CHAPTER 7. CLIMATE CHANGE

Climate change has recently moved to the forefront of conservation planning in the United States. In 2009 legislation proposed by the U.S. House of Representatives required the incorporation of a climate change strategy into each state's Wildlife Action Plan (WAP; AFWA 2009). Although this legislation was not passed by the U.S. Senate, an Executive Order (Executive Order No. 13653) was later issued in 2013 to increase the responsibility of federal agencies, including the U.S. Fish and Wildlife Service (USFWS), in addressing climate change. Therefore, the Louisiana Department of Wildlife and Fisheries (LDWF), is addressing climate change during the WAP revision process, to ensure that the WAP remains consistent with current and future policies and is eligible for any associated funding opportunities to conserve Species of Greatest Conservation Need (SGCN) and their habitats. Our objectives in this chapter are to: (1) present an overview of the current state of climate science, (2) present downscaled climate projections for Louisiana, (3) summarize the results of vulnerability assessments for SGCN and habitats, (4) briefly discuss natural communities that could be impacted by climate change, and (5) concisely present Louisiana's adaptation strategy.

A. Climate Science Overview

1. What is Climate Change?

The *National Fish, Wildlife, and Plants Climate Adaptation Strategy* (National Fish, Wildlife, and Plants Climate Adaptation Partnership (NFWPCAP) 2012) defines climate change as "a significant and lasting change in the statistical distribution of weather patterns." This change can refer to average weather conditions or to extreme weather events, and applies to any geographic scale.

Climate change can be either natural or anthropogenic (human-caused) in origin. Indeed, climatic variability has been a reality throughout the history of Earth, well before humans existed (Inkley et al. 2004). However, recent observed changes in climate have been consistently attributed to increased levels of greenhouse gases due to human combustion of fossil fuels, including carbon dioxide (CO_2; NFWPCAP 2012). The cause of climate change is not as important as the reality that climate change is occurring. Although climate science is a relatively new and evolving discipline, each year science increases our understanding of how and why the climate is changing, and the implications of those changes.

Whereas it is true that climate change projections are only likely future scenarios, it is also true that these projections are based on fundamental principles of the physical sciences and that earlier projections have ultimately been confirmed by observed changes in climatic conditions (Melillo et al. 2014). Although uncertainty still exists regarding the exact rate of change and effects on regional conditions, ignoring climate change is likely to result in an inability to consistently meet wildlife management goals in the future (Inkley et al. 2004).

2. How is climate changing?

The average air temperature in the United States has increased ~1.5-2.0° Fahrenheit since 1895 (Melillo et al. 2014), with much of that increase in the last 40 years. Although temperature increase has been less severe in the southeastern United States than elsewhere (Melillo et al. 2014), temperature has nevertheless increased. Furthermore, average air temperatures in the United States are predicted to continue to increase by the end of this century (Melillo et al. 2014). Perhaps more important than the change in average annual air temperature are potential decreases in the number of freezing days annually. This may allow for "tropicalization" that could potentially benefit certain invasive species while negatively impacting certain native species.

The amount by which temperatures are expected to increase is dependent on several factors, including the rate of emission of greenhouse gases. Assuming an increase in emissions over current levels (A2 Scenario), the predicted temperature increase may be as much as 10°F. However, even the best case emission scenarios (i.e., a reduction from current levels; B1 Scenario) still predict an overall increase in greenhouse gases, and a corresponding increase in global air temperatures of at least 3°F (Glick et al. 2011, Melillo et al. 2014). For more information on what these different scenarios describe, see the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES, IPCC 2000). If emissions could be curtailed, further warming still would be likely, because CO_2 remains in the atmosphere for many years (Wigley 2005). Not only are overall temperatures expected to rise, but the number of days with a maximum temperature of over 95°F is predicted to increase, along with a decreased number of days below 32°F for the U.S. overall (Melillo et al. 2014). Precipitation has increased approximately 5% over the last 50 years in the U.S., with greater changes being seen in more northern states (Glick et al. 2011). Projections of future temperatures are more consistent than projections of future precipitation patterns (Inkley et al. 2004), but a decrease in precipitation by as much as 12% in Louisiana by 2100 has been projected (Kunkel et al. 2013). Regardless of how precipitation patterns or amounts may change, current consensus projections suggest that all of the Southeastern U.S. will see a decrease in available annual moisture by mid-century (Kunkel et al. 2013), as rising temperatures and increasing evapotranspiration will more than offset any increase in precipitation.

Warming temperatures and changes in precipitation are not the only impact of climate change. Other impacts may include increased severity and frequency of extreme weather events, sea level rise (SLR), acidification of the world's oceans, and increased water temperatures in both lentic and lotic systems (NFWPCAP 2012).

In particular, SLR must be considered when discussing climate change impacts in Louisiana. Sea level rise is a product of dynamic interactions, and is influenced by oceanic, atmospheric, and geologic changes including thermal expansion of the oceans and melting of polar ice. Global sea levels have increased by as much as eight inches over the past century (Melillo et al. 2014), and are predicted to continue to rise into the future (Glick et al. 2011). Note that there is a difference between eustatic (global) SLR and relative (local) SLR. Eustatic SLR is a change in global sea level due to alterations in the amount of water in the world's oceans. Relative SLR takes into account local processes such as subsidence and land accretion as well as increases in the volume of sea water due to thermal expansion. Hereafter, "SLR" in this chapter will refer to relative SLR, as that is most relevant for the purposes of the WAP.

Increases in water temperature and ocean acidification may also have negative impacts on fish and wildlife, including SGCN. As water temperatures increase, certain marine species may become subject to heat stress or see a reduction or range shift in important prey species, thereby weakening ecological connections between species (Harley et al. 2006) and increasing the risk of extirpation or extinction for affected species. Acidification has been found to have negative impacts for marine species that rely on calcification for growth (Kurihara 2008), including both mollusks and crustaceans, as the availability of calcium carbonate is reduced. This has the potential to impact SGCN directly (marine mollusks and crustaceans), as well as indirectly impact many SGCN that rely on such invertebrates as prey.

3. What are the impacts of climate change to wildlife?

The effects of climate change on wildlife, including changes in distribution patterns, will differ between species. Some species will be negatively impacted while other species benefit (Inkley et al. 2004), but all biodiversity will be impacted in some way (IPCC 2002). Already, changes in the timing of biological phenomena such as spring leaf-out and the onset of migration events have been documented (Melillo et al. 2014). Negative impacts of climate change may be additive to existing stressors, such as habitat destruction and fragmentation, accelerating existing declines (Staudinger et al. 2012). Species of conservation concern have been found to be more vulnerable to climate change impacts than other species, regardless of habitat or taxonomic group (NABCI 2010), because these species are generally already stressed by other factors. A few of the potential negative impacts of climate change are discussed below.

Wetlands are highly susceptible to changes in climate, with even relatively small reductions in precipitation or increases in temperature leading to greatly degraded conditions (NABCI 2010), particularly for seasonal wetlands, such as Ephemeral Ponds. Streams and rivers may be negatively impacted by decreased precipitation, reduced groundwater recharge, and lowered peak flows (Kunkel et al. 2013). Climate change could result in more frequent or more severe outbreaks of pest species that degrade habitats. It may also provide conditions suitable for the continued spread of invasive species present in Louisiana, as well as potentially allow for invasions of additional exotic species as conditions become more favorable for them. Neotropical migrant landbirds may encounter a lack of available food resources at stopover sites (NABCI 2010), because as birds shift the timing of migration earlier, mismatches between peak migration and peak availability of natural foods such as soft mast and insects are more likely. Further complicating matters is the potential for the phenology of mast-producing plants and insects to change as well, leading to a greater chance of such mismatches. Additionally, emergence times of insect pollinators may shift so that adult insects are not present at the correct time to pollinate some plant species that rely on them. Finally, wildfire frequency could increase as temperatures increase and droughts become more frequent and of longer duration. This could contribute to landscape level changes in the distribution and relative abundance of fire-dependent natural communities (Kunkel et al. 2013). Additionally, there is some speculation that the intensity of wildfires might increase, which could result in negative impacts even to fire-dependent communities.

4. Which species are most at-risk?

The International Union for Conservation of Nature (IUCN) lists 5 traits that serve to make a particular species more vulnerable to the predicted impacts of climate change (Foden et al. 2009):

1) Specialized habitat/microhabitat
2) Narrow environmental tolerances
3) Dependence on specific cues or triggers
4) Dependence on an interaction with another species that may be affected by climate change
5) Poor dispersal ability

Those species that have a preference for a specialized habitat, or highly-specific microhabitat, could be vulnerable to climate change as the chances of the species encountering suitable habitat following a climate change-induced range shift would be much lower than for species that show greater plasticity. The same would be true for those species with narrow environmental tolerances, because the chances of encountering the precise, required conditions would decrease as environmental tolerance decreases. Dependence on specific cues or triggers, such as air or water temperatures, could also increase vulnerability. For example, a species that relies on such triggers for the initiation of events such as nesting or spawning could initiate such behavior earlier as climate changes, leading to a mismatch between the hatching of young and the peak availability of resources. Dependence on one particular species, whether for food, dispersal, or any other inter-specific interaction could also increase vulnerability, as any negative impacts to particular species would necessarily impact the species that relies on it, even if that species is not particularly vulnerable itself. Finally, poor dispersal could serve to increase vulnerability, because it would reduce the ability of the species to track preferred climactic conditions or to escape unfavorable conditions that might arise as a result of climate change.

B. Downscaled Climate Change Projections for Louisiana

1. TACCIMO:

The Template for Assessing Climate Change Impacts and Management Options (TACCIMO) is a tool that was developed by the Eastern Forest Threat Assessment Center, the Western Wildland Environmental Threat Assessment Center, and the USDA Forest Service Regional Forest Planning units. This tool provides a geospatial mapping application that furnishes the user with downscaled historical climate data and climate modeling data to help evaluate the impacts of climate change on forested systems at a given location. These modeling data are intended to inform natural resource managers and planners of potential local impacts of climate change and assist in the development of adaptation strategies.

TACCIMO provides projections for various General Circulation Models (GCM) in the IPCC Special Report on Emission Scenarios (SRES; IPCC 2002). The three emissions scenarios are:

> **SRES B1 (Low emissions path)** – this scenario represents a dramatic reduction in current emissions levels, which will require a strong shift towards sustainable energy sources.
> **SRES A1B (Middle emissions path)** – this scenario represents a more moderate reduction in current emissions levels, which would require an increase in non-fossil fuel energy technology, with fossil fuels remaining an important component of overall energy production.
> **SRES A2 (Higher emissions path)** – This represents the least optimistic future emissions scenario, and is the path that is closest to current emission levels, although recent measured emission levels have been higher than this scenario.

In conjunction with the three emissions scenarios described, TACCIMO also considers three IPCC GCMs, which are summarized in Table 7.1.

Table 7.1. General Circulation Models used in TACCIMO analysis for Louisiana.

Source	Identifier
U.S. Department of Commerce\NOAA\Geophysical Fluid Dynamics Laboratory	CM2.0
Canadian Centre for Climate Modeling & Analysis	CGCM3.1
Hadley Centre for Climate Prediction and Research\Met Office	HadCM3.1

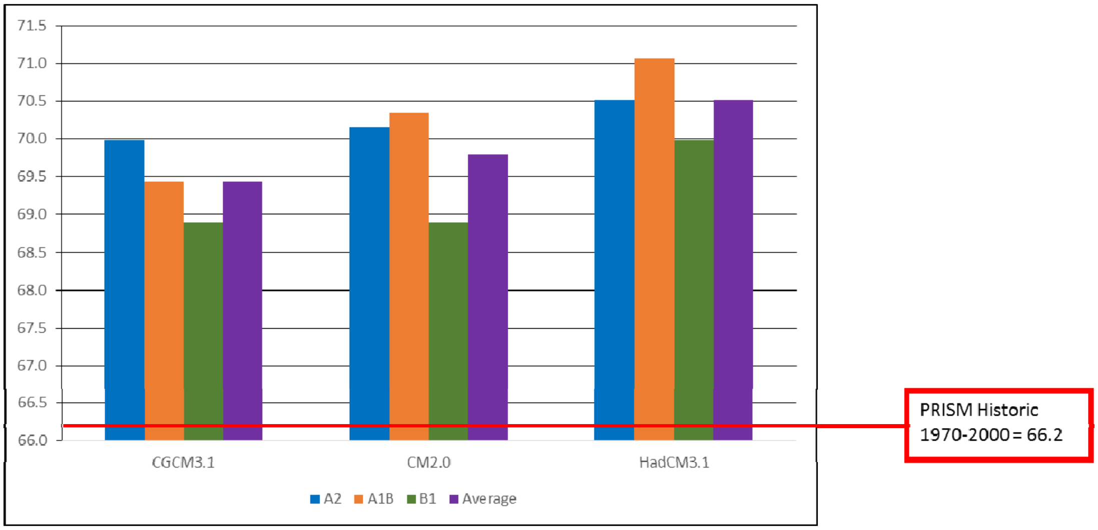
Table 7.2 and Figure 7.1 represent the projected average monthly temperature for Louisiana under each GCM and SRES. Although there is some variation between the different model and scenario combinations, every combination projects an increase over historical levels. Table 7.3 and Figure 7.2 represent projected average monthly precipitation totals for the state under each combination of GCM and SRES. Two of the three GCMs project a decrease in precipitation regardless of the emissions scenario selected, and one GCM projects an increase regardless of emission levels. This reflects the greater uncertainty in precipitation projections compared to temperature projections at the state scale. In summary, these models project an increase in average monthly temperature over the next 85 years of 2.7-4.9°F, while precipitation is projected to change by -0.56 to +0.01 inches/month.

Table 7.2. Projected average monthly temperature (°F) for Louisiana for the period 2009-2099 for each GCM/SRES combination, as well as the average for each GCM, and the PRISM historic average from 1970-2000.

	PRISM	CGCM3.1	CM2.0	HadCM3.1
High Emissions (A2)	N/A	70.0	70.2	70.5
Middle Emissions (A1B)	N/A	69.4	70.3	71.1
Low Emissions (B1)	N/A	68.9	68.9	70.0
Average	66.2	69.4	69.8	70.5

Table 7.3. Projected average monthly precipitation (inches) for Louisiana for the period 2009-2099 for each GCM/SRES combination, as well as the average for each GCM, and the PRISM historic average from 1970-2000.

	PRISM	CGCM3.1	CM2.0	HadCM3.1
High Emissions (A2)	N/A	5.1	4.5	4.7
Middle Emissions (A1B)	N/A	5.0	4.5	4.8
Low Emissions (B1)	N/A	5.0	4.7	4.7
Average	5.0	5.0	4.6	4.7



PRISM Historic
1970-2000 = 66.2

Figure 7.1. Graphical representation of projected average monthly temperature (°F) for Louisiana for the period 2009-2099, with historic average (PRISM Climate Group 2004) for the period 1970-2000 shown in red.

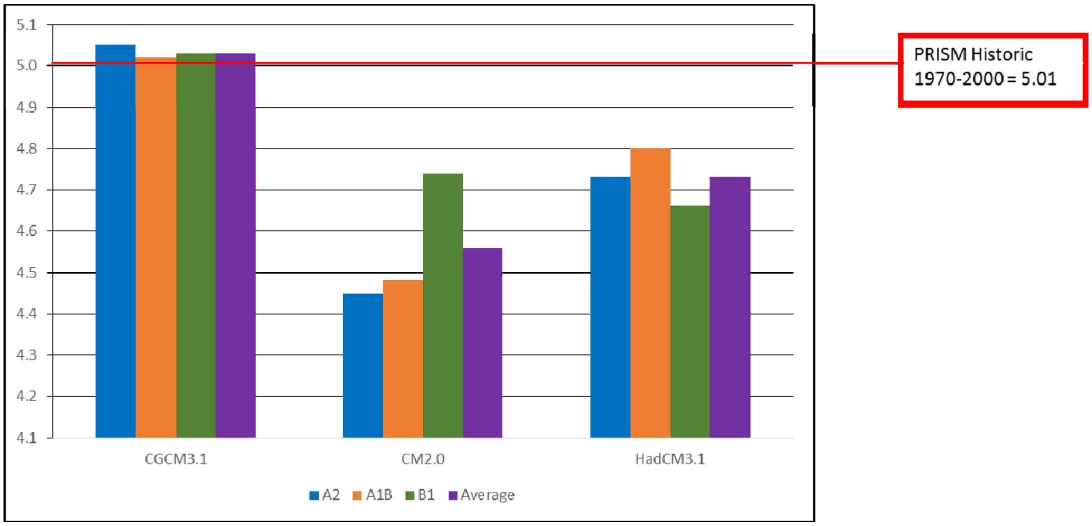
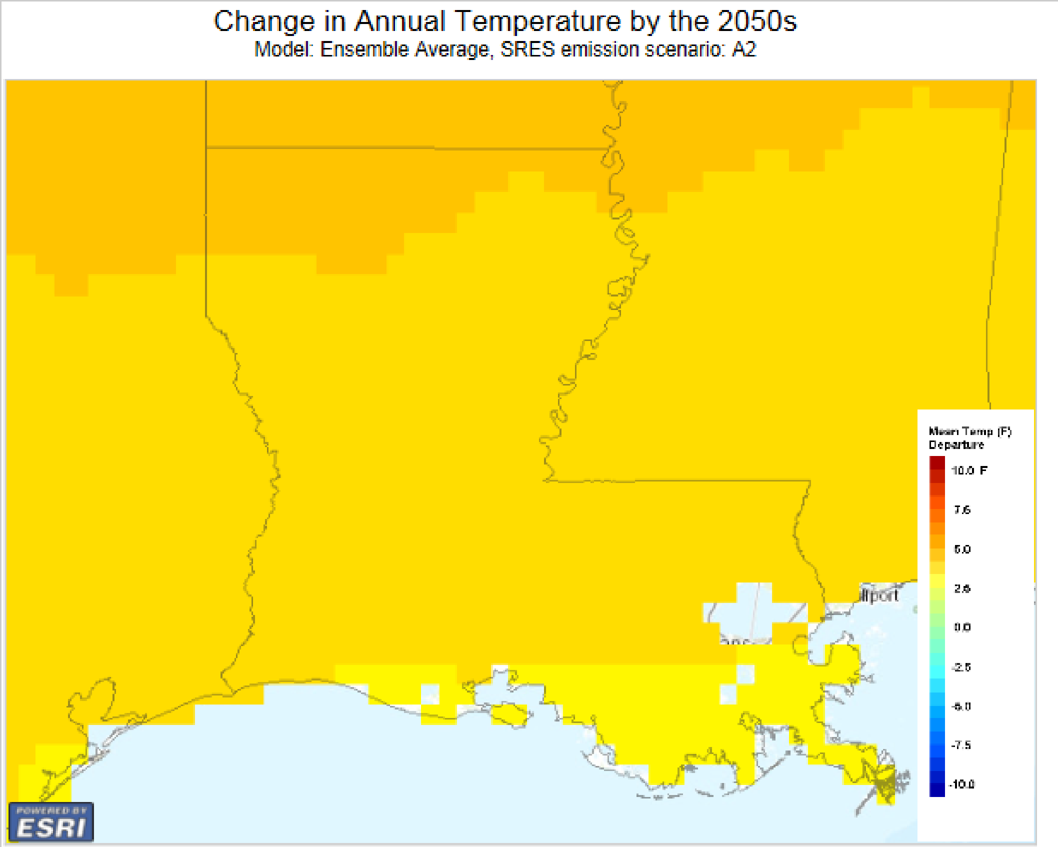


Figure 7.2. Projected average monthly precipitation (inches) for Louisiana for the period 2009-2099, with historic average for the period 1970-2000 (PRISM Climate Group 2004) shown in red.

2. ClimateWizard:

The following figures show projected temperature and precipitation changes for Louisiana, derived from the ClimateWizard website (Girvetz et al. 2009), with all projections for mid-century. Figure 7.3 shows the projected change in temperature for a 16-general circulation model (GCM) ensemble average under IPCC SRES high emissions scenario (A2). Figure 7.4 shows the projected change in temperature for the same ensemble average under the low emissions scenario (B1). Note that both projections indicate overall warming (range = 2.4-4.6 °F) in Louisiana, with temperature increases becoming more pronounced with latitude.



Change in Annual Temperature by the 2050s

Model: Ensemble Average, SRES emission scenario: A2

Map data Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

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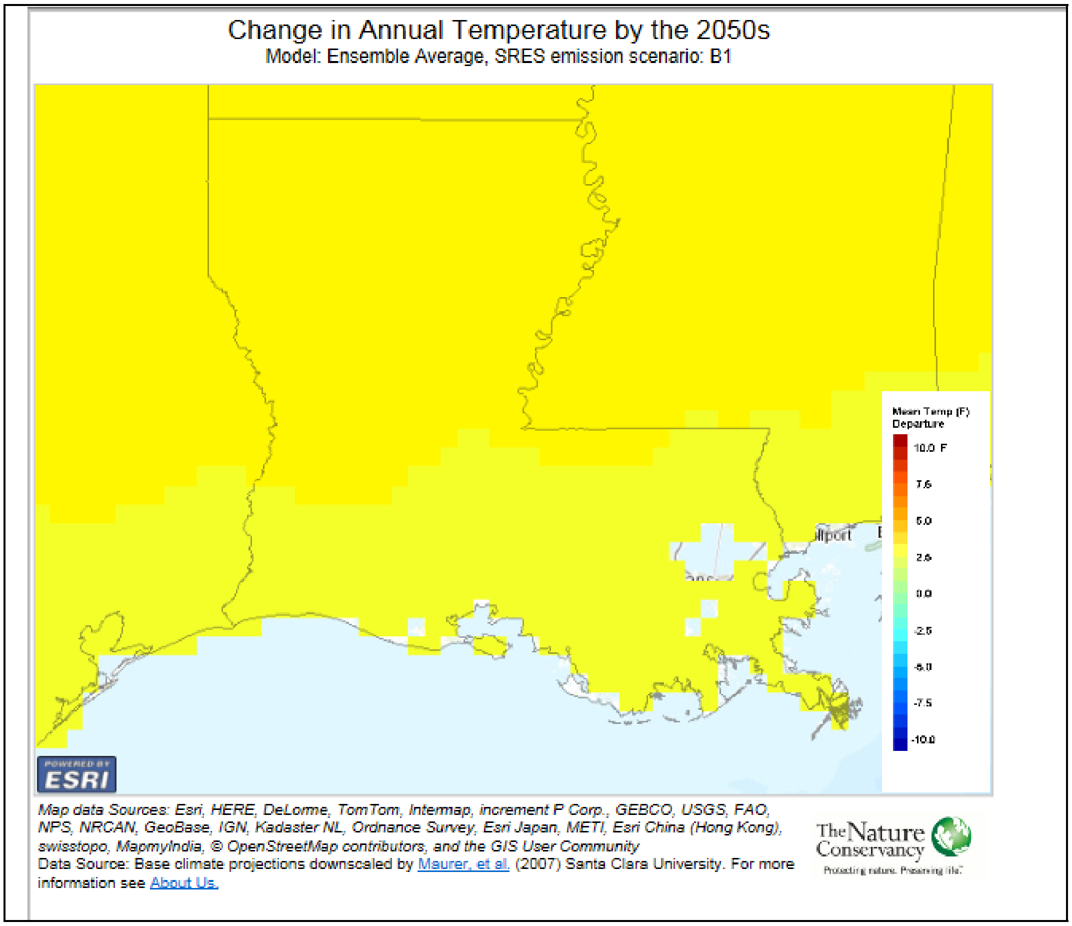
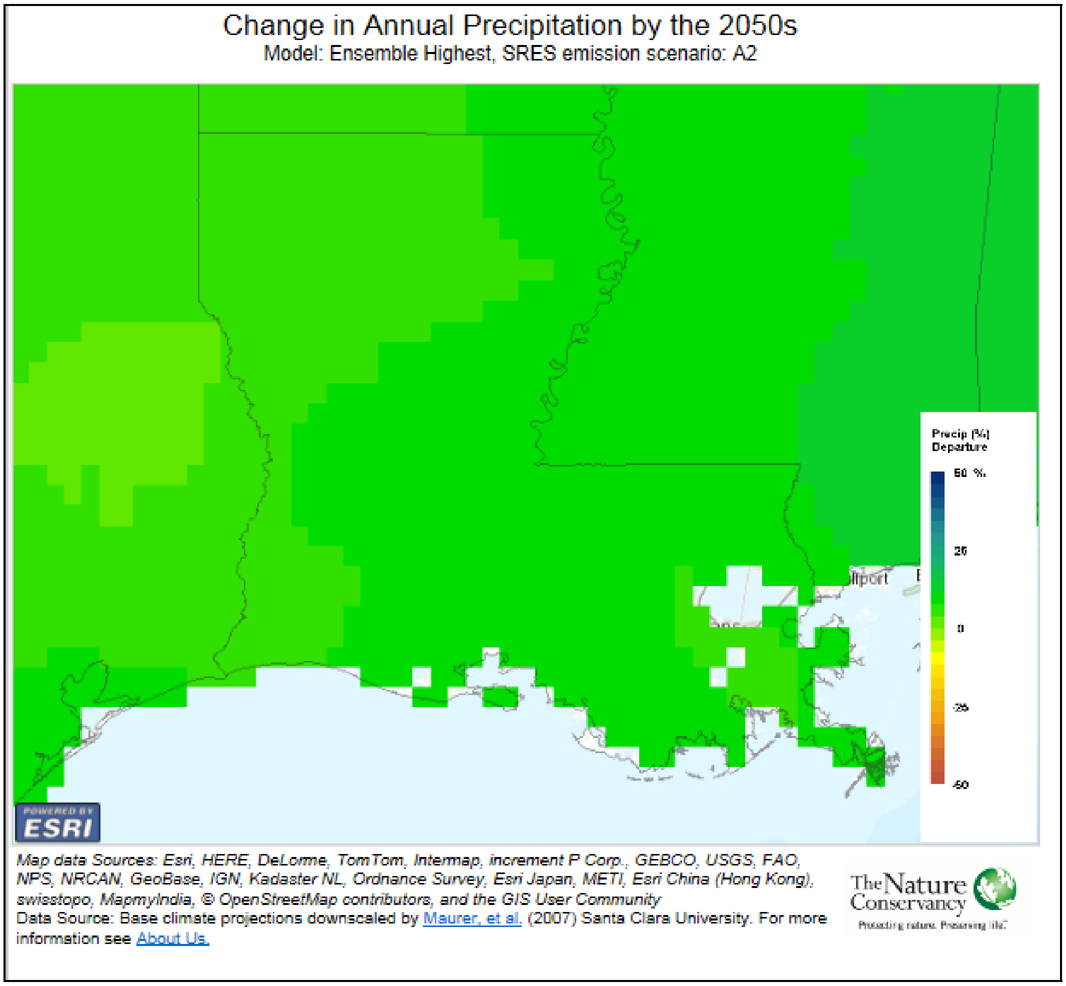
Figure 7.3. ClimateWizard projected temperature change for mid-century based on the Ensemble Average of 16 GCMs under the high (A2) emissions scenario.


Change in Annual Temperature by the 2050s
Model: Ensemble Average, SRES emission scenario: B1

Map data Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Figure 7.4. ClimateWizard projected temperature change for mid-century based on the Ensemble Average of 16 GCMs under the low (B1) emissions scenario.

Figures 7.5, 7.6, 7.7, and 7.8 show ClimateWizard projections of precipitation changes (% change from historical levels) for Louisiana by mid-century. Figures 7.5 and 7.6 show the highest and lowest projected precipitation change, respectively, for the high-emissions scenario (A2). Figures 7.7 and 7.8 show the highest and lowest projected precipitation change, respectively, for the low-emissions scenario (B1). As with the TACCIMO projections, note that the different GCMs vary between an increase or decrease in precipitation over historical levels, regardless of which emissions scenario is considered. Again, this reflects uncertainty over how precipitation patterns will respond at the smaller scale of a state, despite the generally agreed upon overall global increase in precipitation (Adam Terando, personal communication). It does appear that northwest Louisiana is at risk for the greatest extent of drying, based on the minimum and maximum projected changes in precipitation (e.g. projected change of +4.8 to -17.6% for Shreveport; Table 7.5).



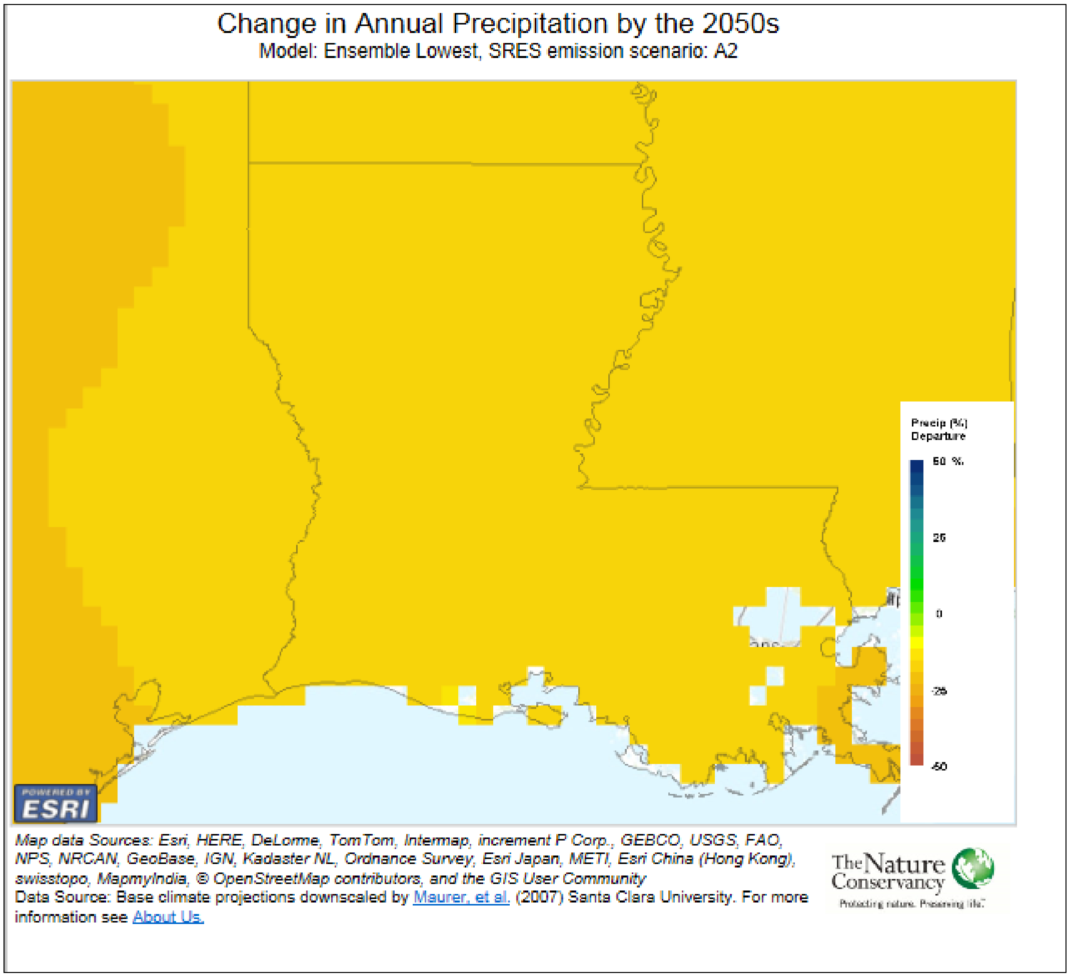
Change in Annual Precipitation by the 2050s

Model: Ensemble Highest, SRES emission scenario: A2

Map data Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Figure 7.5. ClimateWizard projected percent precipitation change for mid-century based on the Ensemble Highest of 16 GCMs under the high (A2) emissions scenario.

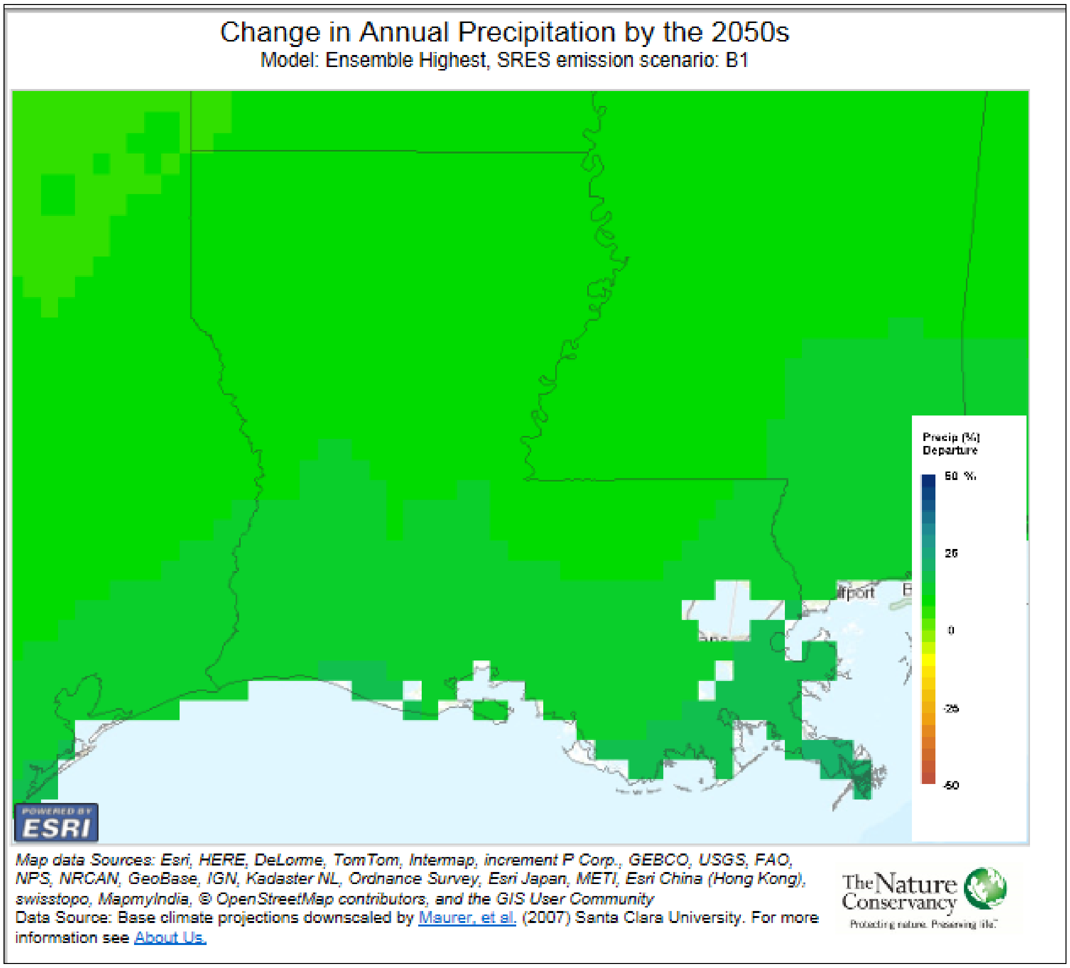

Change in Annual Precipitation by the 2050s

Model: Ensemble Lowest, SRES emission scenario: A2

Map data Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Figure 7.6. ClimateWizard projected percent precipitation change for mid-century based on the Ensemble Lowest of 16 GCMs under the high (A2) emissions scenario.



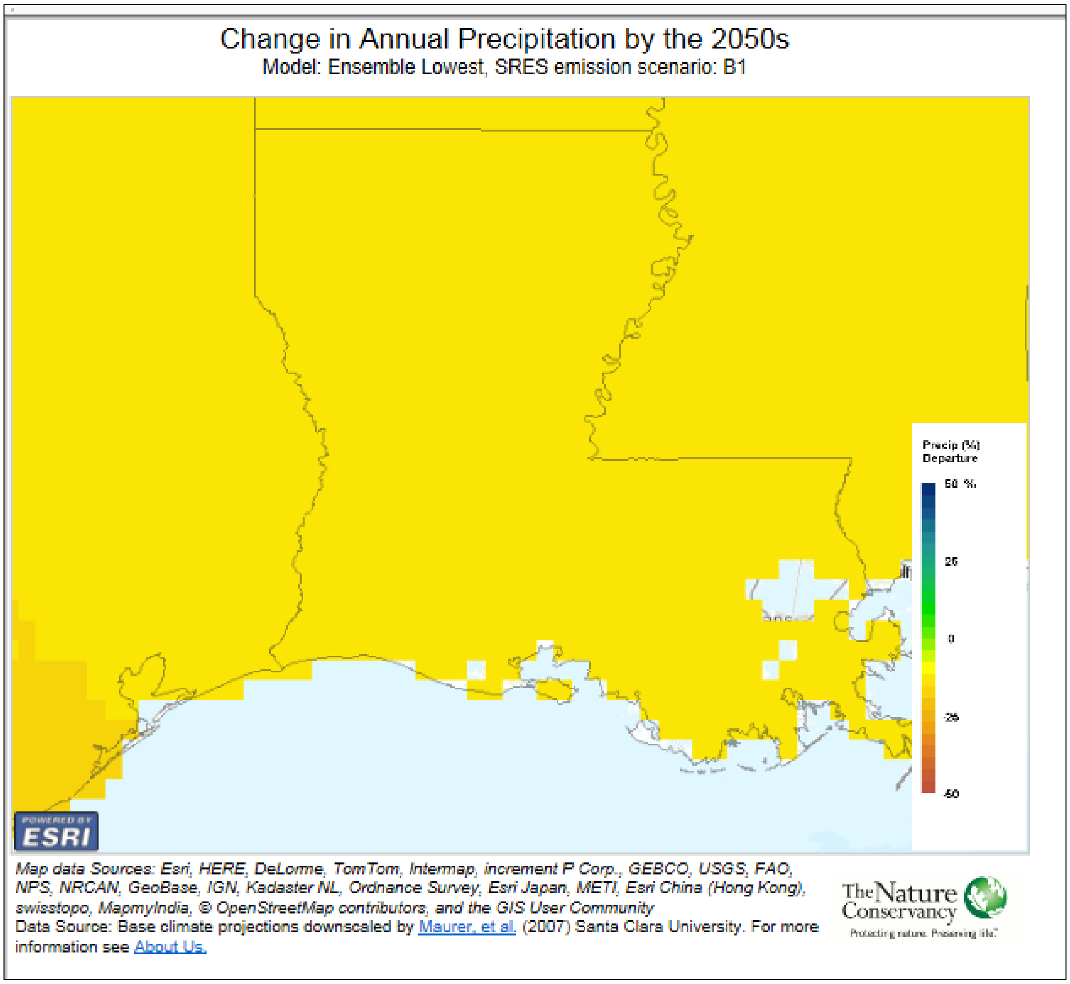
Change in Annual Precipitation by the 2050s

Model: Ensemble Highest, SRES emission scenario: B1

Map data Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Figure 7.7. ClimateWizard projected percent precipitation change for mid-century based on the Ensemble Highest of 16 GCMs under the low (B1) emissions scenario.


Change in Annual Precipitation by the 2050s
Model: Ensemble Lowest, SRES emission scenario: B1

Map data Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Figure 7.8. ClimateWizard projected percent precipitation change for mid-century based on the Ensemble Lowest of 16 GCMs under the low (B1) emissions scenario.

Detailed information on ClimateWizard projected temperature and percent precipitation changes for Louisiana's major cities under both emissions scenarios are reported in Tables 7.4 and 7.5. Under both emissions scenarios, temperature increases are predicted statewide, both annually and in every season. Temperature increases are generally predicted to be greater in the central and northern areas of Louisiana, compared to the coastal zone, and warming is expected to be most severe in the summer months. For the precipitation projections, once again, a dramatic difference between the projections exists for the two different GCMs, with differences between the emissions scenarios being smaller.

Table 7.4: ClimateWizard temperature increase projections for mid-century under both High (A2) and Low (B1) Emissions scenarios, by season and annually for major Louisiana cities (temperature in °F).

	A2 Annual	A2 Winter	A2 Spring	A2 Summer	A2 Fall	B1 Annual	B1 Winter	B1 Spring	B1 Summer	B1 Fall
New Orleans	3.6	3.1	3.6	4.0	3.9	2.7	2.4	2.7	2.9	2.7
Baton Rouge	4.0	3.2	3.8	4.5	4.1	2.9	2.5	2.9	3.2	3.1
Lafayette	3.9	3.3	3.8	4.3	4.1	2.9	2.5	2.8	3.1	3.1
Lake Charles	4.0	3.5	3.9	4.3	4.2	3.0	2.7	2.9	3.2	3.2
Alexandria	4.2	3.5	4.1	4.8	4.3	3.1	2.7	3.0	3.5	3.3
Monroe	4.3	3.3	4.1	5.3	4.5	3.3	2.8	3.1	3.7	3.4
Shreveport	4.4	3.6	4.3	5.1	4.6	3.4	2.9	3.1	3.8	3.6

Table 7.5: ClimateWizard projections for percent change in annual precipitation for mid-century under both High (A2) and Low (B1) Emissions scenarios for the Highest and Lowest of the 16 GCMs considered for major Louisiana cities.

% Change	A2 Ensemble Lowest Annual	A2 Ensemble Highest Annual	B1 Ensemble Lowest Annual	B1 Ensemble Highest Annual
New Orleans	-19.0	7.5	-13.5	15.6
Baton Rouge	-17.4	8.3	-13.9	10.8
Lafayette	-16.7	8.5	-12.8	12.9
Lake Charles	-16.4	6.6	-12.4	12.8
Alexandria	-17.4	8.9	-13.3	10.6
Monroe	-17.0	7.2	-14.8	9.1
Shreveport	-17.6	4.8	-14.3	8.4

3. SLR Projections for Louisiana:

Louisiana is especially vulnerable to SLR due to the unique geology of the Chenier Plain and Deltaic Plain (CPRA 2012b). Inclusion of projected SLR data in the planning and implementation of coastal restoration and conservation efforts is crucial (CPRA 2012b). We have elected to follow the recommendations of modeling conducted by the Coastal Protection and Restoration Authority of Louisiana (CPRA) as part of Louisiana's Comprehensive Master Plan for a Sustainable Coast (CPRA 2012a). Sea level rise is predicted to be between 0.16 to 0.65 meters (6.3-25.6 inches) over the next 50 years (Fig. 7.9). By 2100, CPRA estimates that SLR of 0.5-1.5 meters (19.6-59 inches) will occur in the Gulf of Mexico (CPRA 2012b). To fully gauge the impact of relative SLR on the Louisiana coast, subsidence and marsh vertical accretion must also be considered. Subsidence has been the primary historical driver of SLR in Louisiana, and will likely continue to be into the near future (CPRA 2012b). Marsh vertical accretion, on the other hand, may provide some relief from SLR. Projections of land loss in coastal Louisiana must account for all of these factors. CPRA (2012a) considered two scenarios of land loss over the next half-century. The first, more optimistic scenario (Fig. 7.10) assumes a slower rate of SLR and subsidence, among other factors, and estimates that an additional 770 square miles of land will be lost. The less optimistic scenario (Fig. 7.11), assuming faster rates of SLR and subsidence predicts that 1,750 square miles of land will be lost by mid-century. Regardless of which, if either scenario proves to be accurate, SLR will result in the loss of vast swaths of coastal wetlands which are some of Louisiana's most productive fish and wildlife habitats. Those coastal areas that do not become inundated by SLR may undergo conversion from one habitat type to another, as once inland areas are exposed to coastal processes or as elevated drier lands subside into lowlands. More discussion of the broader Gulf-wide impacts of SLR on land cover and focal species is presented in the summary of the Evaluation of Regional SLAMM Project.

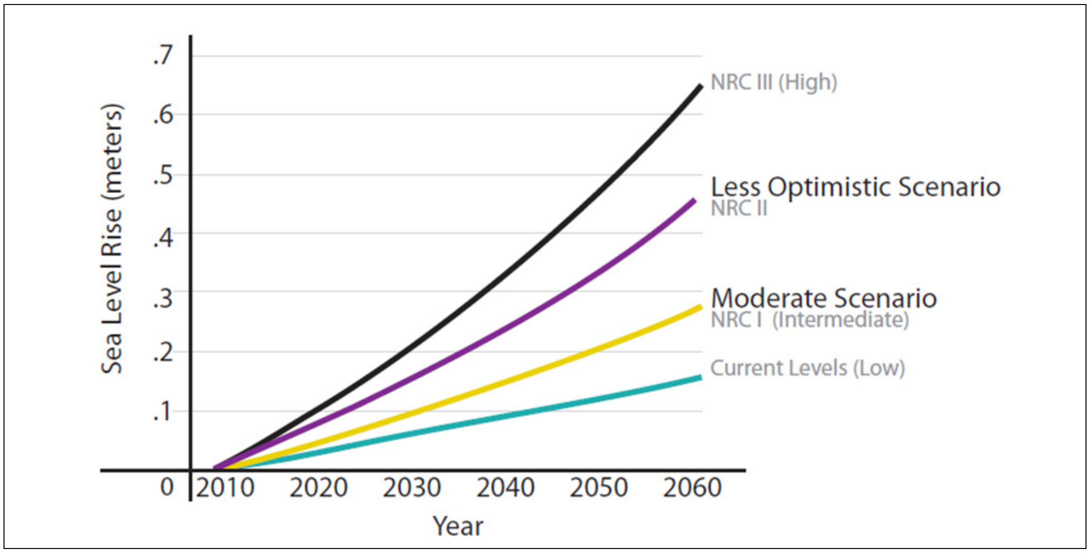


Figure 7.9: Projected SLR by mid-century, based on 3 different scenarios from the National Research Council (NRC). (CPRA 2012a).

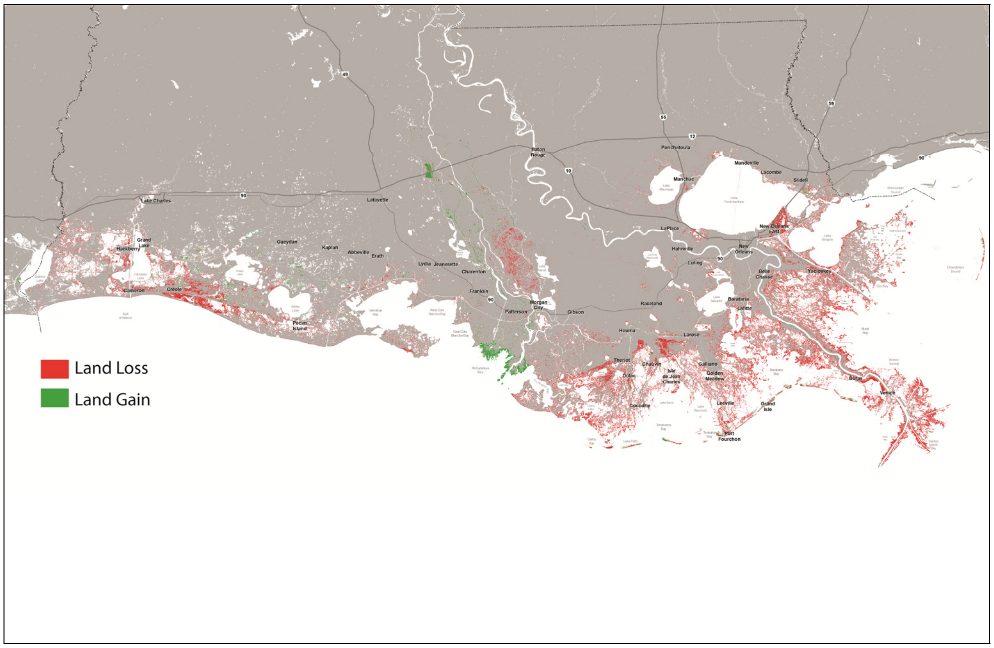


Figure 7.10: More optimistic land-loss scenario for coastal Louisiana (CPRA 2012a).

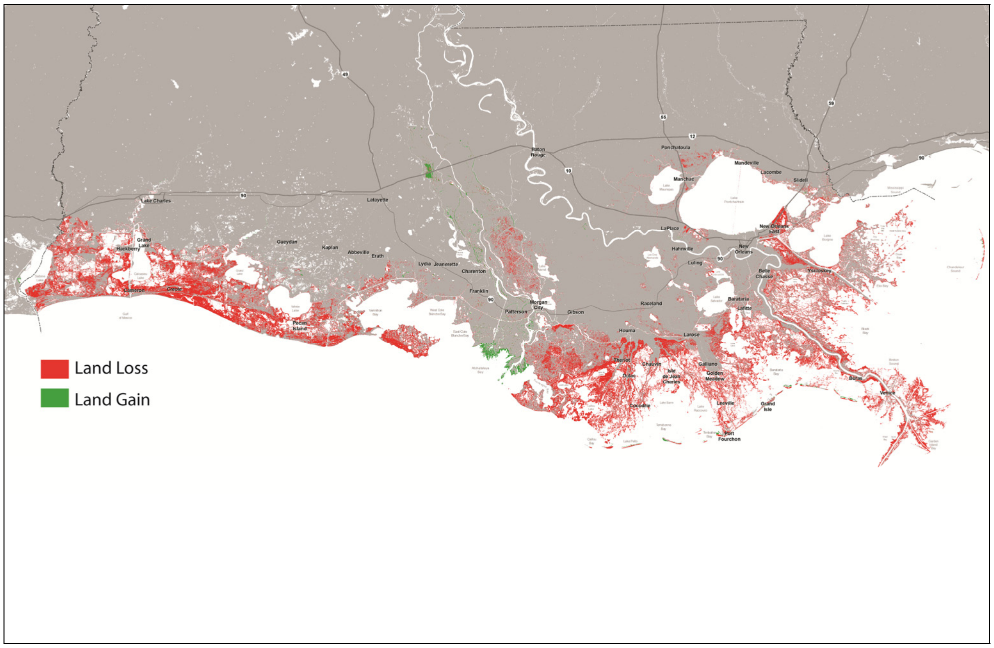


Figure 7.11: Less optimistic land-loss scenario for coastal Louisiana (CPRA 2012a).

C. Vulnerability Assessments

1. What are Vulnerability Assessments?

Climate change vulnerability assessments enable resource managers to identify species and natural communities that are likely to be most strongly affected by projected climate change and understand why those species and habitats are vulnerable. This is vital information that is required for climate change adaptation planning, because it allows for the prioritization of species and communities, and aids in determining which actions will best address the predicted drivers and impacts of climate change.

Vulnerability to climate change has three principle components:

1) Exposure – this component measures the amount of climate change which the target species or community is likely to experience.
2) Sensitivity – this component measures how and to what extent a given community or species is likely to be affected by or responsive to changes in climate.
3) Adaptive capacity – this component measures the ability of a given species or community to adapt or react to climate change in a manner which will reduce the vulnerability of the target to climate change.

Understanding these three components of climate change vulnerability is critical to adaptation planning, as it allows resource managers to identify the specific factors that contribute to the vulnerability of a given species or community and identify adaptation strategies that are appropriate.

Climate change vulnerability assessments will not be used solely to prioritize conservation actions for Louisiana SGCN or natural communities. However, the results of these vulnerability assessments provide an additional factor that can be taken into consideration when prioritizing SGCN, natural communities, or conservation actions. Climate change vulnerability was one of eight criteria used to prioritize SGCN (see Chapter 3 for more detail), and at most, accounted for ~10% of the overall prioritization score.

Climate change vulnerability assessments can be conducted using a variety of tools including vulnerability indices, spatial analysis of distribution shifts, multi-disciplinary models, expert elicitation, and quantitative models. A variety of factors, including management goals, conservation targets (e.g., species, natural communities, etc.), geography, availability of data, technical expertise, monetary constraints, and available time will ultimately dictate the appropriate approach. One approach to climate change vulnerability assessments that has been widely embraced by the national Wildlife Action Plan community is the NatureServe Climate Change Vulnerability Index (CCVI).

2. NatureServe Climate Change Vulnerability Index:

a. Overview of NatureServe CCVI

The NatureServe CCVI (Release 2.1) integrates projected exposure to climate change (Table 7.6) with three categories of sensitivity factors: (1) indirect exposure to climate change (Table 7.7), (2) species-specific factors (Table 7.8), and (3) documented responses to climate change (Table 7.9). The CCVI is used in conjunction with NatureServe conservation status ranks (e.g., State rarity ranks and Global rarity ranks, aka S-ranks and G-ranks) to generate a climate change vulnerability rank (Table 7.10).

Table 7.6. CCVI Direct Exposure Factors

This category allows for analysis of the percentage of a species' range that is likely to be associated with specific changes in temperature or precipitation/moisture conditions under scenarios of modeled future climate change. Typically, this data is at a relatively coarse scale using data from the tool ClimateWizard.

Temperature	**The percent of a species' range in five categories of increasing temperature based on ClimateWizard projections for 2050.** Typically, assessments are based on the results of the Model Ensemble Average for the IPCC SRES A1B emissions scenario.	>5.5° F (3.1° C) warmer (compared to 1961-1990 baseline)
		5.1-5.5° F (2.8-3.1° C) warmer
		4.5-5.0° F (2.5-2.7° C) warmer
		3.9-4.4° F (2.2-2.4° C) warmer
		<3.9° F (2.2° C) warmer
Moisture	The percent of species' range in six categories of changing moisture regime based on ClimateWizard projections for 2050. These figures represent the predicted change in annual moisture based on the Hamon AET:PET Moisture Metric (the ratio of actual evapotranspiration to potential evapotranspiration), rather than changes in precipitation. Negative values indicate net drying: no areas of the contiguous U.S. are predicted to increase in annual moisture.	<-0.119 (a significant change)
		-0.097 - -0.119
		-0.074 - -0.096
		-0.051 - -0.073
		-0.028 - -0.050
		>-0.028 (an insignificant change)

For Louisiana's assessments, the default recommendations in the CCVI guidelines and the GCM Ensemble Average under the SRES Medium A1B emissions scenario were used to generate temperature projections for the year 2050. The predicted net change in moisture by 2050 was based on the Hamon AET:PET Moisture Metric data. These projections, in addition to species-specific information on ecology and life history are used to determine a Vulnerability Score for each species addressed.

Table 7.7. CCVI Indirect Exposure Factors

Within the CCVI framework, indirect exposure factors are those changes that are not directly associated with changing climate conditions (e.g., temperature and precipitation) but rather those that may result from such direct changes. This category also includes several factors that one might consider elements affecting the adaptive capacity of a particular species (e.g., physical barriers to dispersal). This is also where one might consider any ancillary effects that human response to climate change might create. These may be positive, such as protection of forests or other natural areas to enhance carbon sequestration, or negative, such as developing wind farms in important bird or bat migration corridors or damming rivers for new freshwater reservoirs.

Exposure to sea level rise	This factor comes into play only in the case that all or a portion of the range within the assessment area may be subject to the effects of a 0.5-1 m sea level rise and the consequent influence of storm surges.

Distribution relative to natural barriers	This factor assesses the degree to which natural (e.g., topographic, geographic, ecological) barriers limit a species' ability to shift its range in response to climate change. Species for which barriers would inhibit distributional shifts with climate change-caused shifts in climate envelopes likely are more vulnerable to climate change than are species whose movements are not affected by barriers.
Distribution relative to anthropogenic barriers	This factor assesses the degree to which anthropogenic barriers (e.g., roads, urban areas or agricultural areas, seawalls, dams, and culverts) limit a species' ability to shift its range in response to climate change. Species for which barriers would inhibit distributional shifts with climate change-caused shifts in climate envelopes likely are more vulnerable to climate change than are species whose movements are not affected by barriers.
Predicted impacts of land use changes due to human response to climate change	Strategies designed to mitigate or adapt to climate change have the potential to affect very large areas of land, and the species that depend on these areas, in both positive and negative ways. This factor is not intended to capture habitat loss or destruction due to other on-going human activities, which are already considered in existing conservation status ranks.

Table 7.8. CCVI Sensitivity Factors

CCVI sensitivity factors refer to characteristics of the particular species being assessed. Some of the factors may, in fact, be considered elements of adaptive capacity as described previously, but here they are relevant to more "intrinsic" elements of adaptive capacity. Extrinsic factors (e.g., anthropogenic or natural barriers to dispersal) are considered in the previous category of assessment variables.

Dispersal and movements	This pertains to known or predicted dispersal or movement capabilities and characteristics and ability to shift location in the absence of barriers as conditions change over time as a result of climate change. In general, species with poor dispersal ability are likely to be more vulnerable to climate change than those that regularly disperse or move long distances. Specific "barriers" to dispersal (both natural and anthropogenic) are considered as elements of indirect exposure (above).
Sensitivity to changes in temperature	This pertains to the breadth of temperature conditions within which a species is known to be capable of reproducing, feeding, growing, or otherwise existing. Factors evaluated include the historical thermal niche (exposure to past variations in temperature, as approximated by mean annual temperature variation across occupied cells in the assessment area) and the current physiological thermal niche.
Sensitivity to changes in precipitation, hydrology, and moisture regime	This pertains to the breadth of moisture conditions within which a species is known to exist. Factors evaluated include the historical hydrologic niche (exposure to past variations in precipitation) and current hydrologic niche (which pertains to a species' dependence on an narrowly-defined precipitation/hydrologic regime, including strongly seasonal precipitation patterns and/or specific aquatic/wetland habitats or localized moisture conditions that might be vulnerable to loss or reduction with climate change).
Dependence on a	This pertains to a species' response to specific disturbance regimes

specific disturbance regime likely to be affected by climate change	such as fires, floods, severe winds, pathogen outbreaks, or similar events. It includes disturbances that affect species directly as well as those that affect species via abiotic aspects of habitat quality.
Dependence on ice, ice-edge, or snow-cover habitats	This pertains to a species' dependence on habitats associated with ice or snow throughout the year or seasonally.
Restriction to uncommon geological features or derivatives	This pertains to a species' need for a particular soil/substrate, geology, water chemistry, or specific physical feature (e.g., caves, cliffs) for reproduction, feeding, growth, or otherwise existing for one or more portions of the life cycle. It focuses on the commonness of suitable conditions for the species on the landscape, as indicated by the commonness of the features themselves combined with the degree of the species' restriction to them.
Dependence on other species to generate habitat	Habitat here refers to any habitat (e.g., for reproduction, feeding, hibernation, seedling establishment, etc.) necessary for completion of the life cycle, including those only used on a seasonal basis.
Dietary versatility (animals only)	This pertains to the diversity of food types consumed by animal species. Dietary specialists are more likely to be negatively affected by climate change than species that readily switch among different food types.
Pollinator versatility (plants only)	This pertains to the degree to which plants are dependent on one or multiple species for pollination.
Dependence on other species for propagule dispersal	This can be applied to plants or animals (e.g., fruit dispersal by animals). If the propagule-dispersing species is vulnerable to climate change, the dependent species is likely to be so as well.
Other interspecific interaction factors	This may include factors other than habitat, seedling establishment, diet, pollination, or propagule dispersal, such as mutualism, parasitism, predator-prey relationships, etc.
Measured genetic variation	Species with less standing genetic variation will be less able to adapt because the appearance of beneficial mutations is not expected to keep pace with the rate of 21st century climate change.
Occurrence of bottlenecks in recent evolutionary history	In the absence of range wide genetic variation information, this factor can be used to infer whether reductions in species-level genetic variation that would potentially impede its adaptation to climate change may have occurred.
Phenological response to changing seasonal temperature or precipitation dynamics	Recent research suggests that some phylogenetic groups are declining due to lack of response to changing annual temperature dynamics (e.g., earlier onset of spring, longer growing season).

Table 7.9. Documented or Modeled Response to Climate Change	
This category allows for inclusion of information from supplemental studies, if available.	
Documented response to recent climate change	This addresses the degree to which a species is known to have responded to recent climate change based on published accounts in peer-reviewed literature. For example, some species have shifted ranges or shown phenological changes. Species already experiencing change are important sentinels for future impacts.
Modeled future (2050) change in range or population size	Models should be developed based on reasonably accurate locality data using algorithms that are supported by peer-reviewed literature. Relative vulnerability depends on the extent to which species distribution and/or population is projected to change relative to historic or current conditions.
Overlap of modeled future (2050) range with current range	If the range disappears or declines >70% within the assessment area, such that the previous factor is coded as Greatly Increase Vulnerability, this factor should be skipped to avoid double-counting in the scoring.
Occurrence of protected areas in modeled future distribution	“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.

Table 7.10. The CCVI Scoring System	
Extremely Vulnerable (EV)	Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.
Highly Vulnerable (HV)	Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
Moderately Vulnerable (MV)	Abundance and/or range extent within geographical area assessed 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 (increase/decrease) substantially by 2050. Actual range boundaries may change.
Not Vulnerable/Increase Likely (IL)	Available evidence suggests that abundance and/or range extent within the geographical area assessed is likely to increase by 2050.
Insufficient Evidence (IE)	Available information about a species’ vulnerability is inadequate to calculate an Index score.

b. Results of the NatureServe CCVI for Louisiana SGCN

To assess the vulnerability of Louisiana SGCN, the NatureServe CCVI was applied to a subset of those species. In total, 70 of the 308 non-marine SGCN (CCVI is not designed for use for marine species) were assessed using the CCVI. Species assessed using the CCVI were species selected for their suitability to serve as surrogate or umbrella species for the remainder of Louisiana's SGCN (based on expert opinion; Appendix I). Of the 70 species assessed, the distribution of climate change vulnerability scores can be seen in Table 7.11. For the purposes of the Louisiana WAP, Not Vulnerable/Presumed Stable and Not Vulnerable/Increase Likely were lumped into the category Not Vulnerable.

Table 7.11. Distribution of Climate Change Vulnerability ranks for 70 SGCN assessed using NatureServe CCVI.

	Not Vulnerable (NV)	**Moderately Vulnerable (MV)**	**Highly Vulnerable (HV)**	**Extremely Vulnerable (EV)**
# of SGCN	34	22	12	2
% of SGCN assessed	49%	31%	17%	3%

Using the Vulnerability Scores obtained for the 70 representative SGCN, expert opinion was solicited from within LDWF to assign a vulnerability score to the remaining 239 non-marine SGCN. The distribution of vulnerability scores by taxonomic group for all 308 non-marine SGCN can be seen in Figure 7.12. Overall, amphibians (94%), crustaceans (100%), and fishes (79%) were the groups most vulnerable to climate change in Louisiana, based on the percentage of SGCN that showed at least Moderate Vulnerability. Mammals (16%) and birds (35%) showed the least vulnerability of all taxonomic groups assessed.

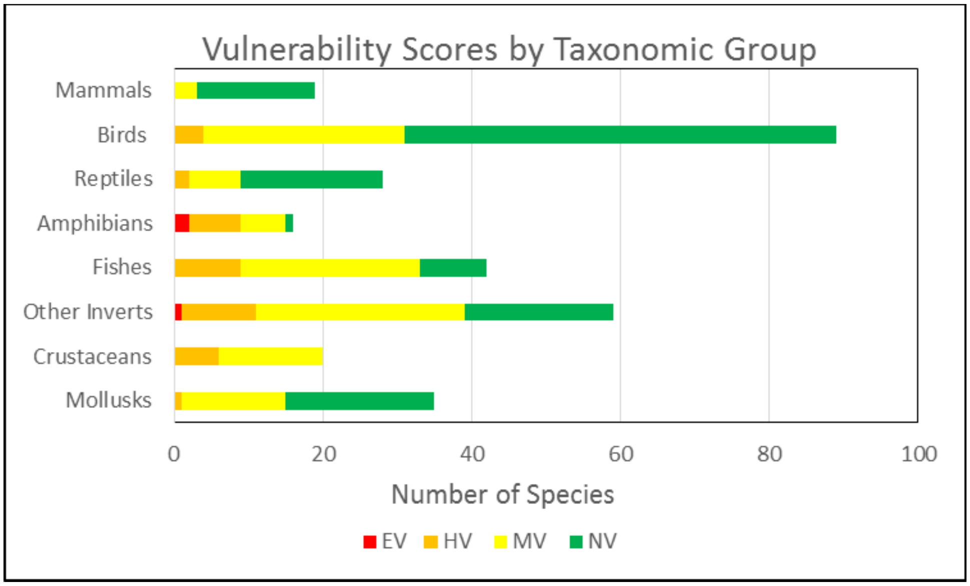


Figure 7.12. Distribution of Climate Change Vulnerability ranks for Louisiana SGCN, using the results of the 70 CCVI-assessed species to assign ranks to all 308 non-marine SGCN.

1. Amphibians

Overall, 56% of amphibian SGCN ranked as either Extremely Vulnerable or Highly Vulnerable and 94% of amphibian SGCN showed at least Moderate vulnerability to climate change. Reasons for the high vulnerability to climate change shown by amphibians (Fig. 7.13) include (1) limited ability to overcome both natural and anthropogenic barriers, (2) a general preference for cooler microhabitats that could be lost as temperatures increase, and (3) a general preference for high-moisture microhabitats that could be reduced as temperatures increase and available moisture decreases. Many amphibian SGCN utilize relatively cool and moist refugia found under logs or woody debris in forested areas. Additionally, many amphibians rely on ephemeral wetlands for breeding, and there is a strong possibility that such wetlands could be lost or degraded due to climate change. The primary factor that decreased vulnerability to climate change was the amount of variation in hydrological conditions historically in Louisiana, which provides evidence that these species have survived past variations in precipitation patterns and could have some resilience to such changes in the future.

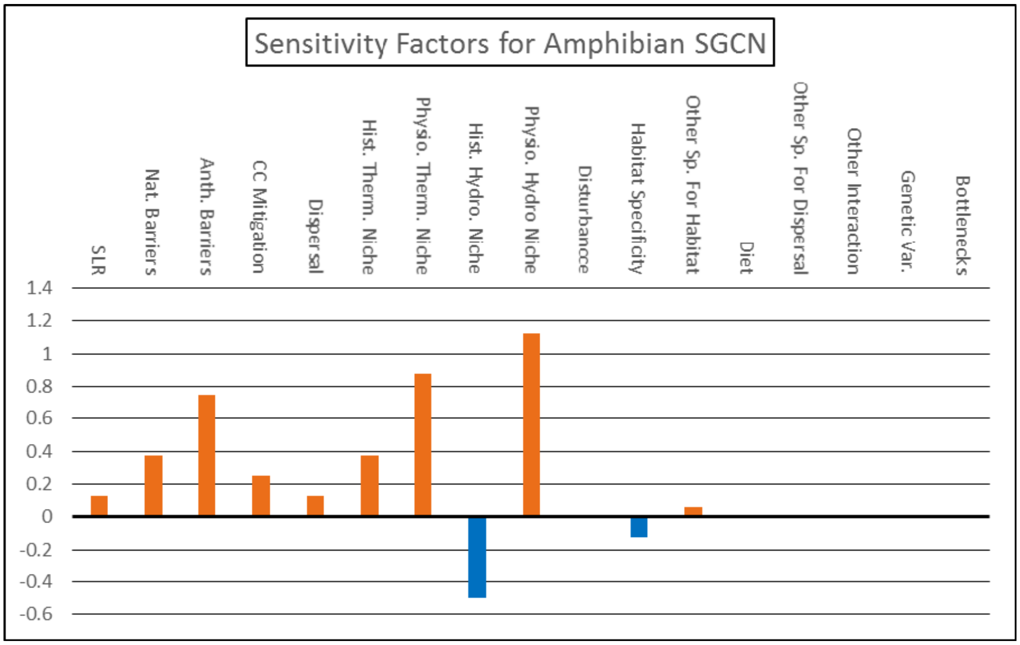


Figure 7.13. Factors affecting climate change vulnerability for Amphibian SGCN.

2. Crustaceans

Crustaceans showed a high degree of vulnerability to climate change impacts, with 30% of crustacean SGCN being ranked as Highly Vulnerable and 100% of crustacean SGCN ranked as at least Moderately Vulnerable to climate change. A number of sensitivity factors contributed to vulnerability (Fig. 7.14). Similar to amphibians, the three most important factors that contributed to vulnerability were (1) limited ability to overcome anthropogenic barriers, (2) a general preference for cooler microhabitats that could be lost as temperatures increase, and (3) a general preference for high-moisture microhabitats that could be reduced as temperatures increase and available moisture decreases. Most of Louisiana’s crustacean SGCN are found in either ephemeral water bodies or in smaller order streams, both of which are at risk of degradation as precipitation patterns change and temperatures increase. As with amphibian SGCN, the past variation in precipitation in Louisiana provides some predicted resiliency to future changes. The other primary factor that served to mitigate vulnerability is the fact that crawfishes have a generalized diet, as highly specific diets tend to increase vulnerability.

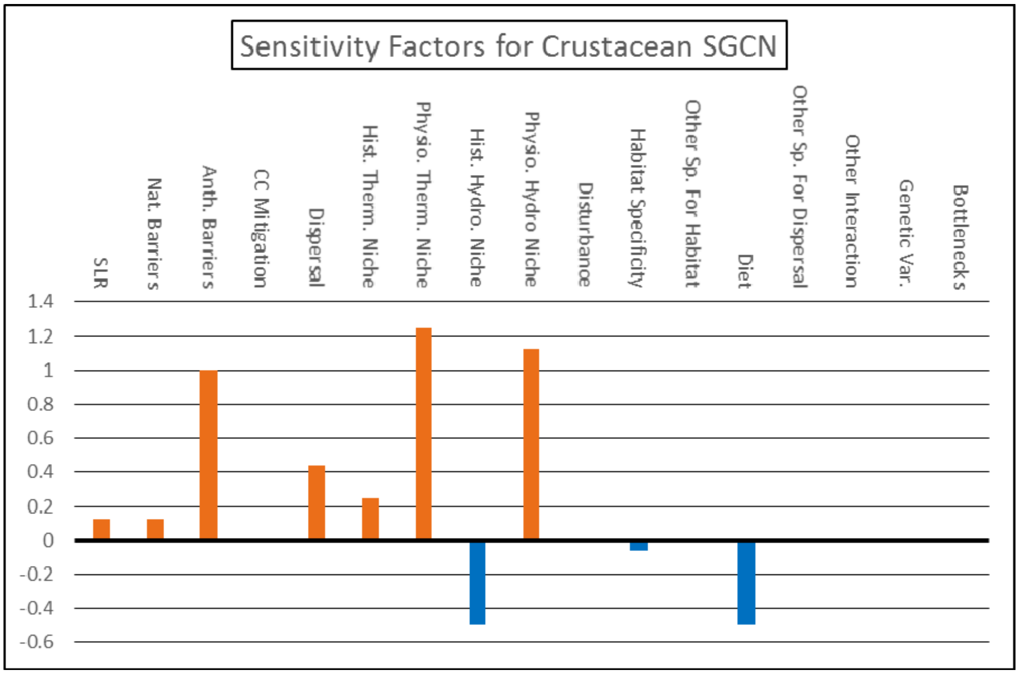


Figure 7.14. Factors affecting climate change vulnerability for crustacean SGCN.

3. Mollusks

Mollusks showed a moderate amount of climate change vulnerability (43% at least Moderately Vulnerable), which might seem somewhat low, given the fact that most mollusk SGCN are aquatic and highly sedentary. However, there are several factors that helped to ameliorate climate change vulnerability for this group (Fig 7.15). First, many of these species have fairly wide habitat tolerances (in terms of water depth, flow, and substrate particle size) as well as a highly generalized detritus based diet. Additionally, the wide range of past hydrological conditions found in Louisiana, as with other taxonomic groups, served to counteract those factors that were contributing to climate change vulnerability for these animals. Those factors included: (1) restricted ability to pass through natural or anthropogenic barriers, as even the glochidial stage would often be blocked by dams when attached to a fish host, (2) the fact that some species require fast flowing areas that could be reduced as a result of changing precipitation patterns, and (3) the fact that mussels are dependent upon other species for propagule dispersal, which means that any negative impacts to their host fishes would have a trickle-down effect on them as well. Additionally, those species that are found in smaller streams (e.g. Louisiana Pearlshell) were predicted to have higher vulnerability, as such streams are more susceptible to drying. Due to potential negative impacts of SLR, species in the Florida Parishes are potentially more at risk, and species in the northwestern part of Louisiana are at higher risk than species in other areas of the state, due to projected greater increases in temperature and decreases in precipitation in that region relative to the rest of the state.

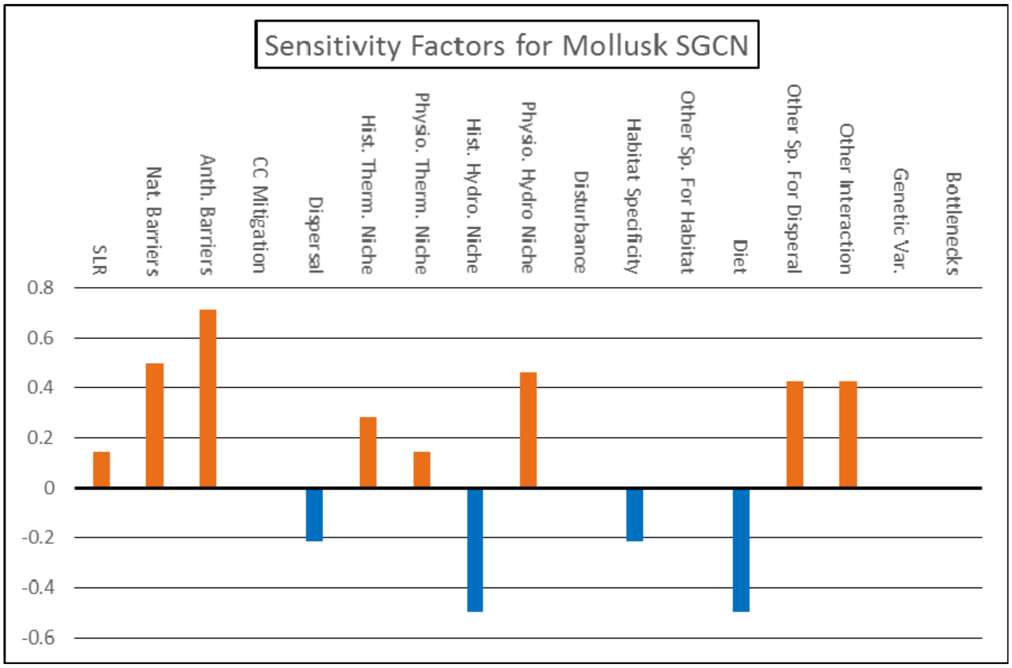


Figure 7.15. Factors affecting climate change vulnerability for mollusk SGCN.

4. Non-crustacean Arthropods

A number of different sensitivity factors contributed to high vulnerability to climate change in this group (66% of SGCN at least moderately vulnerable). The two factors that weighed most heavily were historical thermal niche and physiological hydrological niche (Fig. 7.16). Historical thermal niche reflects the relatively stable historical temperature patterns found in Louisiana, and physiological hydrological niche reflects the fact that many of our insect SGCN are either found in wetland communities, or have at least one life stage that is aquatic (e.g., mayflies, stoneflies, caddisflies, and dragonflies). The specialized diet of many insect SGCN also served to increase climate change vulnerability. Such specialization could be a detriment under changing climatic conditions particularly if the host plant or prey species becomes reduced due to such changes. Serving to mitigate climate change vulnerability for this group is the relatively high dispersal capability of most insects, as well as the past variation in precipitation patterns that has been historically found in Louisiana, which should provide some level of resilience to such changes in the future.

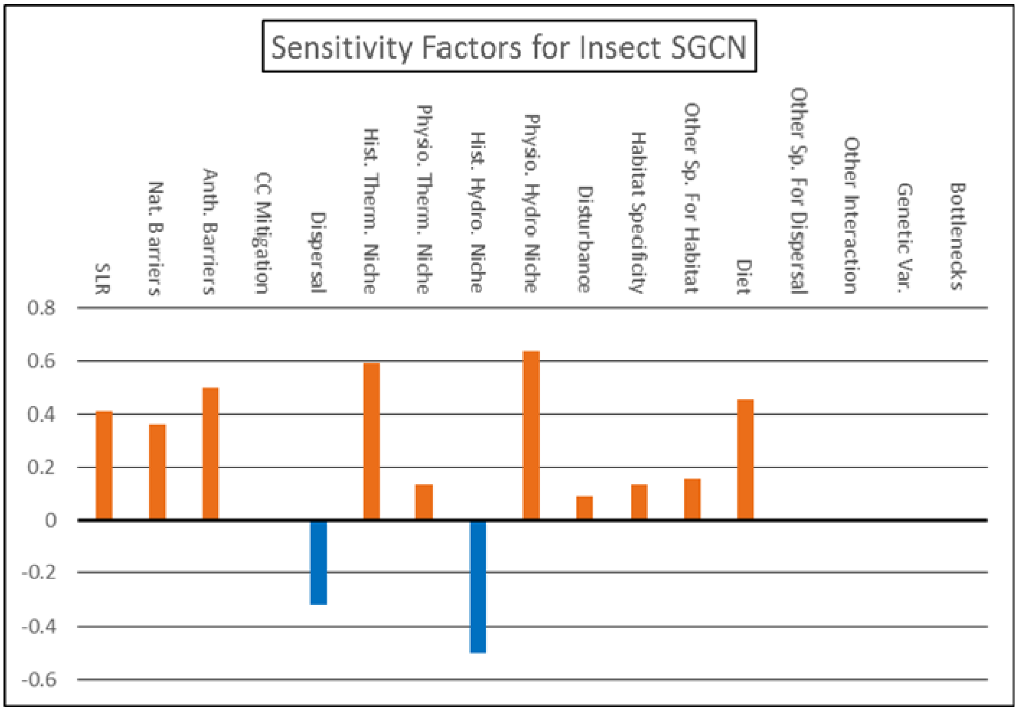


Figure 7.16. Factors affecting climate change vulnerability for non-crustacean arthropod SGCN

5. *Inland Fishes*

Fishes were determined to be among the most vulnerable taxonomic groups to climate change. Seventy-nine percent of fish SGCN were determined to be at least Moderately Vulnerable to climate change; although a relatively small percentage (21%) were considered Highly Vulnerable or Extremely Vulnerable. As with other aquatic taxa, a number of factors contributed heavily to predicted vulnerability (Fig. 7.17). The presence of dams, sills, and other man-made barriers to movement within stream systems was one important factor. The relatively small range of past temperature variation in Louisiana also contributed to climate change vulnerability, as did the fact that many of our fish SGCN are found in smaller streams or shallow areas within larger streams that are subject to a reduction in habitat quality with the drier conditions that are expected. Helping to counteract those factors, is that, in the absence of man-made barriers, many fishes have good dispersal capability within stream systems, as well as significant variation in precipitation patterns historically in Louisiana.

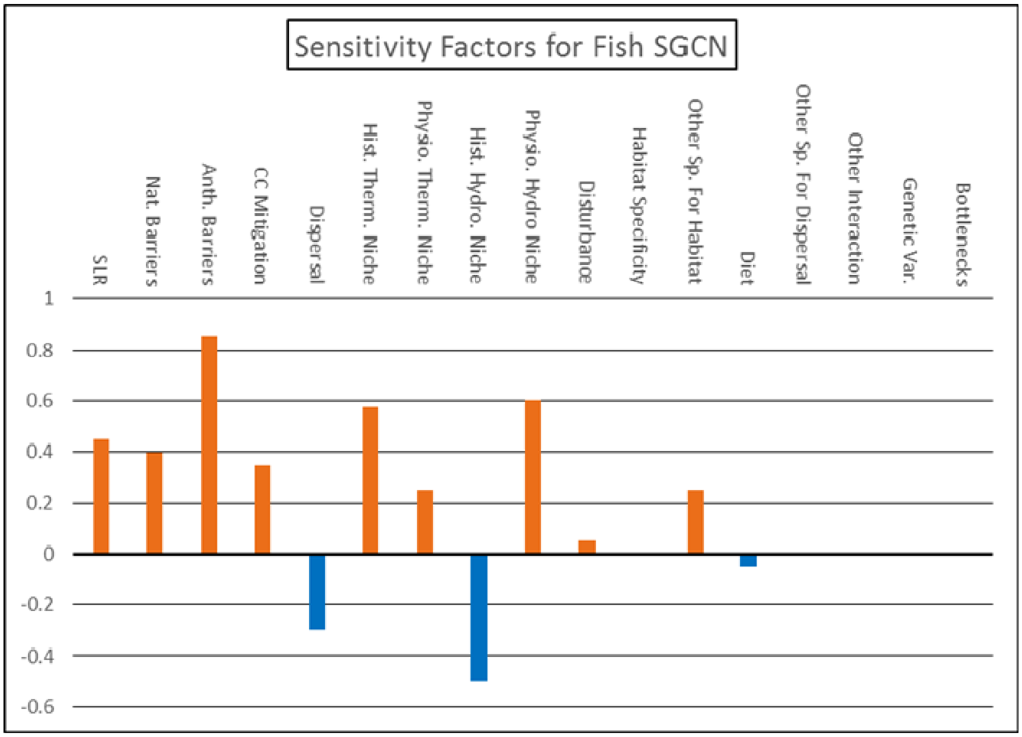


Figure 7.17. Factors affecting climate change vulnerability for fish SGCN.

6. Birds

It is not surprising that birds were among the least sensitive groups evaluated, with only 35% showing some level of vulnerability, and less than 5% being ranked as Highly Vulnerable or Extremely Vulnerable. The primary factor for the low vulnerability shown by birds (Fig. 7.18) is dispersal ability. As birds are highly mobile as a group, it is predicted that many species will be able to shift breeding and non-breeding ranges to track preferred climatic conditions. Among the birds examined, the most sensitive were those that rely on wetland habitats, particularly coastal marshes, and those that breed on Barrier Islands. There are a number of bird SGCN that rely on such habitats, and those habitats are very likely to be negatively impacted by SLR and associated increased storm surge. SLR was found to be one of the two factors that contributed the most to climate change vulnerability among bird SGCN. As with several other taxa, the limited amount of past variation in temperatures within Louisiana was also predicted to be a major contributor to the observed vulnerability, as life history strategies of these species that have developed under relatively stable climatic conditions may not be as successful during a period of more rapid change.

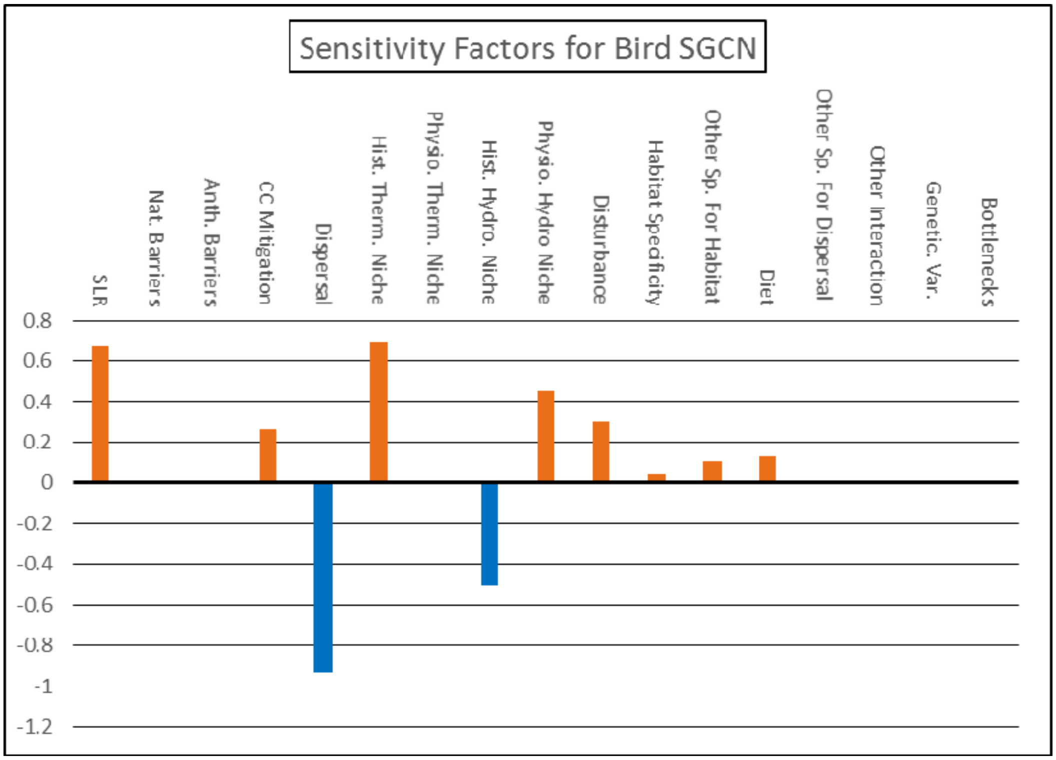


Figure 7.18. Factors affecting climate change vulnerability for bird SGCN.

7. Mammals

This taxonomic group showed the least climate change vulnerability among Louisiana SGCN. Only 16% of mammal SGCN showed any level of climate change vulnerability, and no species were found to be Highly Vulnerable or Extremely Vulnerable. As with birds, an overall high level of dispersal capability (Fig. 7.19) was one of the primary factors that contributed to the observed low level of vulnerability. Many of Louisiana's mammal SGCN do not show high habitat or dietary specificity, and several species that are more habitat specific are found in habitats that are not likely to contract as a result of projected climate change. As with most taxa, the relatively narrow historical thermal niche typical of Louisiana was the primary contributing factor to the vulnerability that was predicted for mammal SGCN.

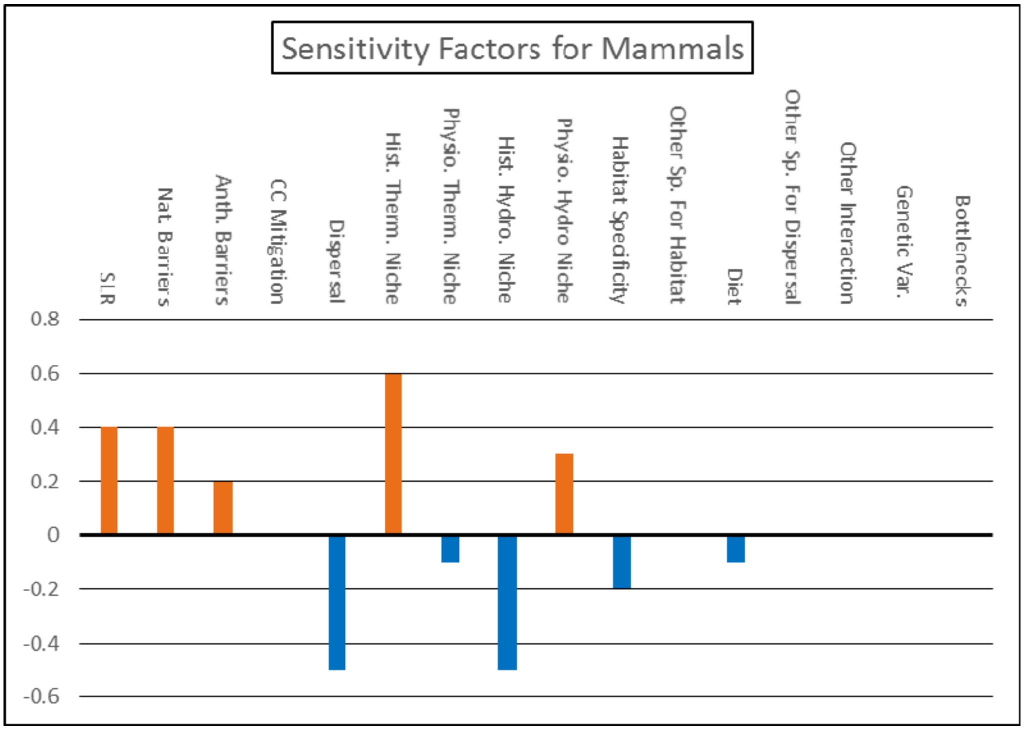


Figure 7.19. Factors affecting climate change vulnerability for mammal SGCN.

8. Reptiles

Ranking behind only mammals in terms of Low Vulnerability to climate change, 32% of reptile SGCN were projected to be vulnerable at some level, and 7% were predicted to be Highly Vulnerable or Extremely Vulnerable. Although the dispersal ability of reptiles is generally greatly reduced compared to birds, and to a lesser extent mammals, the dispersal capability of many reptile SGCN served to reduce predicted vulnerability. As with several other taxa, the relatively large variation in past hydrological conditions in Louisiana also reduced sensitivity. Anthropogenic barriers (i.e. roads) were predicted to be one of the two main factors contributing to the level of vulnerability that was observed. Many species of reptiles suffer elevated levels of mortality during road crossings, which could prevent some reptile SGCN from utilizing their ability to disperse in order to track preferred climatic conditions.

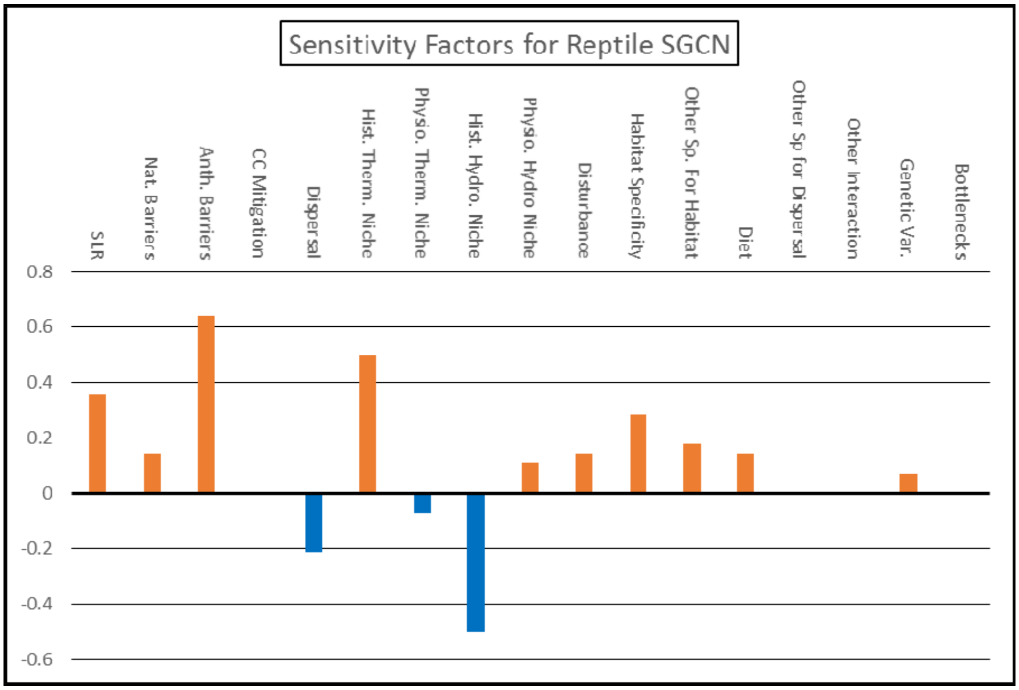


Figure 7.20. Factors affecting climate change vulnerability for reptile SGCN.

9. Coastal SGCN

In addition to the individual taxonomic groups, species that are primarily coastal in distribution were also assessed. This category included birds, mammals, fishes, reptiles, and insects. For this subset of SGCN, 47% were ranked as Highly Vulnerable or Extremely Vulnerable, and 73% were at least Moderately Vulnerable. The primary sensitivity factor contributing to this high level of climate change vulnerability is SLR. Species that rely on low-elevation islands, such as Louisiana's Barrier Islands, for nesting are among those SGCN most vulnerable to negative impacts of climate change (NABCI 2010). The Gulf of Mexico has experienced the greatest rate of relative SLR in the U.S. and continued SLR will fragment or inundate additional coastal habitats (NABCI 2010). These impacts will further exacerbate the existing issue of coastal-land loss in Louisiana, with almost 1,900 square miles having been lost in the last 80 years, and up to an additional 1,750 square miles at risk of being lost in the next five decades (CPRA 2012a). Serving to mitigate the climate change vulnerability of coastal SGCN is good dispersal ability, as about half of these species are birds. However, that dispersal ability might not be as valuable for some coastal birds that rely on Barrier Islands for nesting, as there may be no suitable nesting habitat to disperse to following SLR.

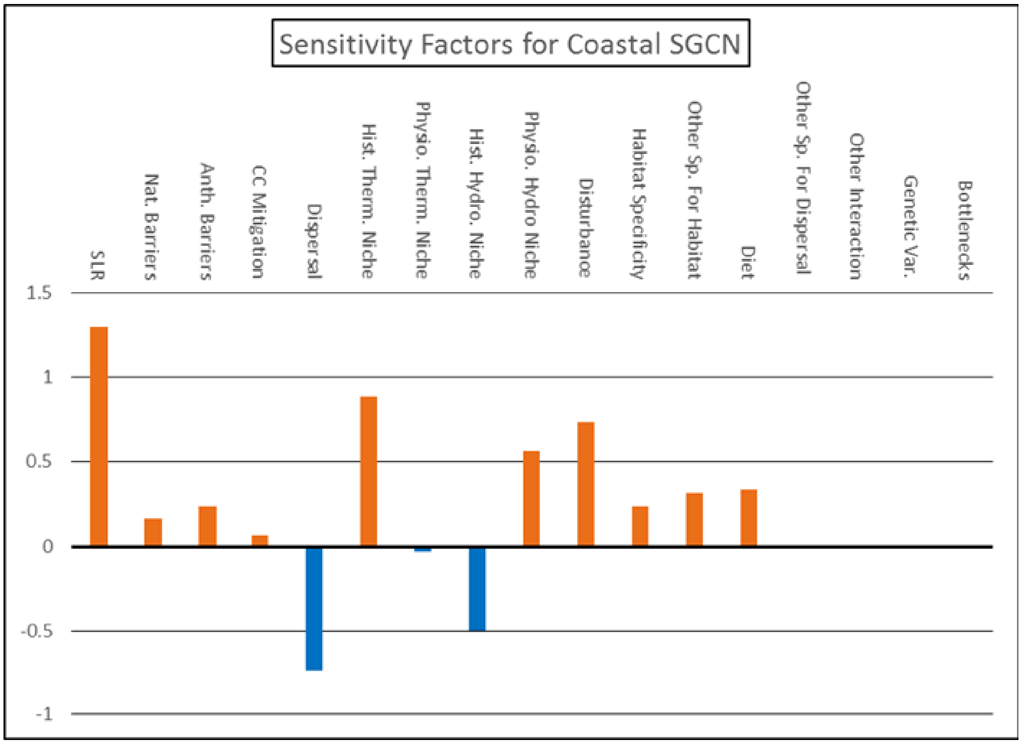


Figure 7.21. Factors affecting climate change vulnerability for coastal SGCN.

3. Gulf Coast Vulnerability Assessment

a. Overview

The Gulf Coast Vulnerability Assessment (GCVA) was initiated by the four LCCs that cover the Gulf of Mexico, the National Oceanic and Atmospheric Administration (NOAA), the Northern Gulf Institute, CPRA, and USGS to assess the relative vulnerability of four key ecosystems and associated species across the Gulf Coast region, including Louisiana.

The Core Planning Team used the Standardized Index of Vulnerability and Value Assessment (SIVVA, Reece and Noss 2014), an expert-opinion approach, to assess vulnerability. This tool enables both the assessment of relative vulnerability and the identification of factors that most influence that vulnerability. More than 50 individual managers, scientists, administrators, and others participated. These individuals assigned vulnerability scores to the species and ecosystems using their best professional opinions and empirical data that were readily available.

Following Glick et al. (2011), for purposes of the GCVA, vulnerability refers to potential impact (estimated exposure and sensitivity) to ecosystems and species of potential threats, coupled with adaptive capacity (ability or lack thereof to adapt to ecosystem changes).

The four ecosystems assessed in the GCVA were mangroves (i.e. Mangrove Marsh Shrublands), tidal emergent marsh (i.e. Freshwater to Salt Marsh), oyster reefs, and Barrier Islands. The assessment estimated the vulnerability of these ecosystems to potential threats. Threats included climate change and associated SLR, hypoxia, wetland loss, quality and quantity of freshwater inflows, invasive species, urbanization, and range shift constraints.

b. Results for Ecosystems

Three of the four ecosystems were determined to be highly vulnerable throughout or in parts of Louisiana. Following is a brief discussion of each of these three highly vulnerable ecosystems (Watson et al. 2015).

1. Tidal emergent marsh (Fig. 7.22)

Tidal emergent marsh was highly vulnerable across Louisiana. The most serious threats are SLR, fragmentation of habitat, altered hydrology, and constraints on range shifts.

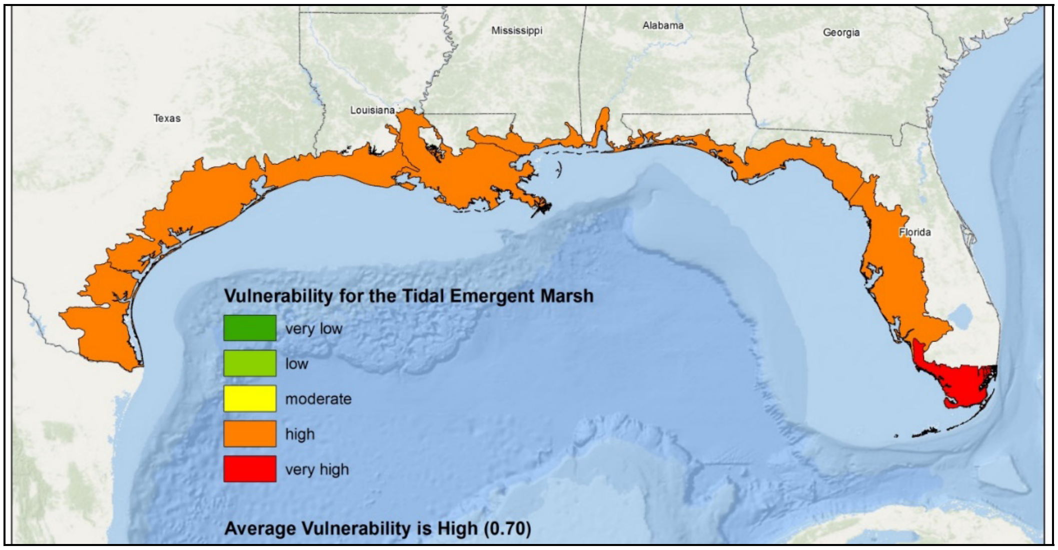


Figure 7.22. Vulnerability of Tidal Emergent Marsh from GCVA

2. Oyster reefs (Fig 7.23)

Oyster reef was highly vulnerable across Louisiana, except for the Southern Coastal Plain in the eastern part of the state. The most serious threats to oyster reef were altered hydrology and the inability of the physical structure to migrate away from threats.

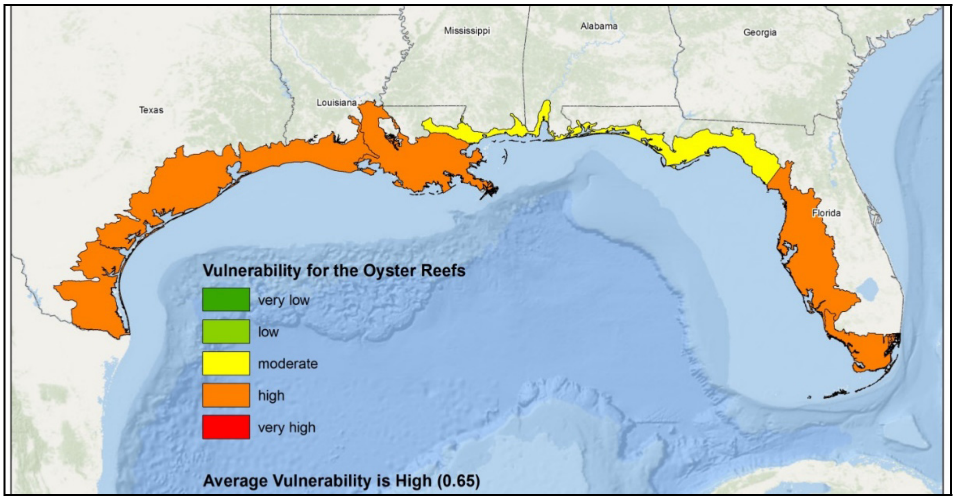


Figure 7.23. Vulnerability of Oyster Reef from GCVA

3. Barrier Islands (Fig 7.24)

Barrier Islands were highly vulnerable across Louisiana. The most serious threat was determined to be SLR.

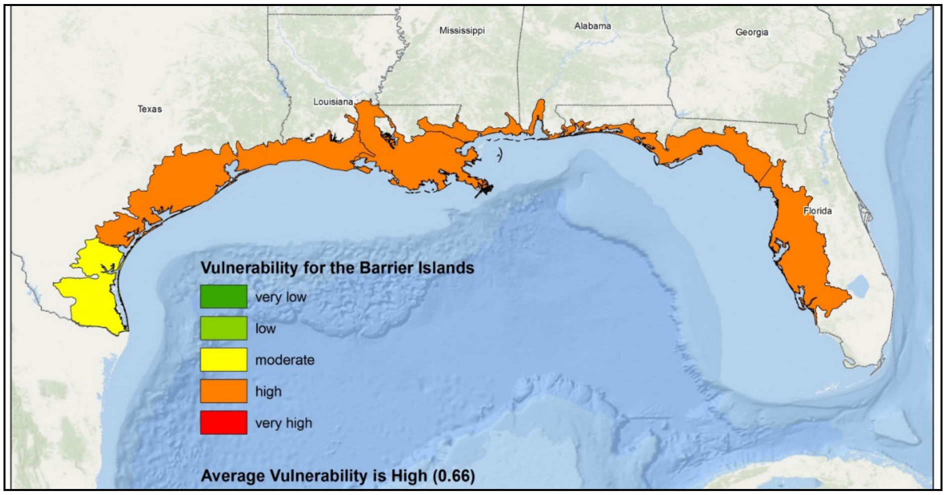


Figure 7.24. Vulnerability of Barrier Islands from GCVA

c. Results for Species

The GCVA assessed eleven species. Those species, and their associated ecosystems, were as follows:

- Roseate Spoonbill (mangroves)
- Mottled Duck (tidal emergent marsh)
- Spotted Seatrout (tidal emergent marsh)
- Blue Crab (tidal emergent marsh)

- Clapper Rail (tidal emergent marsh)
- Eastern Oyster (oyster reefs)
- American Oystercatcher (oyster reefs)
- Red Drum (oyster reefs)
- Black Skimmer (Barrier Islands)
- Wilson’s Plover (Barrier Islands)
- Kemp’s Ridley Sea Turtle (Barrier Islands)

The species were chosen because “they are widely distributed across the Gulf, are recognized as conservation targets by at least one LCC, and are representative of how other species may be impacted by projected changes” (Watson et al. 2015). Of the eleven species assessed, four were determined to be “highly vulnerable” throughout or in parts of Louisiana, all of which are SGCN. Following is a brief discussion of each of the four highly vulnerable SGCN (Watson et al. 2015).

1. Roseate Spoonbill (Fig. 7.25)

Roseate Spoonbills were judged to be highly vulnerable in the Southern Coastal Plain of eastern Louisiana. The most serious threats were increased coastal development, changes to biotic interactions (specifically prey), loss of habitat to SLR and erosion, storm surge, and low adaptive capacity.

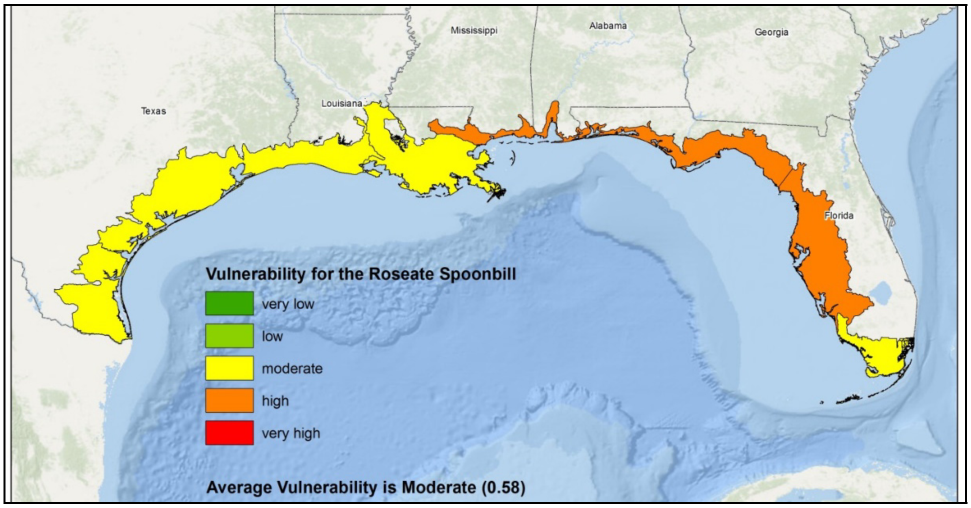


Figure 7.25. Vulnerability of Roseate Spoonbill

2. American Oystercatcher (Fig. 7.26)

American Oystercatchers were judged to be highly vulnerable in the Southern Coastal Plain of eastern Louisiana. The most serious threats were judged to be barriers to dispersal such as coastal development, loss of nesting habitat, SLR, and "synergistic effects of climate change, SLR and urbanization" (Watson et al. 2015).

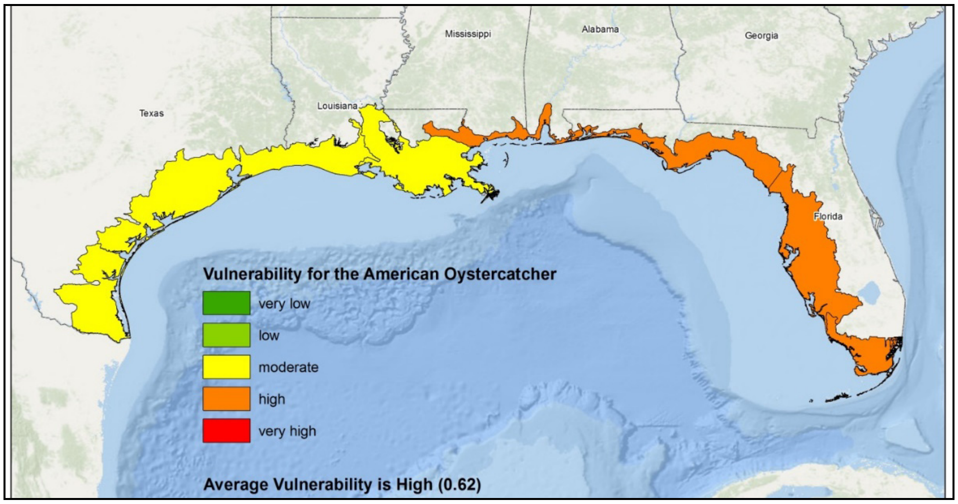


Figure 7.26. Vulnerability of American Oystercatcher

3. Black Skimmer (Fig. 7.27)

Black skimmers were judged to be highly vulnerable in the Southern Coastal Plain of eastern Louisiana. The most serious threats were low adaptive capacity, SLR, storm surge and runoff, synergistic effects of climate change, SLR and urbanization, and changes to the natural disturbance regime.

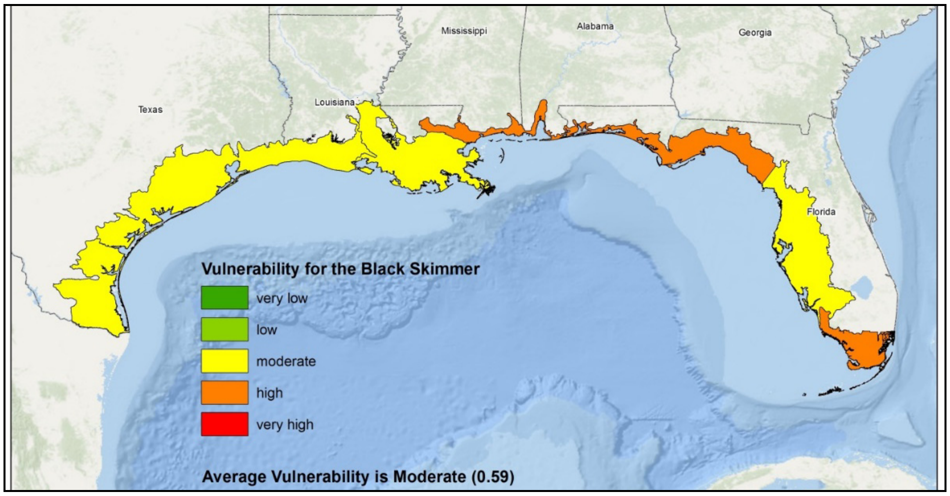


Figure 7.27. Vulnerability of Black Skimmer

4. Wilson's Plover (Fig. 7.28)

Wilson's Plovers were judged to be highly vulnerable in the Southern Coastal Plain of eastern Louisiana. The most serious threats were judged to be loss of habitat to SLR, impacts from storm surge and runoff, synergistic effects of climate change, SLR and urbanization, and changes to the natural disturbance regime.

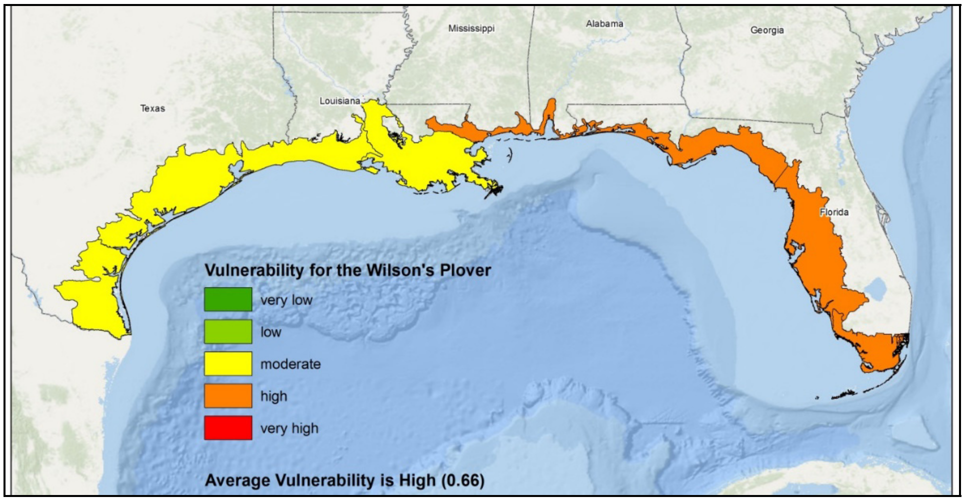


Figure 7.28. Vulnerability of Wilson's Plover

d. Intended Use of the GCVA

The GCVA was intended to be used in the following way:

- Allow for regional coordination of adaptive management plans with the potential to maximize the efficacy of limited conservation funding;

- Focus management actions to address the most vulnerable species and ecosystems and identify the threats to such species and ecosystems;
- Inform state actions (e.g., WAPs) and link state action with regional conservation efforts;
- Identify research gaps.

4. Evaluation of Regional Sea Level Affecting Marshes Model (SLAMM)

The Gulf Coast Prairie Landscape Conservation Cooperative (LCC) funded the Evaluation of Regional Sea Level Affecting Marshes Model (SLAMM) project. The main objectives were to generate a "seamless set of landcover projections for the Gulf of Mexico coast using SLAMM" and to conduct a focal species analysis using SLAMM results (Clough 2015). The principle investigator was Jonathan Clough of Warren Pinnacle Consulting, Inc.

a. Gulf-Wide SLAMM Summary

The project was comprised of 25 study areas across the Gulf of Mexico. Louisiana-specific model results were derived for two study areas, the Mississippi and Eastern Louisiana study area and the Louisiana Chenier Plain study area. SLAMM results were presented as Gulf-wide percent change in each land cover category (i.e., habitat type) over time and for each SLR scenario (0.5m, 1.0m, 1.2m, 1.5m, and 2.0m).

SLAMM predictions for irregularly-flooded marsh (i.e., high marsh) and estuarine beach indicated that these habitats were extremely vulnerable, with significant losses predicted by the year 2100 under all SLR scenarios (Clough 2015).

b. Focal Species Results

1. Seaside Sparrow

The Seaside Sparrow's habitat was considered to be regularly flooded marsh and irregularly flooded marsh areas with patches that were 10,000 acres or more in areal extent. Gulf-wide, the total combined habitat patch area dramatically decreases (~50%) by 2100 for all but the 0.5m SLR scenario (Fig. 7.29, Clough 2015).

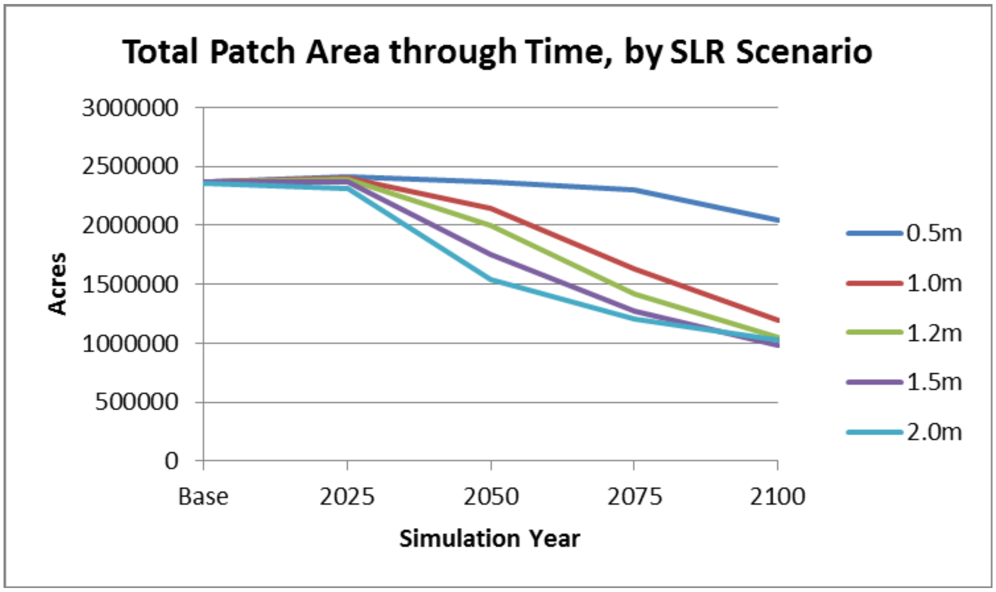


Figure 7.29. Trends in total area of all Seaside Sparrow habitat patches through time, by SLR scenario.

2. Mottled Duck

Mottled Duck habitat was considered to be inland fresh marsh, inland open water, non-salt estuarine marsh (comprising tidal fresh marsh, transitional marsh / scrub shrub, and irregularly flooded marsh areas), and estuarine open water. Mottled Duck habitat analyses were restricted to tidally-influenced classes so as to detect impacts from SLR. For the states of Texas, Louisiana, Mississippi and Alabama, the total patch area of non-salt estuarine marsh dramatically decreases (~50%) by 2100 for all but the 0.5m SLR scenario (Clough 2015). Conversely, the total patch area of estuarine open water showed moderate increases of 14-41% by 2100 depending on scenario (Clough 2015). The increases in open water habitat were attributed to the loss of estuarine beach, tidal flat and tidal marsh at lower elevations (Fig. 7.30, Clough 2015).

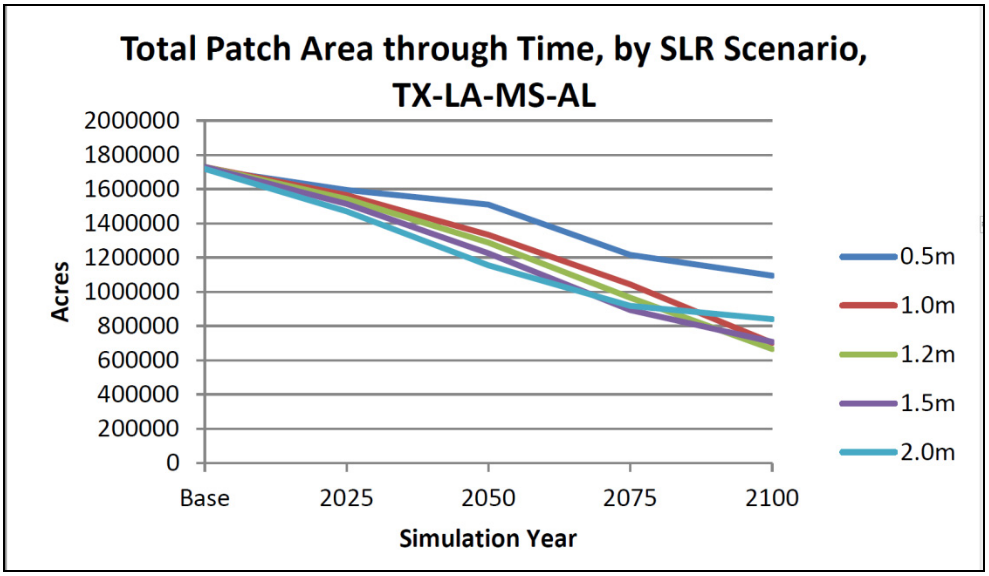


Figure 7.30. Trends in total area of Mottled Duck non-salt estuarine marsh habitat patches in the TX-LA-MS-AL region through time, by SLR scenario.

3. Black Skimmer

The Black Skimmer's habitat was considered to be estuarine beach and ocean beach areas. Gulf-wide, the trends in total patch area through time were "all negative and substantial," and corresponded in magnitude with the amount of SLR (Clough 2015). Habitat losses by 2100 ranged from 34-84% depending on the scenario (Fig. 7.31, Clough 2015).

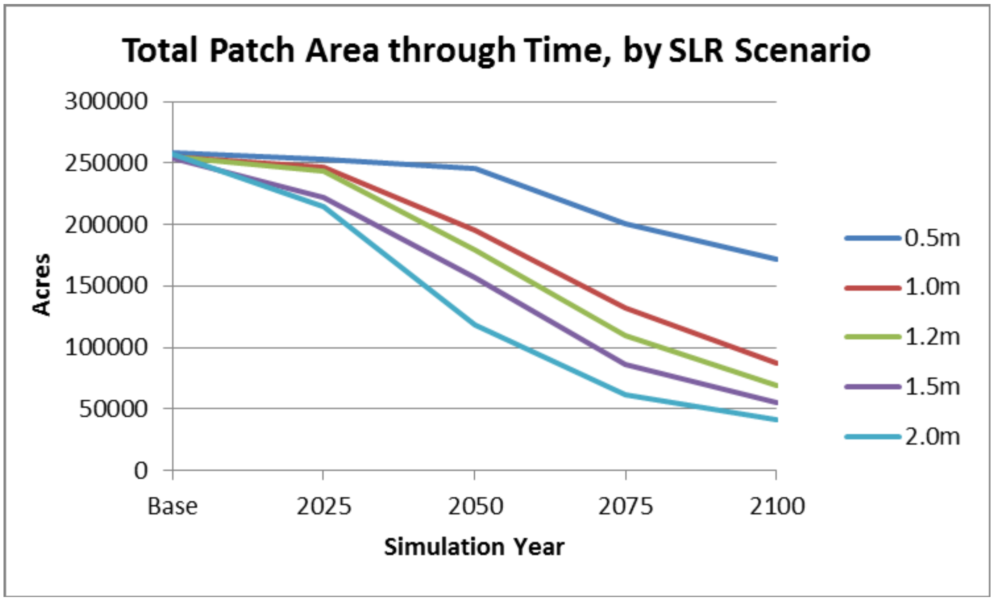


Figure 7.31. Trends in total area of all Black Skimmer beach habitat patches through time, by SLR scenario.

c. Intended Uses

The Evaluation of Regional SLAMM project is intended to provide a Gulf-wide perspective. The model predictions, such as marsh loss and conversion, may be used by state and federal policymakers and planners to determine proper adaptation strategies and to inform conservation efforts and land-use management.

D. Community Vulnerability

Although LDWF has not yet completed an assessment of the impacts of projected climate change on natural communities in the state, some predictions can be made based on other studies. As discussed, the GCVA found tidal emergent marsh, oyster reef and Barrier Islands highly vulnerable across Louisiana (Watson et al. 2015). Furthermore, SLAMM modeling reported that irregularly-flooded marsh (i.e., high marsh) and estuarine beach habitats were extremely vulnerable Gulf-wide (Clough 2015). Other sources have found that coastal habitats such as Barrier Islands and marshes are likely to undergo a decrease in both extent and quality (NABCI 2010). Coastal forests, including both Coastal Live Oak Hackberry Forest and Barrier Island Live Oak Forest are also predicted to be highly vulnerable to projected SLR, with potentially severe consequences for the migratory birds that currently utilize these areas for stopover sites.

As temperatures increase across the southeastern United States, there is predicted to be an increase in the intensity and frequency of wildfires (Melillo et al. 2014), which could result in an increase in fire-dependent communities, with a concurrent decrease in those communities that are intolerant of fire. Even those communities that are fire-dependent could be negatively impacted if the frequency or intensity of natural fires exceeds historical levels. Forested wetlands, including Bottomland Hardwood Forest and Cypress-Tupelo-Blackgum Swamps have the potential to become degraded as a result of increasing temperatures and altered hydrologic patterns (Brandt et al. 2014) that may result in longer periods of drying, or extended periods between inundations. Forest types that are predicted to have the lowest vulnerability to climate change include Eastern and Western Longleaf Pine Flatwoods Savanna and other open pine systems (Brandt et al. 2014). More closed forest types may shift towards savanna-like conditions as a result of drier, hotter conditions (McNulty et al. 2013) that lead to reduced tree density. Although drier conditions might favor native prairies and other grasslands, it has also been suggested that increased atmospheric CO_2 could lead to invasion of woody plants into such systems (NABCI 2010).

As discussed above, despite wide variation in precipitation projections, it is generally agreed that increased evapotranspiration will decrease available water regardless of how precipitation totals change, which could negatively impact both in-stream flow and groundwater recharge (Sun et al. 2013). Reductions of in-stream flow could lead to more frequent and longer periods of stream drying, potentially affecting intermittent and perennial streams (Hopkinson et al. 2014). Additionally, Ephemeral Ponds of all types are potentially at risk of reduction in extent and quality. Another concern related to reduced freshwater input is increased saltwater intrusion into coastal rivers and associated habitats such as Cypress-Tupelo-Blackgum Swamps. Such intrusion can lead to significant mortality of freshwater-adapted vegetation and greatly reduce the value of such habitats to fish and wildlife.

E. Louisiana's Climate Change Adaptation Strategy for SGCN and associated Habitats

As climate change continues, or potentially intensifies, it may not be sufficient to base future management decisions on either current or historical conditions. Failing to account for potential changes in natural communities, SLR, and impacts from human response to climate change could reduce the effectiveness of traditional conservation actions. However, the value of continuing traditional approaches to conservation should not be underestimated, as many of the best strategies for improving resilience to climate change are activities which LDWF and partners are currently engaged in. A philosophy and practice of adaptive management based on appropriate monitoring of our natural resources will provide heightened awareness to managers and society of ongoing changes that may otherwise go unnoticed during the gradual process of change.

The National Fish, Wildlife, and Plants Climate Adaptation Strategy (National Fish, Wildlife, and Plants Climate Adaptation Partnership 2012, (hereafter referred to as the *Strategy*)) presents seven major goals for climate change adaptation (Table 7.12), which will provide a framework for Louisiana's adaptation strategy. Each of these seven goals is consistent with the overall goals and objectives of the Louisiana WAP. Below is a brief discussion of each of the seven goals from the *Strategy*, including how each goal fits into the overall purpose of the WAP. It should be noted that each of the seven goals includes actions that would be conducted by LDWF and partners independent of climate change adaptation, and can therefore be expected to have value to fish and wildlife, regardless of whether or not climate change proceeds as projected.

Table 7.12. Crosswalk between the seven goals of the National Fish, Wildlife, and Plants Climate Adaptation Strategy (2012) and the goals and objectives of the Louisiana WAP.

Climate Change Adaptation Goal	LA WAP Goal(s)	LA WAP Objective(S)
Conserve and Connect Habitat	Goal 2: Habitat Conservation	2.1, 2.2, 2.3, 2.4., 2.5, 2.6
Manage Species and Habitats	Goal 1: Species Conservation	1.1,.1.2, 1.3
	Goal 2: Habitat Conservation	2.1, 2.2, 2.3, 2.4, 2.5, 2.6
Enhance Management Capactity	Goal 1: Species Conservation	1.3
	Goal 2: Habitat Conservation	2.1, 2.2, 2.5
	Goal 4: Partnerships	4.1, 4.2, 4.3
Support Adaptative Management	Goal 1: Species Conservation	1.3
	Goal 4: Partnerships	4.1, 4.2 .4.3
Increase Knowledge	Goal 1: Species Conservation	1.1
	Goal 2: Habitat Conservation	2.1, 2.2, 2.3
	Goal 4: Partnerships	4.2, 4.3
Increase Awareness and Motivate Action	Goal 3: Public Outreach/Education	3.1, 3.2
Reduce Non-Climate Stressors	Goal 1: Species Conservation	1.2, 1.3
	Goal 2: Habitat Conservation	2.1, 2.2, 2.3, 2.4, 2.5, 2.6

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

To maintain populations of all fish and wildlife, including SGCN, it will become more important than ever before to conserve a variety of habitats, and to improve connectivity between protected areas to enhance the ability of wildlife to move in response to changing conditions. Continuing current efforts towards habitat protection, restoration, and the establishment of corridors will be crucial to achieving this goal. Such efforts may not be enough however, as future conditions should also be considered when planning and implementing habitat conservation. For example, it might be beneficial to proactively protect forested lands inland of current migration stopover sites, to ensure the continued availability of such habitat when current stopover habitat is lost. Additionally, the identification of Conservation Opportunity Areas (COAs, see Chapter 8) will allow LDWF and partners to prioritize both land acquisition and the establishment of corridors under changing conditions.

Goal 2. Manage species and habitats to protect ecosystem functions and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Continuing the efforts of LDWF and partners to responsibly manage both wildlife and wildlife habitat will continue to be important, and such management may become even more vital, if changing conditions lead to decreased habitat quality. Programs such as the Prescribed Burn Initiative that seek to restore ecosystem function should be continued and expanded to improve resistance of wildlife and natural communities to climate change. Climate change considerations should also be taken into account when updating management plans, as is being done for the WAP, as this will improve the ability of resource managers to effectively manage SGCN and their habitats. Furthermore, the climate change vulnerability scores may be used to prioritize SGCN in the future, as those that are more vulnerable to the impacts of climate change may require earlier or more substantial efforts to prevent population declines.

Goal 3. Enhance capacity for effective management in a changing climate.

To effectively continue and expand upon current management activities under changing conditions could require novel approaches to data collection and analysis, developing or modifying management techniques, and continuing and expanding collaboration. The first step towards this goal is increasing the awareness of resource managers to the potential challenges ahead, which this chapter is addressing. Additionally, expanding upon current partnerships and emphasizing conservation efforts that cross jurisdictional and political boundaries will enhance the capacity of all partners to address current and future conservation issues. Changes in climate will require a more landscape-scale oriented approach to wildlife conservation (Staudinger et al. 2012), leading to an increased need for conservation that crosses state and national borders (NABCI 2010). For Louisiana, this means that continuing and expanding current partnerships with neighboring states is crucial, as efforts within the borders of Louisiana may not be sufficient to ensure the future of Louisiana’s SGCN. For that reason, participation in landscape level conservation planning and delivery via membership in LCCs and Joint Ventures (JVs) is likely to become increasingly important, for both game species and SGCN. Additionally, cooperation with other states in the southeast will be more critical to the mission of LDWF in the years to come. Mechanisms of such cooperation, including the Southeastern Association of Fish and Wildlife Agencies (SEAFWA) Wildlife Diversity Committee, as well as Southeastern Partners in Amphibian and Reptile Conservation (SEPARC) and Southeastern Partners in Flight (SEPIF) should be maintained or expanded upon.

Goal 4. Support adaptive management in changing climate through integrated observation and monitoring and use of decision support tools.

Improving existing efforts to coordinate and integrate data collection, data management, and decision support tools (DSTs) will help with developing adaptive management strategies to adjust to changing conditions. The continuation and expansion of current wildlife monitoring programs (e.g., United States Geological Survey (USGS) Breeding Bird Surveys (BBS), Louisiana Amphibian Monitoring Program (LAMP), etc.) will be valuable in detecting any changes that may occur due to climate change. The development and use of decision support tools (DSTs), such as the East Gulf Coastal

Plain JV (EGCPJV) Open Pine DST, and the Gulf Coast Prairie (GCP) LCC Mottled Duck DST will also be a valuable tool for resource managers and policy makers. As new downscaled climate data become available, those data should be incorporated into support tools and other decision making processes. Finally, the success or failure of all conservation actions and planning efforts should be used to inform future actions.

Goal 5. Increase knowledge and information on impacts and responses of fish, wildlife, and plants to a changing climate.

Targeted research to fill data gaps for SGCN will continue to be a high priority, as the ability to predict responses to changing climatic conditions will be much improved with a better understanding of the current status, distribution, and limiting factors for SGCN. Increased coordination with partners will allow for time and funding to be better focused on shared priorities, maximizing the impact of research. Efforts to improve regional or sub-regional climate models could also be valuable, as better downscaled climate data could help inform conservation priorities at the state or regional level. Cooperation with other conservation stakeholders, specifically those that have expertise in regard to climate science, such as the USGS Southeast Science Climate Center, will be a necessity for meeting this goal.

Goal 6. Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate.

Climate change adaptation efforts will be most successful with buy-in from conservation partners, landowners, and the general public. Therefore, it could prove advantageous to incorporate information about the potential impacts of climate change into current outreach efforts, or to develop entirely new outreach products or methods. Coordination across jurisdictions could also be valuable, and could include such existing mechanisms as LCCs and JVs.

Goal 7. Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

In particular, the reduction of non-climate stressors is an important part of our approach to addressing the potential impacts of climate change, as this includes the conservation actions that LDWF and other conservation partners are currently undertaking in Louisiana to benefit SGCN and their habitats (see Chapters 4 and 5 for detailed lists of those actions). By continuing efforts to address conservation issues such as habitat fragmentation, invasive species, and natural system modification, the resiliency of SGCN and associated habitats can be increased, which will in turn decrease the potential negative impacts associated with changing climatic conditions. Among the most important strategies for improving the resilience of natural systems to climate change are restoring natural hydrological and fire regimes, as well as connecting existing and future conservation lands through the use of corridors (NABCI 2010). Carbon sequestration is another major strategy to mitigate the impacts of climate change by offsetting carbon emissions. Programs such as those administered by the Natural Resource Conservation

Service (NRCS) that retire agricultural lands from active production will be even more important, as doing so will increase carbon storage (NABCI 2010), potentially slowing the rate of climate change.

In the *Strategy*, there are multiple conservation actions listed to assist resource managers in attaining each of the seven goals. As many of those actions are consistent with the habitat and species conservation actions presented earlier in the WAP, similar detail will not be presented here. Also, implementing those actions in Chapters 4 and 5 of the Louisiana WAP will be of great benefit to Louisiana SGCN and their habitats, even if climate change does not occur at the rate or in the manner in which it is currently projected.

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