on 9/27/10.
Base climate projections were downscaled by Maurer et al. (2007).

Map projection: NAD 1983 HARN Albers

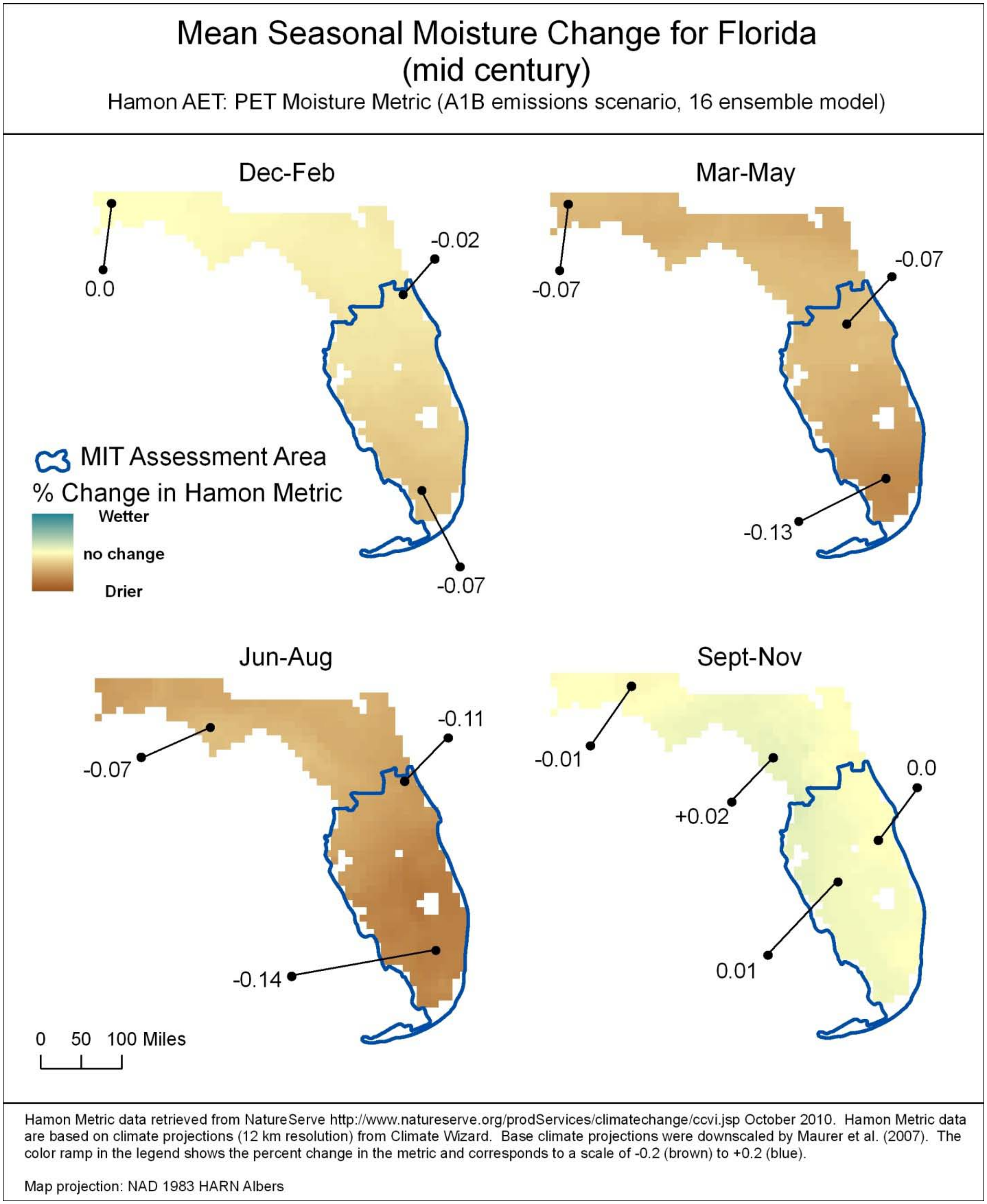
Direct Exposure to Climate Change (cont)

The CCVI utilizes the Hamon AET:PET moisture metric, which is based on data available through Climate Wizard (using the 16-model ensemble average under the A1B emissions scenario above). NatureServe has posted the data for download (http://www.natureserve.org/climatechange). Projected changes in mean annual and seasonal moisture are provided. Please provide information on other more detailed models of moisture availability for the assessment area that may be available.



Hamon Metric data retrieved from NatureServe http://www.natureserve.org/prodServices/climatechange/ccvi.jsp October 2010. Hamon Metric data are based on climate projections (12 km resolution) from Climate Wizard. Base climate projections were downscaled by Maurer et al. (2007). The color ramp in the legend shows the percent change in the metric and corresponds to a scale of -0.2 (brown) to +0.2 (blue).
See map on page 3 for source of species data.

Map projection: NAD 1983 HARN Albers


Mean Seasonal Moisture Change for Florida
(mid century)
Hamon AET: PET Moisture Metric (A1B emissions scenario, 16 ensemble model)
Dec-Feb
0.0
-0.02
-0.07
Mar-May
-0.07
-0.07
-0.13
MIT Assessment Area
% Change in Hamon Metric
Wetter
no change
Drier
Jun-Aug
-0.07
-0.11
-0.14
Sept-Nov
-0.01
+0.02
0.0
0.01
0 50 100 Miles
Hamon Metric data retrieved from NatureServe http://www.natureserve.org/prodServices/climatechange/ccvi.jsp October 2010. Hamon Metric data are based on climate projections (12 km resolution) from Climate Wizard. Base climate projections were downscaled by Maurer et al. (2007). The color ramp in the legend shows the percent change in the metric and corresponds to a scale of -0.2 (brown) to +0.2 (blue).
Map projection: NAD 1983 HARN Albers

Comments on GCMs or downscaled models available for temperature projections Click here to enter text.
Comments on moisture models Click here to enter text.

The following sections ask you to make a selection among a set of categories for a number of factors that affect a species vulnerability to climate change. A set of follow up questions is intended to elicit the supporting information that you used to make your selection(s) and your confidence in the underlying information that is known about the focal species.

Step 1–Consider each factor as it relates to the species of interest *in the assessment area*. Select the category(ies) that best describe the species. Check multiple boxes if more than one box could apply across the species' range in the assessment area or if there is uncertainty as to which category best describes the species. If sufficient data are not available for assessment, please check the insufficient data box.

Step 2–Provide information to support you selection(s) using the follow up questions as a guide. Please specify your level of confidence in the accuracy of the information that you have provided in each response, with 1 indicating high confidence and 5 indicating low confidence. Document sources for this information from the literature or indicate "expert opinion" as appropriate.

What if I cannot assess a factor?
Many factors consist of multiple components, and we have tried to pull these individual components out in the follow up questions. First, try to capture the source of uncertainty in the confidence score that you assign to the different components of the factor. If the uncertainty is associated with a particular component, you may still be able to narrow down your choices by selecting categories that span the probable range. If this is the case you should make multiple selections and would also check the following box:

If multiple boxes are selected
☒ Two or more categories cannot be distinguished due to insufficient data

If you are unable to eliminate any of the choices, leave all the boxes unchecked and select the "insufficient data" box.

Additional guidance on applying the selection criteria to each factor is available in *Guidelines for Using the NatureServe Climate Change Vulnerability Index.* http://www.natureserve.org/prodServices/climatechange/pdfs/Guidelines_NatureServeClimateChangeVulnerabilityIndex_r2.0_Apr10.pdf

Note: Each factor is identified according to the numbering system in the NatureServe Guidelines. For the purposes of this worksheet, most of the examples that have been provided pertain to animals. For additional examples relevant to plant species please see the NatureServe Guidelines.

(B1) Exposure to Sea Level Rise

This factor is relevant for species for which all or a portion of the range within the assessment area may be subject to the effects of a 0.5 - 1 meter sea level rise and the consequent influence of storm surges. Most models suggest an increase of at least 0.5 m in global sea level rise by the end of the century[1]. University of Arizona has produced an interactive map showing the effect of sea level rise (http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm). A map of the lowest modeled rise in sea level (1 m) is shown below. For counties on Florida's Atlantic coast, elevation maps are available from an EPA study[2] (http://maps.risingsea.net/Florida.html).

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[1] A summary of studies providing sea level rise estimates (including some for Florida) can be found in Table 3 of Deyle, R. E., K. C. Bailey, and A. Matheny. 2007. Adaptive Response Planning to Sea Level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning. Florida Planning and Development Lab, Florida State University, Tallahassee, FL. http://www.dca.state.fl.us/fdcp/dcp/publications/Files/AdaptiveResponsePlanningSeaLevelRise.pdf.

[2] Titus, J. G. and J. Wang. 2008. Maps of lands close to sea level along the Middle Atlantic Coast of the United States: An elevation data set to use while waiting for LIDAR. Section 1.1. *in* J. G. Titus and E. M. Strange (Eds.) Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1. EPA 430R07004. U.S. EPA, Washington, D.C. (See also http://maps.risingsea.net/)

Exposure to Sea Level Rise (cont)

☐	> 90% of range occurs in area subject to sea level rise (on low-lying islands or in coastal zone)
☐	50-90% of range occurs in area subject to sea level rise (on low-lying islands or in coastal zone)
☐	10-49% of range occurs in area subject to sea level rise (on low-lying islands or in coastal zone)
☐	<10% of range occurs in area subject to sea level rise (on low-lying islands or in coastal zone)
☐	Occurs in an intertidal habitat that is expected to **increase** in extent with a rising sea level
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. What was your estimate for the percentage of the species' range that is expected to be inundated given this level of sea level rise? %	
2. Please list any other data sources or suggestions for sea level rise models Click here to enter text.	
Information sources Click here to enter text.	

(B2) Distribution Relative to Barriers

This factor assesses the degree to which natural and anthropogenic barriers limit a species' ability to shift its range in response to climate change. This factor is assessing the distribution relative to potential shifts in the climate-envelope on the landscape. Therefore, you should focus on factors that limit dispersal at the range boundaries and not on habitat fragmentation or how the availability of suitable habitat might shift within the species' range. These issues will be addressed in other factors.

Barriers are defined as features or areas that completely or almost completely prevent movement or dispersal of the species. To count as a barrier, a feature can be up to 30 miles from the species' current range when measured across areas where climate changes gradually over latitude or longitude (e.g., relatively flat terrain). Use 15 miles for species that occur in intermediate topography. These distances apply to both terrestrial and aquatic species. Barriers are identified for many species in NatureServe's Element Occurrence Specifications in NatureServe Explorer.

The two types of barriers–natural and anthropogenic–are scored separately although the same categories and criteria apply to both. If both barriers occur, estimate the relative portions of the range margins that are blocked by each type of barrier and score accordingly.

Please provide the following information as it applies to the categories for both types of barriers. Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe the habitat for this species. Click here to enter text.	
2. Does this species occur in a habitat for which projected climate change is expected to significantly reduce habitat or decrease the area of occupancy in the assessment area? ☐ Y ☐ N ➢ *If the answer is no, you should not select categories 1-4 in the assessment table.* Please explain Click here to enter text.	
Information sources Click here to enter text.	

(B2a) Natural Barriers

Examples of features that may function as natural barriers include:

- Upland habitat (i.e., absence of aquatic habitat) is a barrier for fishes but not for semiaquatic or amphibious species.
- Large expanses of water may be barriers for small terrestrial animals but not for birds or for species that readily swim between land areas.

☐	Barriers **completely or almost completely** surround the current distribution such that the species' range in the assessment area is unlikely to be able to shift significantly OR the direction of climate change-caused shift in the species' favorable climate envelope is fairly well understood and barriers prevent a range shift in that direction. Do <u>not</u> select this category for species in habitats <u>not</u> expected to be vulnerable to climate change. Examples: lowland terrestrial species completely surrounded (or bordered closely on the north side) by high mountains, cool-water stream fishes for which barriers would completely prevent access to other cool water areas
☐	Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be **greatly** impaired. Do <u>not</u> select this category for species in habitats <u>not</u> expected to be vulnerable to climate change. Examples: lowland species whose ranges are mostly (50-90%) bordered by high mountains or a large lake
☐	Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be **significantly** impaired. Do <u>not</u> select this category for species in habitats <u>not</u> expected to be vulnerable to climate change. Examples: lowland species whose ranges are partially but not mostly (10-50%) bordered by high mountains or a large lake
☐	Small barriers exist for this species but are not likely to significantly impair distributional shifts with climate change. Do <u>not</u> select this category for species in habitats not expected to be vulnerable to climate change. Examples: terrestrial snakes in extensive plains that may have small barriers that would not impede distributional shifts
☐	Barriers exist but are not likely to contribute significantly to reduced habitat or loss in area of occupancy in the assessment area with projected climate change. Select this category for species in habitats not expected to be vulnerable to climate change. Examples: fishes in large deep lakes or large main-stem rivers that are not thought to be vulnerable to climate change
☐	Significant barriers do not exist for this species. Examples: most birds
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Natural Barriers (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Identify features that would function as natural barriers to movement for this species Click here to enter text.	
2. Describe the distribution of these barriers relative to the species' range in the assessment area (e.g., completely bordered on north side of range, etc.). Click here to enter text. What percentage of the range margin is impacted by these barriers? %	
Information sources Click here to enter text.	

(B2b) Anthropogenic Barriers

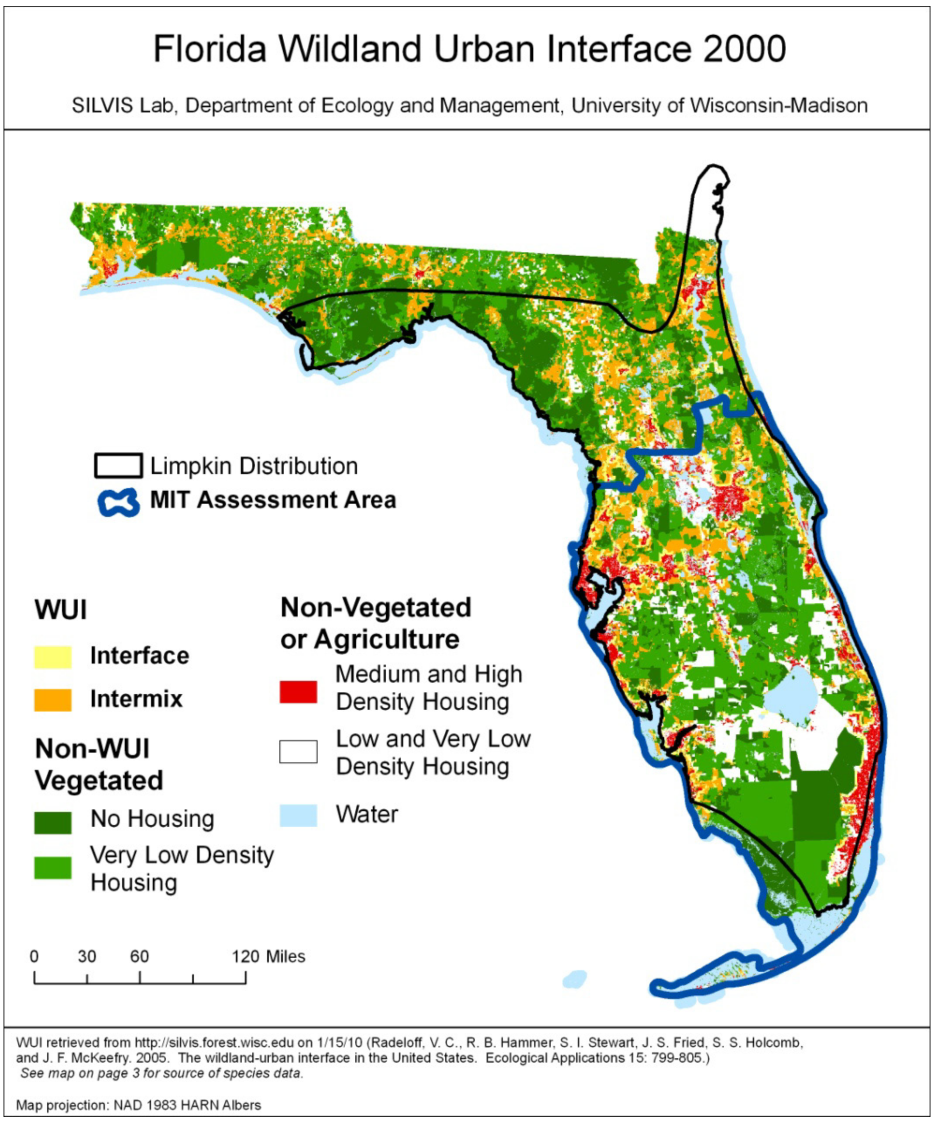
Examples of features that may function as anthropogenic barriers include:

- Large areas of intensive urban or agricultural development are barriers for many species.
- Waters subject to chronic chemical pollution can be a barrier for fishes and other strictly aquatic species.
- Waters subject to thermal pollution may be a barrier for some strictly aquatic species but not for others (note: thermal alterations associated with reservoirs often produce unsuitable habitat rather than imposing a barrier).
- Dams without fish passage facilities and improperly installed culverts can be barriers for fishes.

The Wildland-Urban Interface map (Silvis Lab, University of Wisconsin-Madison and USDA Forest Service North Central Research Station) is provided as a data source for assessing intensity of land use as a potential anthropogenic barrier. For aquatic or semi-aquatic species, a map of wetlands, rivers, and large dams is also provided.

The Wildland Urban Interface (WUI) is composed of interface and intermix communities. In both interface and intermix communities, housing must meet or exceed a minimum density of one structure per 40 acres. Intermix communities are places where housing and vegetation intermingle. Interface communities are areas with housing in the vicinity of contiguous vegetation.

- Intermix WUI is > 50% vegetated and has at least low housing density
- Interface WUI is not vegetated, has at least low housing density, and is within 1.5 mi of an area that is more than 75% vegetated and greater than 2 sq. miles (500 ha) in size
- Housing density is measured in units per acres. Density classes are very low (<0.025), low (0.025-0.2), medium (0.2-3), and high (>3)
- Vegetation includes forest, shrub, grassland, transitional or wetland but not agriculture (NLCD 1992/1993)
- Mapping units are 2000 U.S. census blocks *http://silvis.forest.wisc.edu*



Anthropogenic Barriers (cont)

☐	Barriers **completely or almost completely** surround the current distribution such that the species' range in the assessment area is unlikely to be able to shift significantly OR the direction of climate change-caused shift in the species' favorable climate envelope is fairly well understood and barriers prevent a range shift in that direction. Do not select this category for species in habitats not expected to be vulnerable to climate change. Examples: species limited to small habitats within intensively developed urban or agricultural landscapes through which the species cannot pass
☐	Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be **greatly** impaired. Do not select this category for species in habitats not expected to be vulnerable to climate change. Examples: intensive urbanization surrounding 50-90% of the range of a salamander species
☐	Barriers border the current distribution such that climate change-caused distributional shifts in the assessment area are likely to be **significantly** impaired. Do not select this category for species in habitats not expected to be vulnerable to climate change. Examples: 10-50% of the margin of a plant species' range is bordered by intensive urban development, 25% of the streams occupied by a fish species include dams that are likely to impede range shifts driven by climate change
☐	Small barriers exist for this species but are not likely to significantly impair distributional shifts with climate change. Do not select this category for species in habitats not expected to be vulnerable to climate change. Examples: terrestrial snakes in extensive plains that may have small barriers that would not impede distributional shifts
☐	Barriers exist but are not likely to contribute significantly to reduced habitat or loss in area of occupancy in the assessment area with projected climate change. Select this category for species in habitats not expected to be vulnerable to climate change. Examples: fishes in large deep lakes or large main-stem rivers that are not thought to be vulnerable to climate change
☐	Significant barriers do not exist for this species. Examples: most birds
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Anthropogenic Barriers (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Using the maps provided, identify features (or cover classes) that would function as anthropogenic barriers to movement for this species. Click here to enter text.	
2. Identify other examples of features that may function as anthropogenic barriers for this species. Click here to enter text. Did you use additional geospatial data sets or other sources to assess anthropogenic barriers? ☐ Y ☐ N If so, please provide sources. Click here to enter text.	
3. Describe the distribution of these barriers relative to the species' range in the assessment area (e.g., completely bordered on north side of range, etc.). Click here to enter text. What percentage of the range boundary is impacted by these barriers? %	
Information sources Click here to enter text.	

(B3) Predicted Impact of Land Use Changes Resulting from Human Responses to Climate Change

Strategies designed to mitigate or adapt to climate change have the potential to affect large areas of land and the species that depend on these areas. This factor is NOT intended to capture habitat loss resulting from on-going human activities as these are already included in existing conservation status ranks. Include only new activities related directly to climate change mitigation or adaptation here. Remember that multiple categories can be checked to capture uncertainty.

Examples of land use changes that might impact species or habitats include:

- Plantations for carbon offsets
- New seawalls in response to sea level rise
- Renewable energy projects such as wind farms, solar arrays, or biofuels production

A map from an EPA study[3] that shows the potential for shoreline protection (hardening) based on existing policies is included as an example of the type of strategies that could be addressed in this section. Please note that these data are only available for the Atlantic Coast and are based on land use between 1995 and 2005.

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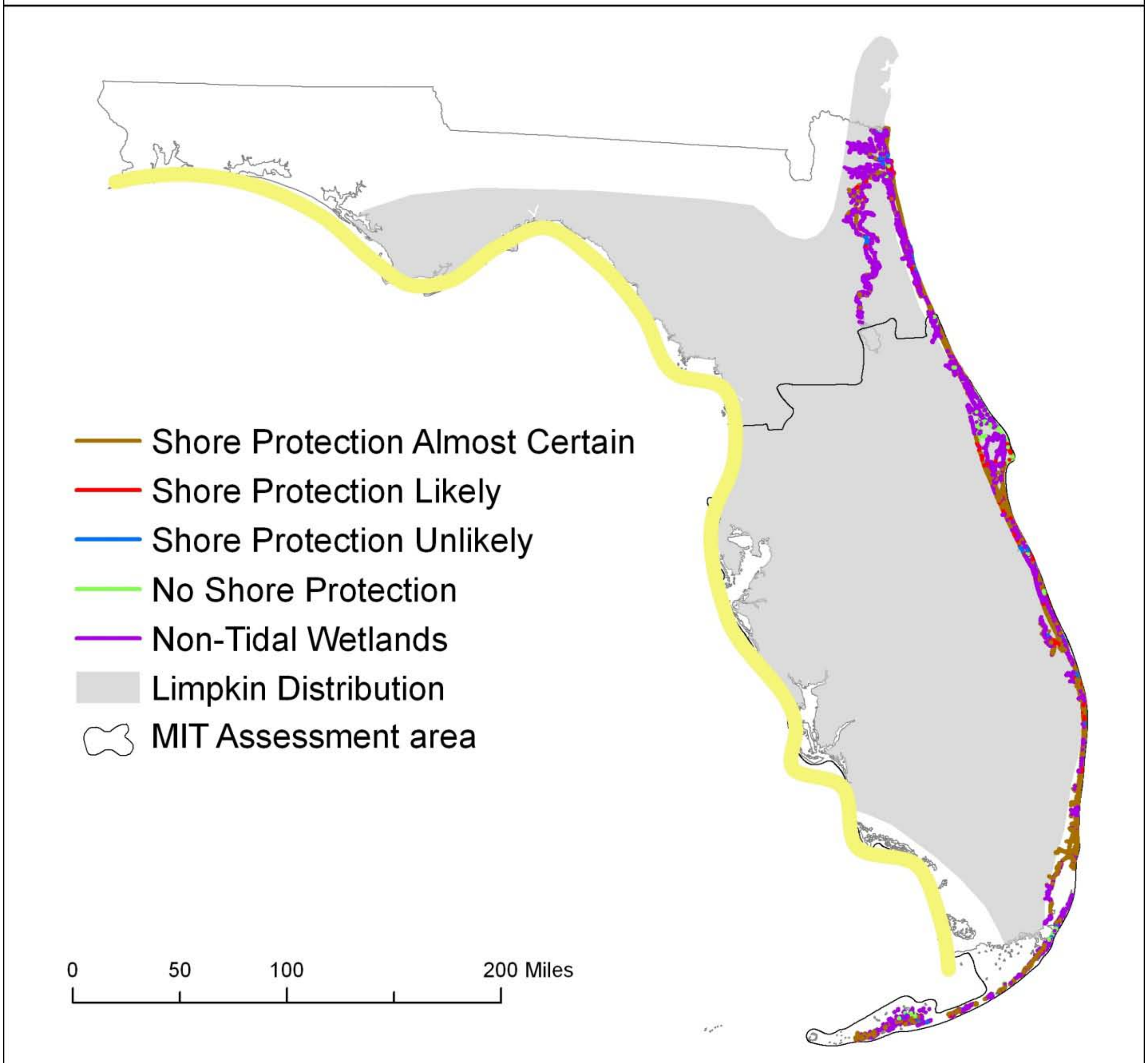
[3] Titus, J. G., D. E. Hudgens, D. L. Trescott, M. Craghan, W. H. Nuckols, C. H. Hershner, J. M. Kassakian, C. J. Linn, P. G. Merritt, T. M. McCue, J. F. O'Connell, J. Tanski, and J. Wang. 2009. State and local governments plan for development of most land vulnerable to rising sea level along the US Atlantic coast. Environmental Research Letters 4: 044008. (Also see, http://plan.risingsea.net/)

Liklihood of Shore Protection (Florida - Atlantic Coast)

(Southwest Florida Regional Planning Council)



Shoreline protection data obtained from the US EPA (Dec 2009). This information was produced under a grant from EPA to the Southwest Florida Regional Planning Council, which subcontracted the analysis to the appropriate Florida regional planning council. The product has been approved for distribuiton by either the Northeast Florida Regional Planning Council, the East Central Florida Regional Planning Council, the Treasure Coast Regional Planning Council, or the South Florida Regional Planning Council. It has not been subjected to an EPA-managed peer review and does not necessarily reflect the view of the Agency. No official endorserment should be inferred. *See map on page 3 for source of species data.*

Map projection: NAD 1983 HARN Albers

Predicted Impact of Land Use Changes Resulting from Human Responses to Climate Change (cont)

☐	The natural history and/or requirements of the species are known to be incompatible with mitigation/adaptation-related land use changes that are **likely or very likely to occur** within the species' current or potential future range. Examples: species requiring open habitats within landscapes that are likely to be reforested or afforested, species whose migratory routes or habitat include existing and/or suitable wind farm sites, species for which >20% of the species' range within the assessment area occurs on marginal agricultural land or open areas with suitable soils for agriculture that are not currently in agricultural production OR >50% of the species' range within the assessment area occurs on non-urbanized land with suitable soils that may be converted to biofuel production, species occurring in rivers/streams with the potential to be developed for hydropower, species dependent on dynamic shoreline habitats likely to be destroyed by shoreline hardening or other fortifications against rising sea levels.
☐	The natural history and/or requirements of the species are known to be incompatible with mitigation/adaption-related land use changes that **may possibly occur** within its current or potential future range, including any of the examples listed for the previous category.
☐	The species is unlikely to be significantly affected by mitigation/adaptation-related land use changes that may occur within its current or potential future range OR it is unlikely that any mitigation/adaptation-related land use changes will occur within the species' current or potential future range.
☐	The species is likely to benefit from mitigation/adaptation-related land use changes that may occur within its current or potential future range. Examples: forest-associated species currently found within a landscape with <40% cover, where increases in forest cover may occur as a result of reforestation or afforestation projects, species currently subject o a higher frequency of fires than experienced historically where there may now be greater incentive to control such fires, species occurring on unprotected lands which may be protected and managed for conservation due to their carbon storage and/or sequestration ability.
☐	The species is likely to benefit from mitigation/adaptation-related land use changes that are likely or very likely to occur within its current or potential future range, including any of the examples listed for the previous category.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Predicted Impact of Land Use Changes Resulting from Human Responses to Climate Change (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe any mitigation/adaptation-related land use changes that might occur within the species current or potential future range. Click here to enter text.	
2. Please identify any potential impacts on the species that you considered in making your category selection(s) for this factor. Click here to enter text.	
Information sources Click here to enter text.	

For factors C1 through C6, <u>at least 10 factors must be assessed</u> in order to calculate an Index score.

- These factors are related to characteristics of the species only (i.e., do not consider anthropogenic effects such as the availability of dispersal corridors when assessing dispersal).

(C1) Dispersal and Movements

This factor pertains specifically to <u>dispersal through unsuitable habitat</u>, which, in most cases, is habitat through which propagules or individuals may move but that does not support reproduction or long-term survival. If all habitat is regarded as suitable, then dispersal ability is assessed for suitable habitat. Provide information on the dispersal distance generally observed for individuals or propagules of this species. Note that anthropogenic effects, such as the availability of dispersal corridors should not be considered in this section.

☐	Species is characterized by **severely restricted** dispersal or movement. This category includes species represented by sessile organisms that almost never disperse more than a few meters per dispersal event. Examples: plants with large or heavy propagules for which the disperser is extinct or extremely rare, species with dispersal limited to vegetative shoots or similar structures that do not survive if detached from the parent.
☐	Species is characterised **by highly restricted** dispersal or movement. This category includes species that rarely disperse through unsuitable habitat more than about 10 meters per dispersal event and species in which dispersal beyond a very limited distance occurs but is dependent on rare events. Examples: clams that may disperse while clamped onto bird feathers or frog toes, species that may be carried by more than 10 meters by strong storm or flood events but otherwise rarely disperse more than 10 meters.
☐	Species is characterized by **limited** dispersal or movement. At least 5% of propagules or individuals disperse 10-100 meters per dispersal event. Examples: small, nonvolant animals such as slugs, snails, and the smallest terrestrial salamanders that move more than 10 meters when conditions are favorable, species that exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are up to 100 meters apart
☐	Species is characterized by **moderate** dispersal or movement. At least 5% of propagules or individuals disperse 100-1,000 meters per dispersal event. Examples: species that exist in small isolated patches of suitable habitat but regularly disperse or move among patches that are 100-1,000 meters apart, species whose propagules are dispersed by small animals that move propagules 100-1,000 meters from the source. This category may include small but somewhat vagile animals such as many small mammals and lizards, many denning snakes and some pond-breeding amphibians that are otherwise terrestrial as adults

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☐	Species is characterized by **good** dispersal or movement capability. Propagules or individuals readily move (or are moved) 1-10 kilometers from natal or source areas.
☐	Species is characterized by excellent dispersal or movement capability. Propagules or individuals readily move (or are moved) more than 10 kilometers from natal or source areas Examples: most large and some medium-sized mammals, most bats, and most birds that regularly disperse or move long distances via their own locomotory abilities, species that are dispersed more than 10 kilometers by other highly mobile animals, air or ocean currents, or humans, including species that readily become established outside their native ranges as a result of intentional or unintentional translocations by humans, animal species whose populations within the assessment area are known to facultatively migrate or shift distributions according to changing environmental conditions
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Identify the species dispersal mechanism *e.g., individuals disperse from natal area via their own locamotory abilities; propagules or individuals dispersed by other animals; propagules dispersed by wind* Click here to enter text.	
2. How far do propagules or individuals generally move per dispersal event? meters	
3. Does habitat patchiness generally limit dispersal? ☐ Y ☐ N *If yes, please explain (e.g., species exists in small isolated patches but moves among patches that are up to 100 meters apart).* Click here to enter text.	
Information sources Click here to enter text.	

(C2aii) Physiological Thermal Niche

This factor assesses the degree to which a species is restricted to relatively cool or cold above-ground terrestrial or aquatic environments that are thought to be vulnerable to loss or significant reduction as a result of climate change. The restriction to these relatively cool environments may be permanent or seasonal. When making your selection(s) consider whether species occurring in cool sites, such as shady ravines or other cooler habitats are likely to simply shift in location without reduction or loss.

☐	Species is **completely or almost completely** restricted (>90% of occurrences or range) to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change.
☐	Species is **moderately** restricted (50-90% of occurrences or range) to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change.
☐	Species is **somewhat** restricted (10-50% of occurrences or range) to relatively cool or cold environments that may be lost or reduced in the assessment area as a result of climate change.
☐	Species distribution is not significantly affected by thermal characteristics of the environment in the assessment area OR the species occupies habitats that are not thought to be vulnerable to projected climate change.
☐	Species shows a preference for environments towards the warmer end of the spectrum.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Physiological Thermal Niche (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Indicate whether the species is associated with a particular thermal environment relative to the range of environments found in the assessment area. Association with these environments may be permanent or seasonal. ☐ Cool/cold environment. Describe: e.g., shady ravines, cold streams ☐ Warm environment. Describe: ☐ No association with a particular thermal environment	
2. Quantify the proportion of occurrences or range within the assessment area restricted to this particular thermal environment. %	
3. Is the availability of this environment likely be affected by climate change? ☐ Y ☐ N Score as no if the habitat is likely to shift in location <u>without</u> reduction or loss.	
Information sources Click here to enter text.	

(C2bii) Physiological Hydrologic Niche

This factor pertains to a species' dependence on a narrowly defined precipitation/hydrologic regime, including strongly seasonal precipitation patterns and/or specific aquatic wetland habitats. Consider the direction, strength, and seasonality of moisture change along with the level of dependence of the species on particular hydrologic conditions. Dependence may be permanent or seasonal.

☐	Species is **completely or almost completely** dependent (>90% of occurrences or range) on a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change. Examples: certain spring-dependent fishes, ephemeral pool-dependent branchiopods
☐	Species is **moderately** dependent (50-90% of occurrences or range) on a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change. Examples: amphibians that often breed in vernal pools but also regularly use other aquatic or wetland habitats

continued next page

☐	Species is **somewhat** dependent (10-50% of occurrences or range) on a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change. Examples: plants (and animals depending on these plants) for which 10-50% of populations occur in areas such as sandy soils that are sensitive to changes in precipitation
☐	Species has **little or no** dependence on a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change OR hydrological requirements are not likely to be significantly disrupted in a major portion of the range.
☐	Species has very broad moisture regime tolerances OR would benefit by the projected change in hydrologic regime.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe any species-specific associations with particular aquatic/wetland habitats or moisture regimes. Click here to enter text.	
2. Quantify the proportion of occurrences or range within the assessment area associated with the habitat or moisture regime. %	
3. What is the expected direction of moisture change for these habitats and/or moisture regimes under climate change? Click here to enter text.	
4. If these changes occurred, would they be likely to reduce the species' distribution, abundance or habitat quality? ☐ Y ☐ N If yes, please describe the potential impacts. Click here to enter text.	
Information sources Click here to enter text.	

(C2c) Dependence on Specific Disturbance Regimes

This factor pertains to a species' response to specific disturbance regimes that are likely to be impacted by climate change, such as fires, floods, severe winds, pathogen outbreaks, or similar events. Consider disturbances that impact species indirectly, such as changes in flood frequency impacting sensitive aquatic species via changes in water turbidity. Also consider potential impacts on species that currently benefit from a lack of disturbance.

☐	Species is **strongly** affected by a specific disturbance regime that is likely to change in frequency, severity, or extent in a way that <u>reduces</u> the species' distribution, abundance, or habitat quality. Examples: many sagebrush-associated species in regions predicted to experience increased fire frequency
☐	Species is **moderately** affected by specific disturbance regime that is likely to change in frequency, severity, or extent in a way that <u>reduces</u> the species' distribution abundance, or habitat quality.
☐	Species has little or no response to a specific disturbance regime OR climate change is unlikely to change the frequency, severity, or extent of that disturbance regime in a way that affects range or abundance of the species.
☐	Species is **moderately** affected by a specific disturbance regime that is likely to change in frequency, severity, or extent in a way that <u>increases</u> the species distribution, abundance, or habitat quality.
☐	Species is **strongly** affected by a specific disturbance regime that is likely to change in frequency, severity, or extent in a way that <u>increases</u> the species distribution, abundance, or habitat quality.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe any species-specific associations (or disassociations) with a particular disturbance regime. Click here to enter text.	
2. How is this disturbance regime expected to change (e.g., frequency, severity, or extent) under climate change? Click here to enter text.	

3. If these changes occurred, would they be likely to affect the species' distribution, abundance or habitat quality? ☐ Y ☐ N If yes, please describe the potential impacts. Click here to enter text.	
Information sources Click here to enter text.	

(C3) Restriction to Uncommon Geological Features

This factor pertains to a species' need for a particular soil/substrate, geology, water chemistry, or specific physical feature (e.g., caves, cliffs, active sand dunes) for one or more portions of its life cycle. Do not include features that have been addressed by previous factors, such as springs or ephemeral pools or biotic habitat components, such as a particular type of plant community, as these will be addressed elsewhere.

☐	Species is **very highly dependent** on (>85% of occurrences) a particular highly uncommon geological feature or derivative (endemic). Examples: species restricted to inland sand dunes, obligate cave-dwelling organisms, spring snails restricted to springs with high dissolved CO_2, fish species requiring uncommon substrate particle size
☐	Species is **moderately to highly dependent** on (65-85% of occurrences) a particular highly uncommon geological feature or derivative OR is restricted to a geological feature or derivative that is not highly uncommon but is not one of the dominant types within the species' range. Examples of the latter: species restricted to active coastal sand dunes, cliffs, or salt flats, or those found only in inland waters within a particular salinity range
☐	Species has a **clear preference** for (>85% of occurrences) a particular geological feature or derivative that is among the dominant types within the species' range. Example: red spruce prefers acidic, organic soils which are not uncommon in its range
☐	Species is **somewhat flexible** but not highly generalized in dependence upon geological features or derivatives. This category should include species found on a subset of dominant substrates occurring within the species' range. Select this category for species for which the idea of specificity to a particular geologic feature or derivative is not relevant (e.g., many birds and mammals). Examples: Most species with habitat descriptions that mention more than one type of relatively widespread geological feature

continued next page

☐	Species is **highly generalized** relative to dependence upon geological features or derivatives. This category includes species described as generalists and/or species known to occur on substrates that represent opposite ends of the spectrum of types within the assessment region.
☐	*Insufficient data for assessment*

If multiple boxes are selected

☐ More than one category applies across the species' range in the assessment area
☐ Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe any species-specific associations with particular geological features or derivatives. Click here to enter text.	
2. Quantify the proportion of occurrences associated with the geologic feature or derivative. %	
3. Relative to other types found in the species' range within the assessment area, the geologic feature or derivative is ☐ highly uncommon (e.g., fish requiring a highly uncommon substrate size) ☐ fairly common (e.g., species restricted to salt flats) ☐ dominant ☐ specificity to soil/substrate, geology, or specific physical features is not particularly relevant to the species	
Information sources Click here to enter text.	

(C4a) Dependence on Other Species to Generate Habitat

For this factor, habitat refers to any habitat necessary for completion of the life cycle, including those used on a seasonal basis. Consider how specialized the species is in its associate with another species to generate habitat AND the vulnerability of the other species to climate change. If a species is dependent on a single species to generate habitat, but the vulnerability of that species is unknown, they first two boxes below should be checked.

☐	Required habitat is generated primarily by a **single species** that is **highly vulnerable** to climate change within the assessment area. Examples: salt marsh sparrow is dependent on *Spartina alternifora* for nesting habitat, the beetle *Onthophilus giganteus* is dependent on southeastern pocket gopher tunnels for habitat, the spider *Masoncus pogonophilus* is dependent on habitat provided by colony chambers of the Florida harvester ant.
☐	Require habitat is generated primarily by a **single species** and that species is <u>at most</u> **moderately vulnerable** to climate change within the assessment area.
☐	Required habitat is generated by one or more of not more than **a few species**. Examples: burrowing owls depend on excavations made by relatively few species of mammals, marbled murrelets depend on a few species of large trees to provide nesting platforms
☐	Required habitat is generated by **more than a few species** or does not involve species-specific processes.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe any associations with other species that are required to generate habitat (e.g., reliance on excavations by burrowing mammals or on specific plant species for nesting) and identify these species by name. For species falling into the last category in the table above, provide a general description of the habitat requirements. Click here to enter text.	

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2. If the required habitat is generated by a single species, is this species expected to be <u>highly</u> vulnerable to climate change? ☐ Y ☐N ☐ unknown ☐ n/a If yes, please describe any factors that you feel make the species particularly vulnerable to climate change. Click here to enter text.	
Information sources Click here to enter text.	

(C4b) Dietary Versatility

This factor pertains to the diversity of food types consumed by animal species.

☐	Diet is completely or almost completely dependent (>90%) on **one species** during any part of the year. Example: Clark's nutcracker depends heavily on the seeds of whitebark pine
☐	Diet is completely or almost complete dependent (>90%) on a **few species** from a single guild of species during any part of the year. Example: the larvae of various fritillary butterflies rely heavily on a few species of violets
☐	Diet is **flexible**, i.e., not dependent on one or a few species (although the diet may be dominated by one or a few species in a particular location).
☐	**Omnivorous** diet include numerous species of both plants and animals.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Dietary Versatility (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe the species' diet. For dietary specialists, identify species known to be included in the diet by name. Click here to enter text.	
Information sources Click here to enter text.	

(C4d) Dependence on Other Species for Propagule Dispersal

This factor can be applied to plants or animals. For example, different species of freshwater mussels can be dispersed by one to many fish species.

☐	Dispersal is completely or almost completely dependent (<90%) on a **single species** for propagule dispersal. Example: whitebark pine relies on Clark's nutcracker as the primary dispersal agent
☐	Dispersal is completely or almost completely dependent (<90%) on a **small number of species** for propagule dispersal. Example: a freshwater mussel for which only a few species can disperse larvae
☐	Species disperses on its own OR propagules can be dispersed by more than a few species. Most animals will fall into this category.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Dependence on Other Species for Propagule Dispersal (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe the dispersal mechanism for the species. For species dependent on one or a few species for dispersal, identify known dispersal species by name. Click here to enter text.	
Information sources Click here to enter text.	

(C4e) Other Interspecific Interactions

This factor refers to interactions unrelated to habitat, diet, or propagule dispersal, such as mutualism, parasitism, or commensalism. Examples:

- the parasitic larvae of some freshwater mussels requiring fish species as a host for development
- the mutualistic relationship between some acacias which feed ant colonies providing protection against herbivores
- the commensalistic relationship displayed tree frogs inhabiting trees

☐	Species requires an interaction with a **single** other species for persistence.
☐	Species requires an interaction with one member of a **small group** of taxonomically related species for persistence. Select this category in cases for which specificity is suspected but not known for certain.
☐	Does not require an interspecific interaction OR many potential candidates can be used.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Other Interspecific Interactions (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Describe any interspecific interactions required by the species for persistence. For species dependent on one or a few other species, identify these other species by name. Click here to enter text.	
Information sources Click here to enter text.	

(C5a) Measured Genetic Variation

For this factor, "genetic variation" may refer to neutral marker variation, quantitative genetic variation, or both. Only provide responses for this factor if genetic variation has been assessed over a substantial portion of the species' range. Genetic variation should be assessed relative to that measured in related species. **If no information is available about rangewide genetic variation for this species, please skip this section and go to section C5b.**

☐	Reported genetic variation is "**very low**" compared to findings using similar techniques on related taxa. This category includes species for which lack of genetic variation has been identified as a conservation issue.
☐	Reported genetic variation is "**low**" compared to findings using similar techniques on related taxa.
☐	Reported genetic variation is "**average**" compared to findings using similar techniques on related taxa.
☐	Reported genetic variation is "**high**" compared to findings using similar techniques on related taxa.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Measured Genetic Variation (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. If available, provide estimates of genetic variation (and methods used) in this species and related species. Indicate whether you know of any special considerations for populations occurring in the assessment area relative to other portions of the species' range. Click here to enter text.	
Information sources Click here to enter text.	

(C5b) Occurrence of Bottlenecks in Recent Evolutionary History

- *This section should only be filled out for species for which rangewide genetic variation information (Section C5a) is not available.*

☐	There is evidence that the total population was reduced to ≤ 250 mature individuals, to one occurrence, and/or that the occupied area was reduced by > 70% at some point in the past 500 years. Only species that suffered population reductions and then subsequently rebounded qualify for this category.
☐	There is evidence that the total population was reduced to 251 - 1,000 mature individuals, to less than 10 occurrences, and/or that the occupied area was reduced by 30 - 70% at some point in the past 500 years. Only species that suffered population reductions and then subsequently rebounded qualify for this category.
☐	No evidence that the total population was reduced to ≤ 1,000 mature individuals and/or that occupied area was reduced by > 30% at some point during the past 500 years.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Occurrence of Bottlenecks in Recent Evolutionary History (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Is there evidence that the species has suffered a population bottleneck at some point in the past 500 years? ☐ Y ☐N	
2. If yes, quantify the reduction in population size, occurrences, and/or occupied area. Click here to enter text. How has the species responded? Provide current estimates of population size, occurrences, and/or occupied area relative to what is known about the species prior to the bottleneck. Click here to enter text.	
Information sources Click here to enter text.	

(C6) Phenological Response

This factor assesses changes in a species' phenological response (e.g., timing of flowering, migration, breeding, etc.) relative to observed changes in temperature or precipitation dynamics. Responses should be assessed relative to other species in similar habitats or taxonomic groups. Potential sources of data include large databases such as that of the U.S. National Phenology Network other multi-species studies.

☐	Seasonal temperature or precipitation dynamics within the species' range show detectable change, but phenological variables measured for the species show <u>no</u> detectable change.
☐	Seasonal temperature or precipitation dynamics within the species' range show detectable change AND phenological variables measured for the species show some detectable change, but the <u>change is significantly less than</u> that of other species in similar habitats or taxonomic groups. *If comparisons to other species are not available, select this category and the next two categories.*
☐	Seasonal temperature or precipitation dynamics within the species' range show detectable change AND phenological variables measured for the species show some detectable change, but the <u>change is average</u> compared to other species in similar habitats or taxonomic groups

continued next page

☐	Seasonal temperature or precipitation dynamics within the species' range show detectable change AND phenological variables measured for the species show some detectable change, but the <u>change is significantly greater</u> than that of other species in similar habitats or taxonomic groups
☐	Seasonal dynamics within the species' range show no detectable change.
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. If changes in seasonal temperature or precipitation dynamics have been detected within the species' range in the assessment area, identify which variable(s) and what amount of change over what time period. Click here to enter text.	
2. List any phenological variable(s) for which you could find long term data sets for this species. Click here to enter text. Have there been changes in the timing of the variable(s)? ☐ Y ☐ N If yes, describe variable(s), amount of change, and time period. Click here to enter text.	
3. Are data available for other species in similar habitats or taxonomic groups? ☐ Y ☐ N If yes, which species:	
Information sources Click here to enter text.	

Factors indicated with a "D" in their code are related to documented or modeled responses to climate change. As the data required for the factors in this section are often not available, none of these factors are required to calculate an Index score.

(D1) Documented Changes in Distribution or Abundance in Response to Recent Climate Change (optional)

This factor pertains to the degree to which distribution or abundance has changed in response to recent climate change, for example range contractions or population declines due to phenology mismatches and critical resources. Consider a time frame of 10 years or three generations, whichever is longer.

☐	Distribution or abundance undergoing **major reduction** (>70% over 10 years or three generations) believed to be associated with climate change.
☐	Distribution or abundance undergoing **moderate reduction** (30-70% over 10 years or three generations) believed to be associated with climate change.
☐	Distribution or abundance undergoing **small but measurable reduction** (10-30% over 10 years or three generations) believed to be associated with climate change.
☐	Distribution and abundance not known to be increasing or decreasing with climate change. Includes species undergoing range shifts without significant change in distributional area or species undergoing changes in phenology but without a change in net range or population size.
☐	Distribution or abundance undergoing **small but measurable increase** (10-30% over 10 years or three generations) believed to be associated with climate change. Distribution changes must be true increases in area, not range shifts
☐	Distribution or abundance undergoing **moderate or major increase** (>30% over 10 years or three generations) believed to be associated with climate change. Distribution changes must be true increases in area, not range shifts
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	More than one category applies across the species' range in the assessment area
☐	Two or more categories cannot be distinguished due to insufficient data

Documented Changes in Distribution or Abundance in Response to Recent Climate Change (cont)

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Provide a brief summary of any documented changes in distribution or abundance that have been linked to climate change. Click here to enter text.	
2. Was the change in: ☐ distribution ☐ abundance Quantify the change % Over what length of time or number of generations was the change observed? Click here to enter text.	
Information sources Click here to enter text.	

(D2) Modeled Future Change in Range or Population Size (optional)

This factor can include both distribution models and population models. Projections should be based on "middle of the road" climate scenarios for the year 2050. Range size should be based on "extent of occurrence." Population models should be based on known processes as described in the peer-reviewed literature. If necessary, check multiple boxes to reflect variation in model output.

☐	Predicted future range disappears entirely from the assessment area OR predicted future abundance declines to zero as a result of climate change processes
☐	Predicted future range represents 50-99% decrease relative to current range within the assessment area OR predicted future abundance represents 50-99% decrease associated with climate change processes
	Predicted future range represents a 20-50% decrease relative to current range within the assessment area OR predicted future abundance represents 20-50% decrease associated with climate change processes

continued next page

☐	Predicted future range represents no greater than a 20% change relative to current range within the assessment area OR predicted future abundance represents < 20% increase or decrease associated with climate change processes
☐	Predicted future range represents 20-50% increase relative to current range within the assessment area OR predicted future abundance represents 20-50% increase associated with climate change processes
☐	Predicted future range represents >50% increase relative to current range within the assessment area OR predicted future abundance represents >50% decrease associated with climate change processes
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	Two or more categories cannot be distinguished due to insufficient data
☐	Multiple boxes are checked to reflect variation in model output

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right.
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

1. Model is a ☐ distribution model ☐ abundance model Which climate scenario(s) were used? (e.g., GCM, emissions scenario, other) Click here to enter text. What is the time period for the model? Are spatial data available for the future distribution/abundance? ☐ Y ☐ N Citation/source:	
2. What was the source of the current distribution or abundance data/model? Click here to enter text.	
3. What is the predicted change in range or abundance in the assessment area? % Is this number based on ☐ Visual estimates from maps or figures (ballpark estimate) ☐ Quantitative comparison of output with current distribution/abundance ☐ Description of results in text ☐ Other, describe:	Score

(D3) Overlap of Modeled Future Range with Current Range (optional)

If a distribution model was available for Factor D2 (p. 37), estimate the percent of the current range represented by the intersection of the predicted future and current ranges. **In order to avoid double counting model results, skip this factor if you selected the first category for factor D2.**

☐	There is no overlap between the current and predicted future range within the assessment area
☐	Predicted future range overlaps the current range by ≤ 30% within the assessment area
☐	Predicted future range overlaps the current range by 30-60% within the assessment area
☐	Predicted future range overlaps the current range by >0% within the assessment area
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	Two or more categories cannot be distinguished due to insufficient data
☐	Multiple boxes are checked to reflect variation in model output

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right:
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Estimate the overlap between the current and predicted future range within the assessment area. % Is this number based on ☐ Visual estimates from maps or figures (ballpark estimate) ☐ Quantitative comparison of output with current distribution (e.g., GIS) ☐ Description of results in text ☐ Other, describe:	
Information sources (if different from Factor M) Click here to enter text.	

(D4) Occurrence of Protected Areas in Modeled Future Distribution (optional)

If a distribution model was available for Factor D2 (p. 32), estimate the percentage of the future distribution that intersects with existing protected areas. Protected area refers to existing parks, refuges, wilderness areas, and other designated conservation areas that are relatively invulnerable to outright habitat destruction from human activities and that are likely to provide suitable conditions for the existence of viable populations of the species. Consider only ranges and protected areas within the assessment area.

☐	< 5% of the modeled future distribution within the assessment area is encompassed by one or more protected areas
☐	5-30% of the modeled future distribution within the assessment area is encompassed by one or more protected areas
☐	>30% of the modeled future distribution within the assessment area is encompassed by one or more protected areas
☐	*Insufficient data for assessment*
If multiple boxes are selected	
☐	Two or more categories cannot be distinguished due to insufficient data
☐	Multiple boxes are checked to reflect variation in model output

Provide justification for your selection(s) using the following questions as a guide.
Include confidence scores (1-5) in the column on the right.
1 = high confidence, 5 = low confidence in the completeness and/or accuracy of the available information

	Score
1. Identify the areas that were considered "protected areas" for this analysis: Click here to enter text. Are spatial data available for the protected areas? ☐ Y ☐ N Citation/source:	
2. Estimate the overlap between the predicted future range and protected areas within the assessment area. % Is this number based on ☐ Visual estimates from maps or figures (ballpark estimate) ☐ Quantitative comparison of overlap (e.g., GIS) ☐ Description of results in text ☐ Other, describe:	
Information sources (if not identified elsewhere) Click here to enter text.	

The final steps!

Please estimate the amount of time it took you to fill out this form. hours
Describe your level of experience regarding the focal species on a scale of 1 to 5, where 1 = very comfortable characterizing the biological characteristics, habitat requirements, and conservation needs of this species and 5 = a general understanding of the biology of this species and/or related species. Score: Additional information: Click here to enter text.
Please provide comments on the ease of use of this worksheet and suggestions for improvements.
Please share any additional information or feedback you may have regarding this process. Click here to enter text.

Thank you for your participation!

Appendix C: Background Materials
Conceptual Modeling Workshop

In April 2011, Defenders co-sponsored an adaptation workshop with a group from the Massachusetts Institute of Technology (MIT) and the Florida Fish and Wildlife Conservation Commission (FWC). As part of this workshop, Defenders facilitated a conceptual modeling exercise in order to provide participants with a framework for understanding how the results of a vulnerability assessment can be incorporated into the conservation planning process. For this workshop, biodiversity targets were identified as the six focal species used in MIT's Alternative Futures analysis: short-tailed hawk, least tern, Atlantic salt marsh snake, American crocodile, Florida panther, and Key deer. Each species was addressed in a two-hour facilitated breakout session with species biologists, wildlife managers, and other conservation professionals. The primary outcome from each breakout session was the identification of potential adaptation strategies for each species.

Included in this appendix are the background materials that were provided to the workshop participants. Prior to the workshop, Defenders staff identified a preliminary set of threats and stresses for each species based on the Florida State Wildlife Action Plan (SWAP) and the vulnerability factors identified in the CCVI. Since the SWAP is organized by habitat, we first listed all of the threats identified for habitats associated with the focal species and highlighted those threats thought to be most relevant to the focal species. Participants were asked to review and modify these basic components as needed, and used them as the starting point for the conceptual modeling exercise. A list of the general action categories identified in the SWAP was also provided.

Short-tailed Hawk

Associated habitats: (1) Bay Swamp, (2) Cypress Swamp, (3) Disturbed/Transitional,(4) Hardwood Hammock Forest, (5) Hardwood Swamp/Mixed forest, (6) Hydric Hammock, (7) Natural Pineland, (8) Tropical Hardwood

A. Threats associated with habitats in the SWAP

1. Residential and Commercial Development
Conversion to housing and urban development
Conversion to recreation areas

2. Agriculture & Aquaculture
Conversion to agriculture
Incompatible agricultural practices
Incompatible grazing and ranching

3. Energy Production and Mining
Incompatible resource extraction: mining/drilling

4. Transportation and Service Corridors
Roads
Utility corridors

5. Biological Resource Use
Incompatible animal harvest
Incompatible vegetation harvest
Incompatible forestry practices

6. Human Intrusions and Disturbance
Incompatible residential activities
Military activities

7. Natural System Modifications
Incompatible fire
Ground water withdrawal
Surface water withdrawal and diversion
Management of nature (water control structures)
New dams
Dam operations

8. Invasive and Other Problematic Species
Invasive animals
Invasive plants
Nuisance animals

9. Pollution
Chemicals and toxins
Nutrient loads-urban
Nutrient loads-agriculture

B. Factors influencing vulnerability to climate change (identified in CCVI analysis)

- Exposure to sea level rise
    - Significant portion of current wintering range in an area subject to inundation under sea level rise

- Natural barriers
    - Unsuitable habitat to north of area of occupancy may present a natural barrier in terms of habitat, but would not be considered a physical barrier to species shifts.

- Land use changes resulting from human responses to climate change
    - The area of occupancy may be reduced due to a shift of the human population further inland

- Dependence on a narrowly defined hydrologic regime
    - Associated with mature swamp forest during breeding season
    - Loss of wetlands could affect availability of prey

- Impacts from an altered disturbance regime
    - More frequent fire could result in declines in extent, earlier successional states (unsuitable habitat), and/or vegetation shifts

- Dietary versatility
    - In wintering range dependent on winter migrants, may be more restricted than prey sources in breeding range (however loss of wetlands could affect prey availability, see above)

- Measured genetic variation
    - Indication of past population bottleneck and/or low genetic variation associated with small population size

Least Tern

Associated habitats: (1) Beach/Surf Zone

A. Threats associated with habitat in the SWAP

1. Residential and Commercial Development
Coastal development
Incompatible industrial operations

2. Agriculture & Aquaculture
Incompatible aquaculture operations

3. Energy Production and Mining
Incompatible resource extraction: mining/drilling

4. Transportation and Service Corridors
Roads, bridges, and causeways
Utility corridors
Channel modification/shipping lanes
Vessel impacts

5. Biological Resource Use
Incompatible fishing pressure
Incompatible wildlife and fisheries strategies
Incompatible fishing operations
Fishing gear impacts
Key predator/herbivore losses

6. Human Intrusions and Disturbance
Incompatible recreational activities

7. Natural System Modifications
Dam operations/incompatible releases of water
Inadequate storm water management
Surface water withdrawal
Ground water withdrawal
Shoreline hardening
Management of nature (beach nourishment, impoundments)
Management of nature (inlet relocation and dredging)
Management of nature (beach raking)
Management of nature (driving for maintenance)
Disruption of longshore transport of sediments

8. Invasive and Other Problematic Species
Invasive animals
Invasive plants
Nuisance animals

9. Pollution
Harmful algal blooms
Chemicals and toxins
Nutrient loads-urban
Industrial spills
Nutrient loads-agriculture
Solid waste
Light pollution
Sonic pollution

B. Factors influencing vulnerability to climate change (identified in CCVI analysis)

- Exposure to sea level rise
  - Greater than 90% of current range occurs in an area subject to inundation under sea level rise (excluding gravel rooftops)

- Anthropogenic barriers
  - Coastal development limits the ability of habitats to shift in some parts of the current range, however birds would be expected to be able to move if new habitat generated

- Land use changes resulting from human responses to climate change
  - Shoreline hardening could reduce availability of nesting habitat and prevent habitat migration under sea level rise

- Thermal tolerance requirements
  - Increased temperatures may increase risk of heat exposure for eggs in areas where disturbance is a problem (flushing adults from nests)

- Dependence on a narrowly defined hydrologic regime
  - Freshwater prey availability could be affected by changes to hydrology

- Impacts from an altered disturbance regime
  - Early-successional species attracted to recently disturbed habitat for nesting
  - Reproductive success would be adversely impacted by increases in the frequency or intensity of storms during spring/summer that increase risk of nest overwash/flooding
  - Heavy rain events also have the potential to flood out nesting on rooftops
  - Turbidity potentially decreases foraging success

- Physical habitat specificity
  - Sandy beaches without vegetation are required for nesting habitat

- Dietary versatility
  - Very young chicks may have specialized diet

ATLANTIC SALT MARSH SNAKE

Associated habitats: (1) Coastal Tidal River or Stream, (2) Inlet, (3) Salt Marsh, (4) Tidal Flat

A. Threats associated with habitats in the SWAP

1. Residential and Commercial Development
Coastal development
Conversion to housing and urban development
Conversion to commercial and industrial development
Incompatible industrial operations

2. Agriculture & Aquaculture
Incompatible aquaculture operations

3. Energy Production and Mining
Incompatible resource extraction–mining, drilling

4. Transportation and Service Corridors
Roads, bridges, and causeways
Utility corridors
Channel modification/shipping lanes
Vessel impacts

5. Biological Resource Use
Incompatible wildlife and fisheries management strategies
Incompatible fishing pressure
Fishing gear impacts

6. Human Intrusions and Disturbance
Boating impacts
Incompatible recreation activities
Military activities

7. Natural System Modifications
Surface water withdrawal
Dam operations
Inadequate storm water management
Groundwater withdrawal
Shoreline hardening
Management of nature–vegetation clearing/snagging for water conveyance
Management of nature–beach nourishment, impoundments
Disruption of longshore transport of sediments
Placement of artificial structures

8. Invasive and Other Problematic Species
Invasive plants
Invasive animals

9. Pollution
Harmful algal blooms
Chemicals and toxins
Nutrient loads-urban
Nutrient loads-agriculture
Industrial spills
Solid waste
Acoustic pollution
Thermal pollution
Light pollution

B. Factors influencing vulnerability to climate change (identified in CCVI analysis)

- Exposure to sea level rise
  - Greater than 90% of current range occurs in an area subject to inundation under sea level rise

- Natural barriers
  - Sandy coastlines and dunes present barrier to range shifts along coast

- Anthropogenic barriers
  - Coastal development limits the ability of species and habitat to shift in current range

- Land use changes resulting from human responses to climate change
  - Coastal development that interrupt the hydrology of tidal cycles (e.g., sea walls, impoundments, canals) by creating permanent standing water provide inapproriate habitat
  - Shoreline hardening could prevent habitat migration under sea level rise

- Dependence on a narrowly defined hydrologic regime
  - Species associated with brackish coastal habitat
  - Requires shallow pools isolated by falling tides for foraging

- Impacts from an altered disturbance regime
  - Increased strength of hurricanes could inhibit the formation of salt marsh and/or exacerbate coastal flooding resulting in elevated rates of salt marsh erosion

- Habitat dependence
  - Relies on a narrow set of species to generate habitat (*Spartina alterniflora* and *Juncus roemeriana*)

- Dietary versatility
  - Strictly piscivorous feeding almost exclusively on a variety of small brackish marsh fish

- Altered interspecific interactions
  - Strong storm events associated with increased hybridization with banded water snake

AMERICAN CROCODILE

Associated habitats: (1) Beach/Surf Zone, (2) Canal/Ditch, (3) Coastal Tidal River or Stream, (4) Inlet, (5) Mangrove Swamp, (6) Salt Marsh, (7) Submerged Aquatic Vegetation, (8) Subtidal Unconsolidated Marine/Estuary Sediment, (9) Tidal Flat.

A. Threats associated with habitats in the SWAP

1. **Residential and Commercial Development**
Coastal development
Conversion to housing and urban development
Conversion to commercial/industrial development
Incompatible industrial operations

2. Agriculture & Aquaculture
Incompatible aquaculture operations

3. Energy Production and Mining
Incompatible resource extraction: mining/drilling

4. Transportation and Service Corridors
Roads, bridges and causeways
Utility corridors
Channel modification/shipping lanes
Vessel impacts

5. Biological Resource Use
Key predator/herbivore losses
Incompatible wildlife and fisheries management strategies
Incompatible aquarium trade
Incompatible fishing pressure
Fishing gear impacts

6. Human Intrusions and Disturbance
Boating impacts
Incompatible recreational activities
Military activities
Management of nature (driving for maintenance)

7. Natural System Modifications
Dam operations/incompatible release of water
Inadequate storm water management
Surface water withdrawal
Ground water withdrawal
Shoreline hardening
Management of nature (nourishment)
Management of nature (beach nourishment, impoundments)
Management of nature (inlet relocation and dredging)
Management of nature (beach raking)
Management of nature (vegetation clearing/snagging for water conveyance)
Management of nature (driving for maintenance)
Disruption of longshore transport of sediments
Placement of artificial structures

8. Invasive and Other Problematic Species
Invasive animals
Invasive plants
Nuisance animals
Parasites/pathogens

9. Pollution
Harmful algal blooms
Chemicals and toxins
Nutrient loads-urban
Industrial spills
Nutrient loads-agriculture
Solid waste
Light pollution
Sonic pollution
Thermal pollution

B. Factors influencing vulnerability to climate change (identified in CCVI analysis)

- Exposure to sea level rise
  - Greater than 90% of current range occurs in an area subject to inundation under sea level rise

- Anthropogenic barriers
  - Coastal development limits the ability of habitats to shift in some parts of the current range, unknown whether site fidelity would limit use of newly generated habitat

- Land use changes resulting from human responses to climate change
  - Shoreline hardening could limit access to nesting habitat and/or prevent habitat migration under sea level rise

- Thermal tolerance requirements
  - Increased temperatures may increase likelihood of nest desiccation

- Dependence on a narrowly defined hydrologic regime
  - Requires appropriate saltwater wetlands, including low salinity areas for hatchlings

- Impacts from an altered disturbance regime
  - Reproductive success would be adversely impacted by nest flooding, overwash erosion, and/or increased inundation with salt water due to hurricanes

- Physical habitat specificity
  - Beaches are required for nesting habitat

- Altered interspecific interactions
  - Habitat loss due to sea level rise may lead to increased interspecific competition for nesting sites

- Measured genetic variation
  - Indication of past population and/or low genetic variation

- Other factors identified by reviewers
  - Impacts on temperature dependent offspring sex ratios
  - Mortality from cold snaps

Florida Panther

Associated habitats: (1) Agriculture, (2) Bay Swamp, (3) Coastal Strand, (4) Cypress Swamp, (5) Disturbed/Transitional, (6) Dry Prairie, (7) Freshwater Marsh and Wet Prairie, (8) Grassland/Improved Pasture, (9) Hardwood Hammock Forest, (10) Hardwood Swamp/Mixed Wetland Forest, (11) Industrial/Commercial Pineland (corridor), (12) Mixed Hardwood-Pine Forest, (13) Natural Pineland, (14) Pine Rockland, (15) Scrub, (16) Shrub Swamp, (17) Tropical Hardwood Hammock

A. Threats associated with habitats in the SWAP

1.
Residential and Commercial Development
Conversion to housing and urban development
Conversion to commercial/industrial development
Incompatible industrial operations
Conversion to recreation areas

2. Agriculture & Aquaculture
Conversion to agriculture
Conversion to more intensive agriculture
Incompatible agricultural practices
Incompatible grazing and ranching

3. Energy Production and Mining
Incompatible resource extraction: mining/drilling

4. Transportation and Service Corridors
Roads, bridges and causeways
Channel modifications/shipping lanes

5. Biological Resource Use
Incompatible animal harvest
Incompatible vegetation harvest
Incompatible forestry operations
Key prey/herbivore losses

6. Human Intrusions and Disturbance
Incompatible recreational activities
Incompatible residential activities
Military activities

7. Natural System Modifications
Incompatible fire
Ground water withdrawal
Surface water withdrawal and diversion
New dams
Dam operations
Shoreline hardening
Management of nature (nourishment)
Management of nature (impoundments)
Management of nature (inlet relocation and dredging)
Management of nature (water control structures)
Management of nature (storm water facilities)
Management of nature (dredge soil deposition)

8. Invasive and Other Problematic Species
Invasive animals
Invasive plants
Nuisance animals
Parasites/pathogens

9. Pollution
Chemicals and toxins
Nutrient loads-urban
Nutrient loads-agriculture
Solid waste
Light pollution

B. Factors influencing vulnerability to climate change (identified in CCVI analysis)

- Exposure to sea level rise
  - Less than 10% of range occurs in an area subject to inundation under sea level rise

- Anthropogenic barriers
  - Urban development on the east and west coasts were considered barriers, but were not considered likely to contribute significantly to habitat loss by restricting habitat shifts resulting from climate change

- Natural barriers
  - The Caloosahatchee River (to the north) was identified as a major barrier for females, but was not considered likely to contribute significantly to habitat loss by restricting habitat shifts resulting from climate change

- Land use changes resulting from human responses to climate change
  - The area of occupancy may be reduced due to a shift of the human population further inland

- Impacts from an altered disturbance regime
  - Panthers benefit from fire as it increases forage for their primary prey (deer). However fire also reduces daytime resting sites and available den sites in thick vegetation.

- Dietary versatility
  - Requires large mammalian prey (deer, feral hogs, armadillos, raccoons)

- Measured genetic variation
  - Indication of past population bottleneck and/or low genetic variation

KEY DEER

Associated habitats: (1) Disturbed/Transitional*, (2) Mangrove Swamp, (3) Natural Pineland, (4) Pine Rockland, (5) Salt Marsh, (6) Tropical Hardwood Hammock, (7) Urban/Developed*
*not addressed in the threat prioritization workshops

A. Threats associated with habitats in the SWAP

1. **Residential and Commercial Development**
Conversion to housing and urban development
Conversion to commercial and industrial development
Incompatible industrial operations
Conversion to recreation areas

2. Agriculture & Aquaculture
Conversion to agriculture
Incompatible agricultural practices
Incompatible grazing and ranching
Incompatible aquaculture operations

3. Energy Production and Mining
Incompatible resource extraction–mining, drilling

4. Transportation and Service Corridors
Roads, bridges, and causeways
Utility corridors
Channel modification/shipping lanes

5. Biological Resource Use
Lack of knowledge/appreciation of early successional habitat
Incompatible wildlife and fisheries management strategies
Incompatible wild animal harvest
Incompatible vegetation harvest
Incompatible forestry operations
Incompatible fishing pressure
Fishing gear impacts

6. Human Intrusions and Disturbance
Incompatible recreation activities
Incompatible residential activities
Military activities

7. Natural System Modifications
Incompatible fire
Dam operations/incompatible release of water
Inadequate storm water management
Groundwater withdrawal
Surface water withdrawal
Shoreline hardening
Management of nature–beach nourishment, impoundments
Disruption of longshore transport of sediments
Placement of artificial structures

8. Invasive and Other Problematic Species
Invasive plants
Invasive animals
Nuisance animals
Parasites/pathogens

9. Pollution
Harmful algal blooms
Chemicals and toxins
Nutrient loads-urban
Nutrient loads-agriculture
Industrial spills
Solid waste
Acoustic pollution
Thermal pollution
Light pollution

B. Factors influencing vulnerability to climate change (identified in CCVI analysis)

- Exposure to sea level rise
  - Greater than 90% of current range occurs in an area subject to inundation under sea level rise

- Natural barriers
  - Range restricted to Keys

- Dependence on a narrowly defined hydrologic regime
  - Requires freshwater drinking sources–uses freshwater holes and other freshwater wetlands (threatened by saltwater incursions)

- Dependence on a specific disturbance regime
  - Storm surges are a source of saline incursion
  - Direct mortality from hurricanes

- Measured genetic variation
  - Indication of past population bottleneck and/or low genetic variation

Action Categories Identified in the SWAP

- Land/Water Protection
  - Establishing or expanding protected areas
  - Establishing protection or easements of some specific aspect of the resource

- Land/Water/Species Management
  - Management of protected areas and other resource lands Habitat & Natural Process
  - Enhancing degraded or restoring missing habitats
  - Controlling and/or preventing spread of invasive species and pathogens
  - Managing specific plant and animal populations of concern.

- Education and Awareness
  - Enhancing knowledge, skills, and information exchange Awareness
  - Raising environmental awareness and providing information

- Policy
  - Influencing legislation or policies
  - Influencing implementation of laws
  - Implementing voluntary standards & professional codes that govern private sector practice
  - Monitoring and enforcing compliance

- Planning and Standards
  - Setting, implementing, influencing, or providing input into planning directives, codes, and standards

- Economic and Other Incentives
  - Providing alternatives that substitute for environmentally damaging products and services
  - Using direct or indirect payments to change behaviors and attitudes

- Capacity Building
  - Institutional & civil society development
  - Alliance & partnership development
  - Raising and providing funds for conservation work

- Research

Appendix D:
Participants & Workshop Agendas

CCVI Species Experts

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Boyd Blihovde, USFWS
Robert Brooks, Pennsylvania State University
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Roel Lopez, Texas A&M University
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Ken Meyer, Avian Research Institute
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Marc Minno, St. Johns River Water Management Dist
Paul Moler, Florida Fish and Wildlife Conservation Commission
Jim Rodgers, Florida Fish and Wildlife Conservation Commission
Kathleen Smith, Florida Fish and Wildlife Conservation Commission
Marsha Ward, Florida Fish and Wildlife Conservation Commission
Joe Wasilewski, Natural Selections of South Florida
Jeffrey Wilcox, Florida Fish and Wildlife Conservation Commission
Gary Witmer, USDA/APHIS

WORKSHOP I PARTICIPANTS

(January 25-26, 2011, St. Petersburg, FL)

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Tim O'Meara, Florida Fish and Wildlife Conservation Commission
Dave Onorato, Florida Fish and Wildlife Conservation Commission
Doug Parsons, Florida Fish and Wildlife Conservation Commission
Kelly Rezac, Florida Fish and Wildlife Conservation Commission
Jim Rodgers, Florida Fish and Wildlife Conservation Commission
Samantha Ruiz (and five students), IDEAS
Beth Stys, Florida Fish and Wildlife Conservation Commission
Ron Taylor, Florida Fish and Wildlife Conservation Commission
Ann Vanek, Florida Wildlife Federation
Juan Carlos Vargas Moreno, MIT
Gary Witmer, USDA/APHIS

Florida Fish and Wildlife Commission
Vulnerability Assessment Workshop
January 25-26, 2011
Fish & Wildlife Research Institute
Florida Fish and Wildlife Conservation Commission
St. Petersburg, FL

Agenda

January 25, 2011

9:00am -- Welcome and Introductions

9:30am - 10:30am -- CCVI Overview (Dr. Natalie Dubois, Defenders of Wildlife)

15 min. Break

10:45am - 12:00 -- Overview of MIT Geospatial Mapping Process (Dr. Michael Flaxman)

12:00 - 12:45pm -- Lunch served on site (may be a working lunch)

15 min. Break

1:00pm - 4:00pm -- Concurrent Species Breakout Sessions

4:00pm - 5:00pm -- Receive Reports from Breakout Session Leaders

6:00pm - 7:30pm -- Reception hosted by FWF, Florida Defenders of Wildlife, Audubon of Florida. Heavy hors d'oeuvres and refreshments poolside at the Hilton Hotel Downtown (weather permitting, inside if not).

January 26, 2011

8:30am - 9:00am -- Opening remarks; Recap of first day setting the stage for day 2 accomplishments

9:00am - 12:00 Noon -- Concurrent Species Breakout Sessions

12:00 Noon -- Lunch served on site

1:00 pm - 2:30pm -- Assessment Modeling discussion (15 minute presentation of climate envelope model by Laura Brandt)

2:30 - 3:00pm --- Wrap up and Evaluation

3:00 Workshop concludes

WORKSHOP II PARTICIPANTS

(April 28-29, 2011, Oakland, FL)

Andrea Alden, Florida Fish and Wildlife Conservation Commission
Chad Anderson, USFWS
Chris Belden, USFWS
Judy Boshoven, Defenders of Wildlife
Brian Branciforte, Florida Fish and Wildlife Conservation Commission
Janell Brush, Florida Fish and Wildlife Conservation Commission
Susan Cameron Devitt, University of Florida
Aimee Delach, Defenders of Wildlife
Natalie Dubois, Defenders of Wildlife
Thomas Eason, Florida Fish and Wildlife Conservation Commission
Kevin Enge, Florida Fish and Wildlife Conservation Commission
Clayton Ferrara, Oakland Nature Preserve
Michael Flaxman, MIT
Bob Glazer, Florida Fish and Wildlife Conservation Commission
Tom Hoctor, University of Florida
Chris Horne, MIT
Adam Kent, Florida Fish and Wildlife Conservation Commission
Jay Liles, Florida Wildlife Federation
Laurie Macdonald, Defenders of Wildlife
Noah Matson, Defenders of Wildlife
Ken Meyer, Avian Research Institute
Doug Parsons, Florida Fish and Wildlife Conservation Commission
Dan Pennington, 1000 Friends of Florida
Mona Phipps, Oakland Nature Preserve
Kelly Rezac, Florida Fish and Wildlife Conservation Commission
Beth Stys, Florida Fish and Wildlife Conservation Commission
Steve Traxler, USFWS
Juan Carlos Vargas Moreno, MIT

Florida Fish and Wildlife Commission

Climate Change Vulnerability Workshop

April 28-29, 2011

Oakland Nature Preserve, Oakland, Florida

Agenda: Managing for Climate-resilient Conservation

DAY 1: APRIL 28th, 2011

8:30 coffee

9:00am to 10:00am Review of Alternative Futures methods and scenarios

10:00am to 11:00am CCVI Methods and Findings across 24 species

11:00am to 12:00pm MIT habitat and impact model refinements

12:00 lunch

1:00pm to 3:00pm Parallel species breakout groups - conceptual modeling 1

1. Panther
2. Salt marsh snake
3. Hawk

3:00pm to 5:00 Parallel species breakouts - conceptual modeling 2

1. Least tern
2. Crocodile
3. Key deer

DAY 2: APRIL 29th, 2011

8:15am to 8:30am Coffee

8:30am to 9am Intro to Management Sessions

9:00 am to 11:00am Parallel sessions on climate-sensitive conservation challenges and management strategies:

1. Conservation challenges in small areas with strong geographic constraints
2. Conservation challenges in large areas with extensive public ownership

3 Conservation challenges in large areas with extensive private ownership

11:00am to 11:30am Summary survey: info needs methods. Research priorities

11:30-12:30pm Wrap up session.

Workshop Adjournment