Species Status Assessment Report
for the
Cedar Key Mole Skink (*Plestiodon egregius insularis*)

Version 1.2

Cedar Key mole skink found on Seahorse Key. Credit: Melissa Lyttle/Audubon Magazine

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Cedar Key Mole Skink (*Plestiodon egregius insularis*)

EXECUTIVE SUMMARY

The Species Status Assessment (SSA) reports the results of the comprehensive status review for the Cedar Key mole skink (*Plestiodon egregius insularis*). For the purpose of this assessment, we generally define viability as the ability of the Cedar Key mole skink to sustain resilient populations in the natural coastal ecosystems over time. Using the SSA framework, we consider what the subspecies needs to maintain viability by characterizing the status of the subspecies in terms of its resiliency, redundancy, and representation (USFWS 2016, entire; Wolf et al. 2015, entire). This SSA Report provides a thorough assessment of biology and natural history and assesses demographic risks, stressors, and limiting factors in the context of determining the viability and risk of extinction for the subspecies. This process used the best available information to characterize viability as the ability of a subspecies to sustain populations in the wild over time.

The Cedar Key mole skink is a small lizard subspecies known to occur only on the islands of the Cedar Keys along a ten-mile section of Florida's Gulf Coast in Levy County. The Cedar Key mole skink is a small, shiny brown lizard with a pair of light, dorso-lateral stripes running the length of the body. This is the largest of the subspecies, approaching 15 cm (5.9 in) with the tail accounting for two-thirds of the length. The subspecies is semi-fossorial (adapted to digging, burrowing, and living underground) and cryptic in nature. The Cedar Key mole skink occurs in the beach berm and coastal hammock habitats; relies on dry, unconsolidated soils for movement, cover, and nesting; and needs detritus, leaves, wrack, and other ground cover for shelter, temperature regulation, and food (insects found in ground cover).

Preliminary genetic research on the five mole skink subspecies, including the Cedar Key mole skink, has recently identified at least three genetically distinct populations within the Cedar Key mole skink subspecies (Parkinson et al. 2016, entire). Currently, the range and abundance of these populations are unknown. However, it appears each of the three islands has a genetically distinct population, and each population's range may be restricted to the island of occurrence. The preliminary genetic evidence indicates that there is minimal to no interbreeding or connectivity between the three populations, and there is little genetic variation within the Cedar Key mole skink subspecies (Parkinson et al. 2016, entire). Stochastic passive dispersal of Cedar Key mole skink individuals, primarily via rafting (i.e. carried with floating debris and marsh vegetation wrack), is likely occurring at some level, but the degree and success to which this plays in establishing new populations on unoccupied islands is uncertain (Adler et al. 1995, pp. 535-537; Branch et al. p. 2003 p. 207; Losos and Ricklefs 2010, p.360 -361).

The Cedar Key mole skink has been found in low numbers on eight of the islands of the Cedar Keys. Historically (1951-1988), Cedar Key mole skinks were documented and collected from Cedar Key, Seahorse Key, and Way Key. Between 2000 and 2017, Cedar Key mole skinks have been documented from Cedar Key and Seahorse Key and also from five new island locations: Atsena Otie Key, Deer Island, North Key, Scale Key, and Snake Key; Way Key has not been

recently surveyed. Additional islands have been identified as having potential habitat but not been surveyed.

The primary stressors currently affecting the Cedar Key mole skink are sea level rise (SLR) and climate change-associated shifts in rainfall, temperature, and storm intensities. These stressors account for indirect and direct effects at some level to all life stages and the habitat and soils across the subspecies' range. The long-term trend in SLR at the National Oceanic and Atmospheric Association (NOAA) Cedar Key Station shows a 2 millimeter (mm) (0.08 in) increase of the mean high water line (MHWL) per year from 1914 to 2016. The Cedar Key mole skink utilizes the transitional coastal zone of the upland beach habitat (50 to 80 cm (20 to 31 in) above sea level) into the upland coastal maritime hammock habitat during all of its life stages, and these coastal habitats are susceptible to flooding, inundation, and saltwater intrusion from SLR and climate change-associated factors.

As part of the SSA, we geospatially assessed potentially available suitable habitat (beach berm, maritime hammock, and other suitable habitats) and soils (Orsino Fine, Paola Fine, Pompano Fine, Zolfo, Immokalee Fine) for the Cedar Key mole skink. The current total acreage of the available suitable habitat in the Cedar Keys is approximately 480 ha (1,173.5 ac), and the current suitable soils identified total approximately 315 ha (778.3 acres). Of this available suitable habitat, the eight islands where Cedar Key mole skink has been documented encompass 305 ha (752.9 ac). There are an additional 19 islands totaling 170 ha (420.6 ac) that have not been surveyed. It must be noted that while a strong correlation between available suitable habitat and soils and population resilience can be inferred, the certainty level of the inference is not sufficient for these habitat metrics to be used as a surrogate for skink abundance or presence. Of the 480 ha (approximately 1,200 acres) of available suitable habitat in the Cedar Keys, approximately 42% is located on two mostly developed islands (Cedar Key and Way Key), approximately 8% on undeveloped, privately-owned islands, and the remaining 50% on islands in public ownership including the Cedar Keys National Wildlife Refuge. Of the approximately 305 ha (752.9 ac) of available suitable habitat on skink occupied islands, approximately 60% is located on the two mostly developed islands, approximately 36% on islands in public ownership, and approximately 4% on undeveloped, privately-owned islands.

Currently, the Cedar Key mole skink subspecies has limited genetic and environmental variation (representation) within the Cedar Keys. Recent searches (since 2000) have added five additional islands to the three historical islands where Cedar Key mole skinks are documented to occur. Despite the subspecies' distribution across many islands, it should be noted that the overall distribution (redundancy) for this subspecies only occurs within the Cedar Keys. There are three identified populations and additional individuals (not yet identified into populations) occurring across separate islands; however, little information exists on the abundance or growth rate of these populations (resiliency). Observation data indicates low numbers within populations. The longest and most consistently surveyed area (1951 to present), Seahorse Key, indicates that all life stages and breeding and nesting are occurring in this area. Although available suitable habitat and soils that offer cover, nesting habitat, and food sources for the skinks exist across the range of the Keys, the Cedar Key mole skink may be experiencing stressors from SLR, storm surge, and flooding.

The current and ongoing climate change stressors of SLR and climate change-associated shifts in rainfall, temperature, and storm intensities are the most significant stressors to the Cedar Key mole skink future condition and status (Pearson et al. 2014, p. 217). As presented in the "current condition" discussion above, the rate of global SLR has been measured at approximately 3 mm (0.12 in)/year since 1993 (NOAA 2017e, p. 8) with the Cedar Keys experiencing a rate of approximately 1.8 mm (0.07 in) between 1914 and 2006 (NOAA 2017a, entire). However, this rate of global and regional SLR is projected not to continue in the future but will accelerate (Park and Sweet 2015, entire; NOAA 2017b, entire; Rahmstorf et al. 2015, entire; Zhang et al. 2011, entire).

To examine the potential future condition of the Cedar Key mole skink, three feasible future scenarios representing Best, Moderate, and Worst case were developed. These followed the Low, Medium, and High regional climate change SLR projections, respectively, that were developed by the United States Army Corps of Engineers (USACE) and used by the University of Florida (Univ. of FL 2015). These projections do not yet reflect National Oceanic and Atmospheric Administration modeling based on new increased SLR rate estimates (which are approximately 15% higher) (NOAA 2017b, entire). Suitable habitat for the eight islands with documented occurrence of the Cedar Key mole skink was analyzed to predict inundation from the three projections. The SLR projections predict inundation only and do not model the complex set of shifts that are anticipated to be triggered over time as the effects of sea level rise are experienced. Also, for all three future scenarios, the Intergovernmental Panel on Climate Change's description and likelihood of occurrence in the 21st century of extreme weather and climate events, including changes in temperature, precipitation, and storm intensity, were used (IPCC 2013, p. 7).

The subspecies' future condition is most influenced by the increased trend in SLR. The observed trend in SLR is currently meeting the high curve projected in 2009 global models, and the rate of SLR is also found to be accelerating (NOAA 2017b, p. 25; Carter et al. 2014, pp. 401-403; Park and Sweet 2015, entire). Based on the analysis that incorporated regional SLR projections, we expect loss of 13 to 20 percent (2040), 14 to 29 percent (2060), and 16 to 62 percent (2100) of the 305 ha (752.9 ac) estimated to be suitable habitat on the eight islands of occurrence.

To assess Cedar Key mole skink viability, we used the three conservation biology principles of resiliency, representation, and redundancy (Shaffer and Stein 2000, pp. 306–310). Briefly, resiliency supports the ability of the species to withstand environmental and demographic stochasticity; representation supports the ability of the species to adapt over time to long-term changes in the environment (for example, climate changes); and redundancy supports the ability of the species to withstand catastrophic events (for example, droughts, hurricanes). In general, the more redundant and resilient a species is and the more representation it has, the more likely it is to sustain populations over time, even under changing environmental conditions.

Resiliency

The Cedar Key mole skink may experience reductions in population resiliency across all future scenarios due to SLR and climate change-associated factors. During historical and current survey efforts, the Cedar Key mole skink has been found in low numbers on eight islands in the Cedar Keys, and future occurrence data are expected to show similar (or reduced) numbers and distribution on these islands. However, there are an additional 19 islands with suitable habitat that have not been surveyed, and future survey efforts could find additional individuals or populations on these islands. Based on preliminary research, there are at least three genetically distinct populations and additional individuals (not yet identified into populations) occurring across separate islands; however, little information currently exists on the abundance or growth rate of these populations. When considering the subspecies' needs, there will be a reduction in suitable habitat from inundation which may lead to a reduction in population abundance and distribution. As ground cover becomes inundated or washed away, the Cedar Key mole skinks' ability to find cover, forage for insects, and nest in dry, unconsolidated soils will be reduced.

Redundancy
Despite the subspecies' occurrence across multiple islands, there are data gaps on the subspecies' actual range-wide distribution and abundance. Historically, the Cedar Key mole skink has been found in low numbers on three islands: Cedar Key, Seahorse Key, and Way Key. Recent surveys documented the subspecies from Cedar Key and Seahorse Key and from five new island locations: Atsena Otie Key, Deer Island, North Key, Scale Key, and Snake Key; Way Key has not been recently surveyed. As previously mentioned, there are multiple islands that have not been surveyed for the Cedar Key mole skink, and future surveys efforts could provide certainty into the actual range-wide distribution of the subspecies. Across all future scenarios, the Cedar Key mole skink may experience reduced redundancy. Due to SLR and climate change-associated factors, we expect some habitat loss and inundation across the known range of the Cedar Key mole skink, but we expect some level of redundancy to be retained due to the continued existence of 71 to 87 percent of the suitable habitat (under all except the 2100 SLR high projection (38% habitat) on the eight islands into the future.

Representation
The Cedar Key mole skink has limited genetic and environmental variation within the Cedar Keys, and there is no behavioral or morphological variation within the subspecies. The entire subspecies is represented from a chain of coastal islands within approximately 50 mi^2 range. The Cedar Key mole skink may experience reductions in subspecies representation across all future scenarios as suitable habitat on islands becomes inundated. This island subspecies occurs across a narrow geographic and ecological range, and there is no variation in habitat types. The Cedar Key mole skink is represented across only slight elevation differences across the separate islands. Many of the islands are less than 10 ft. in elevation but several of the larger islands with known populations of mole skinks have elevations that range from 15 to 50 ft. The larger islands may provide more persistent habitat due to larger island size, available habitat that can buffer flooding effects, and increased elevation.

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CHAPTER 1 - INTRODUCTION

The Cedar Key mole skink (*Plestiodon egregius insularis*) is a small, semi-fossorial lizard subspecies known to occur only on the islands of the Cedar Keys along a ten-mile section of Florida's Gulf Coast.   We, the U.S. Fish and Wildlife Service (Service), On July 11, 2012, we received a petition from the Center for Biological Diversity, C. Kenneth Dodd, Jr., Kenney Krysko, Michael J. Lannoo, Thomas Lovejoy, Allen Salzberg, and Edward O. Wilson to list 53 amphibians and reptiles, including the Cedar Key mole skink, as endangered or threatened species under the Act and designate critical habitat. On July 1, 2015, the Service published the 90-day finding, which determined that the petition contained substantial information indicating the Cedar Key mole skink may warrant listing (76 FR 59836). Therefore, a review of the status of the subspecies was initiated to determine if the petitioned action is warranted. Based on the status review, the Service will issue a 12-month finding for the Cedar Key mole skink.

We conducted a Species Status Assessment (SSA) to compile the best available data regarding the subspecies' biology and factors that influence the subspecies' viability. The SSA framework (USFWS 2016, entire) is intended to be an in-depth review of the subspecies' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Service's Ecological Services Program, from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document that may be used to inform Endangered Species Act decision making, such as listing, recovery, Section 7, Section 10, and reclassification decisions (the former four decision types are only relevant should the subspecies warrant listing under the Act).

Importantly, the SSA Report is not a decisional document by the Service; rather, it provides a review of available information strictly related to the biological status of the Cedar Key mole skink. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the Federal Register, with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the Cedar Key mole skink to sustain resilient populations in natural coastal ecosystems over time. Using the SSA framework (**Figure 1-1**), we consider what the subspecies needs to maintain viability by characterizing the status of the subspecies in terms of its resiliency, redundancy, and representation (USFWS 2016, entire; Wolf et al. 2015, entire).

Resiliency describes the ability of a population to withstand stochastic events (events arising from random factors). Stochastic events are those arising from random factors such as weather, flooding, or fire. Resilient populations are better able to withstand disturbances such as random fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), and the effects of anthropogenic activities. Generally speaking, populations need enough individuals, within habitat patches of adequate area and quality, to maintain survival and reproduction in spite of disturbance.

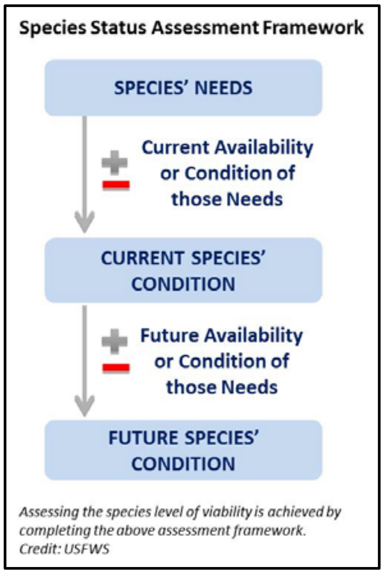


Figure 1-1. Species Status Assessment Framework

Representation describes the ability of the subspecies to adapt to changing environmental conditions over time. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the subspecies' range. Theoretically, the more representation the subspecies has, the higher its potential of adapting to changes (natural or human caused) in its environment.

Redundancy describes the ability of a subspecies to withstand catastrophic events. A catastrophic event is defined here as a rare, destructive event or episode involving multiple populations and occurring suddenly. Redundancy is about spreading risk among populations, and thus, is assessed by characterizing the number of resilient populations across a species' (or subspecies') range. The more resilient populations the subspecies has, distributed over a larger area, the better chances that the subspecies can withstand catastrophic events.

To evaluate the current and future viability of the Cedar Key mole skink, we assessed a range of conditions to characterize the subspecies' resiliency, representation, and redundancy (together, the 3Rs). This SSA Report provides a thorough account of known biology and natural history and assesses the risk of threats and limiting factors affecting the future viability of the subspecies.

This SSA Report includes: (1) a description of Cedar Key mole skink ecology (Chapter 2); (2) a description of needs at both population and subspecies levels and a characterization of the historical and current distribution of resilient populations across the subspecies' range (Chapter 3); (3) an assessment of the factors that contributed to the current condition of the subspecies and the degree to which various factors influenced viability (Chapter 4); and (4) an assessment and synopsis of the factors characterized in earlier chapters as a means of examining the future biological status of the subspecies (Chapter 5). This document is a compilation of the best available scientific information (and associated uncertainties regarding that information) used to assess the viability of the Cedar Key mole skink.

CHAPTER 2 – SUBSPECIES BIOLOGY

In this chapter, we briefly describe basic biological information about the Cedar Key mole skink, including its taxonomic history, morphological description, genetics, and life history traits such as reproduction, diet, habitat, and distribution. These life history characteristics provide an understanding of the individual needs for the Cedar Key mole skink.

2.1 Taxonomy

The Cedar Key mole skink (*Plestiodon egregius insularis*) is one of five distinct subspecies of the mole skink, all in the genus *Plestiodon* (previously referred to as *Eumeces*) (Brandley *et al.* 2005, pp. 387-388). Analyses of mitochondrial DNA were used to determine phylogenetic relationships among Scincidae lizards and found *Eumeces* to be polyphyletic (a group of organisms derived from more than one common evolutionary ancestor or ancestral group and therefore not suitable for placing in the same taxon) (Brandley et al. 2005, pp. 387-388). Following these analyses, the genus name *Plestiodon* was designated for all species, including *E. egregius*, of the North American / east Asian Eumeces + Neoceps clade (Brandley et al. 2005, pp. 387-388). Therefore, we find that the best available scientific and commercial information indicate the Cedar Key mole skink is within the genus *Plestiodon*.

The other four subspecies of mole skink are northern (*Plestiodon egregius similis*), peninsular (*Plestiodon egregius onocrepis*), blue-tailed (*Plestiodon egregius lividus*), and FL Keys (*Plestiodon egregius egregius*) mole skinks. They are all restricted to sandy soil environments in Florida, Georgia, and Alabama (**Figure 2-1**). The northern mole skink is the most wide-ranging and has been documented in Florida, Georgia and Alabama. The peninsular mole skink occurs throughout much of peninsular Florida. The blue-tailed mole skink is restricted to the Lake Wales Ridge in central Florida, and the FL Keys mole skink is restricted to the Florida Keys (Mount 1968, entire) (**Figure 2-1**). Mount (1965, entire) based the mole skink taxonomy on morphological characteristics of tail coloration, scale counts, and width of dorsal stripes. The Cedar Key mole skink has inconspicuous light stripes that neither widen nor diverge, ≤21 scale rows at mid-body, and a large size; tail color varies from dull, dark orange to maroon (Enge et al. 2017b, entire). Recent genetic research by the University of Central Florida Parkinson (Conservation Genetics) Laboratory indicates the Cedar Key mole skink subspecies is more closely related to the peninsular mole skink but also identifies a lack of interbreeding between the two subspecies (nor with the other three subspecies).

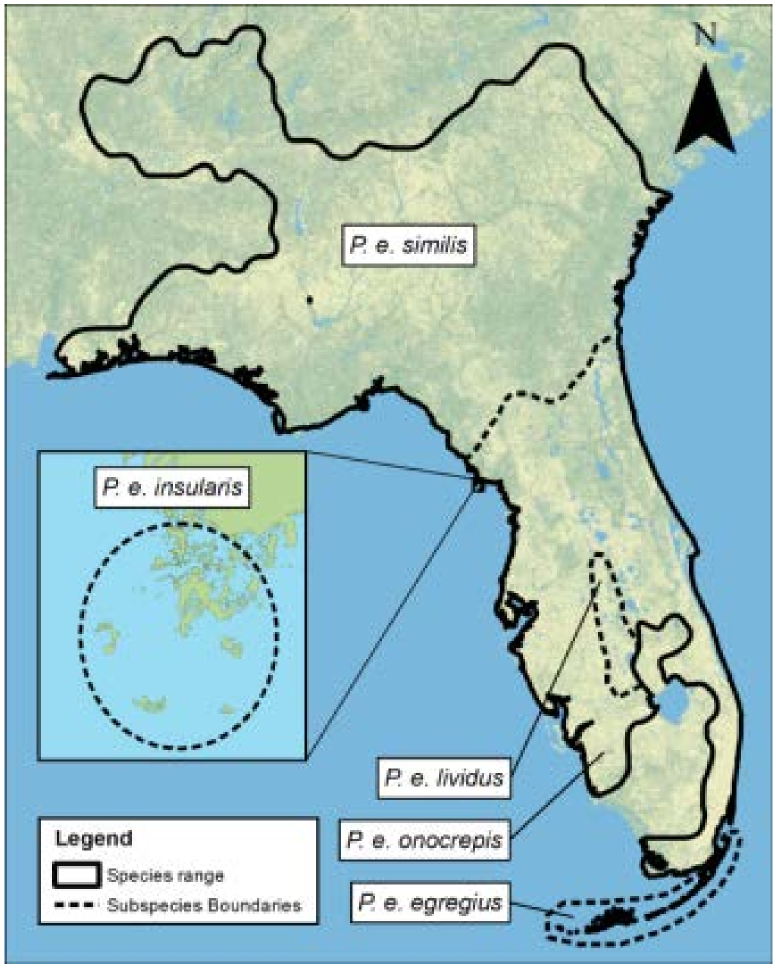


Figure 2-1. Mole skink species and subspecies range (credit: Kathryn Mercier, University of Central Florida 2017).

2.2 Description

The Cedar Key mole skink is a small lizard subspecies known to occur only on the islands of the Cedar Keys along a ten-mile section of Florida's Gulf Coast (**Figures 2-2 and 2-3**). This subspecies represents a unique genetic lineage that is genetically distinct from the other four mole skink subspecies (Brandley et al. 2005, pp. 387-388; Parkinson et al. 2016, entire). The Cedar Key mole skink is a shiny brown lizard with small, well-developed legs; a pair of light, dorso-lateral stripes running the length of the body; and a light pink colored tail. This is the largest of the five subspecies with adults reaching a total length of approximately 15 centimeters (cm) (5.9 inches (in)) with the tail accounting for two-thirds of the length.

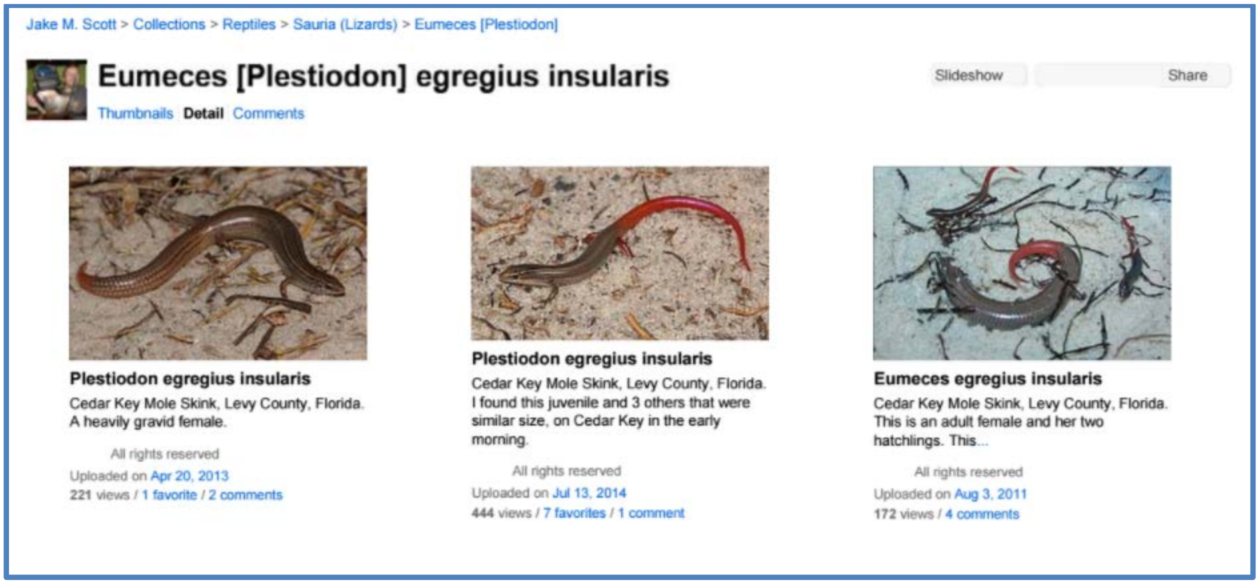


Figure 2-2. Cedar Key mole skink pictures.

Mole skinks are semi-fossorial (adapted to digging, burrowing and living underground) and are cryptic in nature. They can run but more often utilize "swimming" as a method to move in sandy substrate. The Cedar Key mole skink rely on ground cover over loose substrate as cover and the insects existing in this ground cover as a food source. In this case, "ground cover" as a resource for the Cedar Key mole skink, refers to, "leaf litter, debris, and tidal wrack" rather than a strictly vegetative ground cover such as grass. This subspecies needs detritus, leaf litter, tidal wrack, and other ground cover over loose substrate as cover and the insects existing in this ground cover as a food source. These ground cover and substrate conditions also provide reproductive and thermoregulatory refugia.

The Cedar Key mole skink is a cold-blooded (ectothermic) animal and therefore highly dependent on the air and soil temperature to thermoregulate (maintain body core temperature) (Mount 1963, p. 362). Ground cover moderates soil temperatures and provides shade to assist in the skinks' thermoregulation in the hot climate. Based on field studies by Mount (1963, p. 363), the optimum temperature range for the mole skink species (*Plestiodon egregius*) is 26 to 34 degrees Celsius(C) (78.8 to 93.2 degrees Fahrenheit [F]) with a mean of 29.5 C (85.1 F). The mole skink is a thermoconformer, lacking the capacity to adjust or regulate to changes in temperature outside of this stable and relatively narrow thermal range in which it occurs (Gallagher et al 2015, p. 62).

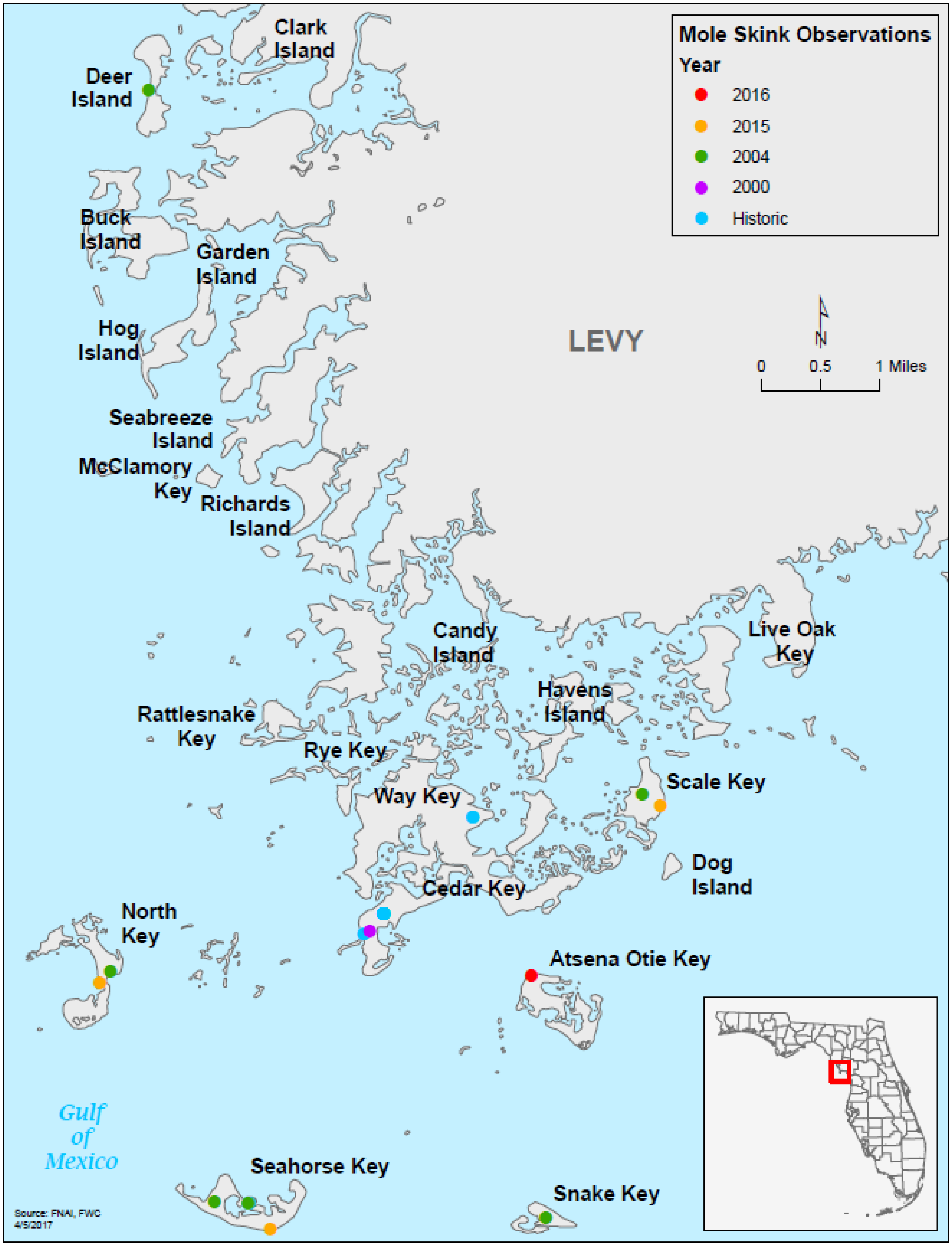


Figure 2-3. The Cedar Keys. Data points indicate current and historical observation/collection locations of the Cedar Key mole skink.

2.3 Genetics

Preliminary results of 22 samples from three islands where Cedar Key mole skinks have been documented have identified at least three genetically distinct populations (Parkinson et al. 2016, entire). Currently, the range and abundance of these populations are unknown. However, it appears each of the three islands has a genetically distinct population, and each population's range may be restricted to the island of occurrence. The preliminary genetic evidence indicates that there is minimal to no interbreeding or connectivity between the three populations and there is little genetic variation within the Cedar Key mole skink subspecies (Parkinson et al. 2016, entire). This research has also documented similar island population characteristics for the FL Keys mole skink subspecies. See Section 3.2.2 Population Structure for further information about population structure and genetic information.

2.4 Life History

The Cedar Key mole skink has three identified life stages: eggs, immature (juvenile), and adult. The immature stage is approximately one year from hatching to reproductively mature adult (fall of first year). Juvenile FL Keys mole skinks, another mole skink subspecies, have only been found in beach habitats. It is unknown if the life stages of the Cedar Key mole skink is limited to a specific habitat. It is important to note that locating and capturing mole skinks is difficult because of their small size, cryptic nature, and low abundance. Observations may reflect survey bias of the coastal system.

The generation time for the Cedar Key mole skink has not yet been documented. As such we look to a similar lizard species that occupies similar habitat in Florida that we have more ecological information and use as a surrogate for life history information. McCoy et al. (2010; pp. 641-642) used mark-recapture data to determine that 60 years represented 15 to 20 generations for the Florida sand skink (*Plestiodon reynoldsi*). The data illustrated that the previous estimate, based on the age at first reproduction, of generation length (30 to 37 generations in sixty years) for the Florida sand skink was underestimated (McCoy et al. 2010, p. 642-643). The age at first reproduction for the Cedar Key mole skink and the Florida sand skink are similar (twenty-four months compared to nineteen to twenty two months (McCoy et al. 2010, p. 641), respectively) and may suggest a comparable generation time of approximately one generation every three to four years.

The Cedar Key mole skink is under-surveyed and little is known about its life history. So the following description of life history is based primarily on red-tailed skink (*Eumeces* [now *Plestiodon*] *egregius*) work conducted in a laboratory setting (Mount 1963, entire). Scent is the most important factor in finding and selecting mates (Mount 1963, p.367). Mating typically takes place in fall or winter. This mating period has been observed for the Cedar Key mole skink by field biologists surveying for the subspecies (Technical Team Working Group 2016). After mating, the female enters a period of inactivity that last approximately one month (Mount 1963, p. 372). Eggs are laid under debris and usually in nest cavities. Female mole skinks den and attend their nests annually between April and June. The females lick, turn, and protect the eggs from predators. Research has shown that when any of these activities are prevented, the eggs are at risk of not developing normally (Mount 1963, pp. 376-377).

Soils used for nesting are generally dry and unconsolidated to allow for the digging of nest cavities and their "swimming" movement through the substrate. Nest depth is probably dependent upon substrate depth and is documented to vary greatly from 0.33 centimeters (cm) (0.13 in) to 1.83 meters (m) (6 ft.) (Hamilton and Pollack 1958, p. 27; Neill 1940, p. 266). Based on laboratory research, an individual skink lays a clutch of two to eleven eggs with an average of three to five eggs (Bartlett and Bartlett 1999, p. 195; Mount 1963, p. 376). Eggs incubate for thirty-one to fifty-one days (Mount 1963, p. 376). Age at maturity is unknown, but it can be inferred from the closely related blue-tailed mole skinks (*Plestiodon egregius lividus*) which bred for the first time in the fall of their hatch year in a laboratory setting (Mount 1963, p. 381). No in-situ nests have been identified for the Cedar Key mole skink. The Cedar Keys are low, sandy islands of dune origin. The Cedar Keys' unconsolidated soil types include Immokalee Fine, Orsino Fine, Paola Fine, Pineda Fine, Pompano Fine, Wekiva Fine and Zolfo sands and total only approximately 307.8 hectare (ha) (760.5 acres) of sandy soils known to be occupied by Cedar Key mole skinks.

In a central FL sandhill scrub habitat, Mount (1965, pp. 372-373) captured more *P. egregius* females with greater regularity than males during February and March and more males than females in November through January. The spring months coincide with a period of heavy foraging by females (Mount 1963, p. 373). The sex ratio for the Cedar Key mole skink is uncertain at this time. The sex ratio for the sand skink, which has similar breeding behavior to the Cedar Key mole skink, has been documented at a 1:1 ratio (Gianopulos, 2001, p. 23-24; Sutton 1996, p. 36).

2.5 Diet

The Cedar Key mole skink preys on a variety of small insects (Hamilton and Pollack 1958, p. 26; Mount 1963, p. 364; Technical Team Working Group 2016). Mount (1963, p. 365) examined the gut content of skinks from Cedar Key collected under tidal wrack and found almost entirely crustaceans. Amphipods were found in all specimens. One specimen had eaten a small fiddler crab. The only non-crustaceans found were two earwigs and a beetle larva. Mount (1963, p. 365) also examined gut contents of specimens from Seahorse Key under tidal wrack. He found no amphipods in any of the guts, but earwigs were in most of the specimens. Hamilton and Pollack (1958, p. 26) examined digestive tracts of thirty-six *Plestiodon egregius* subspecies and found crickets, beetles, termites, small bugs, mites, butterfly larva, pseudo scorpions, and fungus. The make-up of *Plestiodon egregius* subspecies diets has been shown to shift seasonally with prey relative to abundance. Prey is also thought to be caught and eaten underground (Mount 1963, p.365). Recent surveys and field work by species experts indicate generalist and opportunistic (preying on those insects that are present and are of size that the skink can ingest) feeding behavior of mole skinks within their ground cover habitat (Technical Working Group, 2016; Appendix B).

2.6 Habitat

The Cedar Key mole skink inhabits and utilizes the beach berm and dry coastal hammock habitats in the Cedar Keys. Mole skinks require, or highly prefer, loose soils (Christman 1992, p.

179). Loose, sandy soils allow for "swimming" mobility through substrate and are conducive to burrowing and nesting. Mount (1963, entire) identified the two key ecological factors affecting mole skink distribution as soil structure and moisture conditions. He seldom encountered mole skinks where the soil was not well drained and friable (Mount 1963, p. 359). Mount (1963, p. 359-361) found mole skinks along sandy shorelines beneath tidal wrack on Cedar Key and Seahorse Key. Most were found at or above the spring tide mark under wrack that was dry or mostly dry. Mount also found several skinks under piles of dead grass at the airport (Mount 1963 p. 360-61). Recent surveys by Florida Fish and Wildlife Conservation Commission (FWC) and others have documented mole skinks along the dry beach berm habitat (above the high tide) under dry wrack and other vegetative debris (Enge, pers. comm. 2017).

As part of the SSA, we geospatially assessed potentially available suitable habitat (beach berm and maritime hammock) and soils (Orsino Fine, Paola Fine, Pompano Fine, Zolfo, Immokalee Fine) for the Cedar Key mole skink. The current total acreage of the available suitable habitat in the Cedar Keys is approximately 480 ha (1,173.5 ac), and the current suitable soils identified total approximately 315 ha (778.3 acres). This includes the eight larger islands (752.9 acres) where Cedar Key mole skinks have been documented, twelve unsurveyed islands 133.3 ha (329.4 acres) with potential mole skink habitats, and seven other smaller islands (**Table 2-1**).

2.7 Dispersal and Home Range

There is a high confidence level among the herpetological experts that juvenile skinks newly establish a territory or home range away from their parents (Technical Team Working Group 2016). Direct evidence is lacking on the Cedar Key mole skink home range distance. Schrey et al (2011, p. 63) showed that sand skinks (*Plestiodon reynoldsi*) that were captured within 25 m (82 ft.) of each other were genetically more similar (statistically significant) than other individuals who were beyond that distance. Because genetic differentiation requires time to become develop, it shows a pattern of behavior in which individuals interbreed within 25 m (82 ft.) of each other. In this study, the maximum distance used for captures was limited to 25 m (82 ft.). Mushinsky et al. (2001 p. 55) found that adult female sand skinks had an average dispersal distance of 23 m (75 ft.).

Maximum dispersal distances for sand skinks (*Plestiodon reynoldsi*) in Florida scrub habitat have been documented at 35 m (115 ft.) upwards to 140 m (460 ft.) although just a few adults were recorded at distances greater than 100 m (328 ft.) (Gianopulus 2001, p.81; Mushinsky et al., 2001, p. 54). The larger home range distances of a few individual sand skinks beyond 100 m (328 ft.) could be attributed to localized resource limitations or adult "floaters".

As mentioned, the dispersal distance or typical home range for Cedar Key mole skink individuals has not been yet been studied but it is expected that the mole skink home range is similar to that documented for the sand skink. The overall high population structure found in the mole skink (five Florida subspecies) also supports limited dispersal for individuals of these subspecies (Adler et. al. 1995, p. 535; Branch et al. 2003, p. 2007). In general, males skinks are expected to have a slightly longer dispersal range than females to search for mates. Female skink dispersal distances are likely lower than the males as they need to have soils for nesting, and remain with the nest.

Table 2-1. Cedar Key mole skink available suitable habitat and sandy soils of the islands of the Cedar Keys. This table was derived from two independent GIS data sources (Florida Natural Areas Inventory Cooperative Land Cover Version 3.2 2016 and USDA Natural Resources Conservation Service Soil Survey of Levy County (U.S. Department of Agriculture 2016)) and confirms the upland, habitat types, and soil types are similar in acreage.

CEDAR KEYS (1,200 acres)	**SUITABLE HABITAT** (1,173.5 acres)	**SANDY SOILS** (778.3* acres)
Occupied Islands	(752.9 acres)	(665.0 acres)
Atsena Otie Key	52.2	54.8
Cedar Key	326.0**	305.4**
Deer Island	34.9	5.4
North Key	48.5	34.5
Scale Key	34.7	6.0
Snake Key	13.9	15.1
Seahorse Key	57.1	60.1
Way Key	185.6**	183.7**
Unsurveyed Islands	(329.4 acres)	(96.2 acres)
Buck Island	7.6	8.0
Candy Island	2.9	0
Clark Island	75.6	0
Dog Island	2.4	0
Garden Island	2.9	0
Havens Island	25.2	10.0
Hog Island	24.8	11.6
Live Oak Key	45.9	41.2
McClamory Island	7.8	0
Rattlesnake Key	5.2	0
Richards Island	54.5	11.8
Seabreeze Island	74.6	13.6
Other Islands	(90.87 acres)	(17.1 acres)
Deadman's Key	0.77	no data
Derrick Key	0.55	no data
Gomez Keys	3.7	no data
Grassy Key	0.43	no data
Horse Island	0.85	0.0
Long Cabbage Island	1.2	0.0
Raleigh Islands	86.7(check)	17.1

**Developed islands.

Home range and maximum dispersal distances have been based on the findings of individual skinks. The total size of an area needed to support a population of skinks has not been defined. Rafting as a dispersal mechanism is known to play a role for immigration/emigration of skinks to new locations or other islands (Adler et al. 1995, p. 535-537; Branch et al. 2003, p. 207). The degree and success to which this mechanism plays on the Cedar Key mole skink in establishing new populations on unoccupied islands is uncertain.

2.8 Size Distribution and Density

Gianopulos (2001, p. 26) found no statistically significant differences in size distributions of sand skinks (adult versus juvenile) among sites in any given time of the year. However, three to five times more adult than juvenile sand skinks were captured during spring surveys (February thru March; using pitfall traps) (Gianopulos 2001, p. 24). This result may be a reflection of differences in abundance rather than or in addition to the motility and distribution between the two life stages. It is uncertain if such size distributions exist for the Cedar Key mole skink.

Density values for the Cedar Key mole skink across the landscape are unknown; however, the distribution of individuals is not expected to be uniform across the range or even within a localized area of suitable habitat. Also, as an island subspecies and based on historical and current observations, the Cedar Key mole skinks, it likely is an uncommon subspecies. Its overall abundance compared to that of mainland mole skinks is likely low.

For the peninsular mole skink (*Plestiodon egregius onocrepis*), one of the mainland subspecies, density values have been documented as high as 62.5 adults per ha (25 per ac) (Christman 1992, In: Moler 1992, p. 120). Notably, however, even in what was apparently suitable habitat, the mole skink showed limited dispersal, and individuals were “concentrated in more localized pockets” (Christman 1992, In: Moler 1992, p. 120). A similar clumped distribution is expected to exist for the Cedar Key mole skink. The presumed limited range of individual skinks and the patchy distribution of the suitable habitat throughout the Cedar Keys is likely resulting in a clumped distribution for the Cedar Key mole skink subspecies (although in low abundance).

In a comparison of density values, the more common Florida sand skink has an average density of 163 per ha (per 2.5 acre), and individual sand skinks were found 20 times more frequently in field collections than blue-tailed mole skinks (*Plestiodon egregius lividus*), a rare and related subspecies of the Cedar Key mole skink (Christman 2005, p. 12; Christman 1992, In: Moler 1992, p. 120).

CHAPTER 3 - POPULATION AND SUBSPECIES NEEDS

In this chapter, we consider the Cedar Key mole skink's historical distribution, its current distribution, and the ecological needs at the population and subspecies level. We first review the historical and current information on the range and distribution of the subspecies. Then, we evaluate population and subspecies' ecological needs to consider their relevant influence on Cedar Key mole skink resiliency, representation, and redundancy.

3.1 Range and Distribution (Historical and Current)

The Cedar Key mole skink has been found in small numbers on eight of the islands of the Cedar Keys (**Figure 2-3**). This coastal complex of islands, tidal creeks, bays, and salt marsh is located along 10 miles of Florida's central Gulf of Mexico coast in Levy County; 60 miles north of Tampa and 50 miles southwest of Gainesville. The Cedar Keys occupy approximately 50 $miles^2$ of coastal habitats. Most of these sandy-soil islands are separated from the mainland and each other by salt marshes, bays, tidal creeks, channels, sand flats, mud flats and oyster reefs. The six offshore islands (i.e., Atsena Otie Key, Deadman's Key, Grassy Key, North Key, Seahorse Key, and Snake Key) are surrounded by waters of the Gulf of Mexico and range from 0.75 to 2 miles offshore of Cedar Key and are part of the Cedar Keys National Wildlife Refuge. This area of Florida's coast is micro tidal (tidal range of 73 cm (29 in)) and is considered to be a low-energy coastal environment relative to wave energy. The Cedar Keys are low, sandy islands. Many of the smaller islands have low elevation profiles (less than 10 feet); however, five of the eight islands where Cedar Key mole skinks have been documented have elevations greater than 15 feet (**Table 3-1**). The three islands where the Cedar Key mole skink were historically documented all have elevations greater than 20 feet. Seahorse Key has the highest elevation at 52 feet.

Historically (1951-1988), Cedar Key mole skinks were documented and collected from Cedar Key, Seahorse Key, and Way Key. Specimens from the earliest surveys are the basis for the taxonomic determination of this subspecies of the mole skink (Mount 1965, entire). Between 2000 and 2017, Cedar Key mole skinks have been documented from Cedar Key and Seahorse Key and also from five new island locations: Atsena Otie Key, Deer Island, North Key, Scale Key, and Snake Key; Way Key has not been recently surveyed. Additional islands have been identified as having potential habitat but not been surveyed. These include Buck Island, Candy Island, Clark Island, Dog Island, Garden Island, Havens Island, Hog Island, Live Oak Key, McClamory Island, Rattlesnake Key, Richards Island, and Seabreeze Island (Moler, pers. comm. 2017) (**Figure 2-3**).

Table 3-1. Islands where Cedar Key mole skinks have been documented or collected, island elevation, habitat acreage, and upland sandy soils acreage. This table was derived from two independent GIS data sources and confirms the upland and soil types are similar in acreage.

LOCATION	HIGHEST CONTOUR LINE (ELEVATION)	UPLAND HABITAT acres	UPLAND SAND SOILS acres
Cedar Key	25 feet	326.0	305.4
Way Key	35 feet (37)	185.6	183.7
Seahorse Key	50 feet (52)	57.1	60.1
Atsena Otie Key	20 feet (21)	52.2	54.8
North Key	15 feet (16)	48.5	34.5
Scale Key	5 feet	34.7	6.0
Snake Key	5 feet	13.9	15.1
Deer Island	10 feet	34.9	5.4
Total	5-50	752.9	665.0

From 1951-2016, there are 52 vouchered and unvouchered records for the Cedar Key mole skink (**Table 3-2**). These records come from eight of the islands within the Cedar Keys: Atsena Otie Key, Cedar Key, Deer Island, North Key, Scale Key, Seahorse Key, Snake Key, and Way Key (Mount 1963, entire; Mount 1965, entire; FWC, unpublished data 2017). All records since 2001 have been from opportunistic surveys. As part of a summer Island Ecology college course, an annual opportunistic survey has documented the presence of Cedar Key mole skinks in association with the dry beach berm habitat and wrack material on Seahorse Key each summer from 2001to present (Sheehy pers. comm. 2017).

Table 3-2. Location and year of historical and recent observations of the Cedar Key mole skink.

Location	**Year (number of specimens or observations; U = unknown)**
Cedar Key	1951 (12); 1952 (12); 1954 (2); 1959 (1); 1960 (22); 1962 (1); 1965 (6); 1968 (1); 1971 (5); 1973 (U); 2000 (U);
Way Key	1952 (1); 1954 (2); 1988 (U);
Seahorse Key	1960 (18); 1972 (U); 2004 (1+); 2015(U); 2001-2017 (Sheehy) (U)
Atsena Otie Key	2016 (U)
North Key	2004 (U); 2015 (U)
Scale Key	2004 (U); 2015 (U)
Snake Key	2004 (U)
Deer Island	2004 (U)

Cedar Key and Way Key are mostly developed (see Section 4.2.2 Land Development and Conversion). Deer Island is privately owned and for sale and could be developed. The other occupied islands are undeveloped, in public ownership, and protected under the federal National Wildlife Refuge system. A total of thirteen islands are part of the Cedar Keys National Wildlife Refuge: Atsena Otie Key, North Key, Scale Key, Seahorse Key, Snake Key are occupied; and it is unknown if other Refuge islands are occupied: Candy Island, Cedar Point Key, Deadman's

Key, Linda's Key, Live Oak Key, and Richard's Island. It should be noted that some named islands/keys have multiple islands.

3.2 Needs of the Cedar Key Mole Skink Subspecies

In order to assess the current and future condition of the subspecies, it is necessary to identify the population and subspecies needs. As defined earlier, resiliency is the ability to withstand disturbances associated with population abundance and demography, genetic diversity, growth rate, and habitat quality (Schaffer and Stein 2000, pp. 305-310). Population resiliency is reflected by the quality of these factors and resources.

3.2.1 Population Needs

As part of the population needs assessment, we first identified and described the most influential factors representing the individual and population needs for the subspecies. The methods used to identify population needs included convening a Technical Team Working Group Workshop (2016), the use of published literature, unpublished reports, and data from current survey and taxonomic research projects.

Focused studies at the population scale have not been conducted on the Cedar Key mole skink. As mentioned, their cryptic nature makes sightings and captures of individual skinks difficult. Recent surveys have been opportunistic and are biased toward focused locations, on accessible islands with sandy beaches, and thus, population abundance, distribution, age class, or density cannot be confidently inferred at this time. Specific information on population carrying capacity, birth rates, and nesting success is lacking for this subspecies. Previously cited work on other mole skink subspecies has indicated the importance of suitable habitat, ground cover, insect food sources, and unconsolidated dry soils for meeting life history needs (breeding, feeding, cover, movement) of the mole skink. Therefore, due to the lack of specific information on population demographics, population needs and resiliency were assessed primarily through habitat quantity, habitat quality, and food resources. Specifically, the most influential population factors identified for defining population resiliency for the Cedar Key mole skink are:

- Coastal beach and maritime hammock habitat;
- Unconsolidated dry soils and sandy substrates;
- Ground cover/vegetation or wrack; and
- Arthropods and insects (food source found within the ground cover of the habitat).

A quantitative equation for habitat and soils as a surrogate for Cedar Key mole skink population size or abundance does not exist; however there is a high level of confidence among experts that as long as available suitable habitat and soils is present, populations are able to be supported in the system (Technical Team Working Group 2016). Considering the cryptic nature and inability to directly and easily observe or locate skinks, suitable habitat and soils are used as a guide for potential presence of the Cedar Key mole skink. These habitat metrics will be used as a factor in assessing population resilience. In other words, the amount of suitable habitat or soils on an island or at a site will not be directly associated to defining population abundance or occurrence.

While the presence of suitable habitat and sandy soils provides confidence that skinks are able to occur there, an immediate inference cannot be made that if there is suitable habitat then there will be skinks present. As an example from the FL Keys mole skink, biologists in the Florida Keys have completed 600 coverboard checks on Ohio Key resulting in no observations of FL Keys mole skinks at this location even though this site was selected to due to existing suitable habitat. This could also be the case for the Cedar Key mole skink on unsurveyed islands with suitable habitat. Due to the difficulty in locating the Cedar Key mole skink, it is also possible that the searches have not observed skinks that may be present. The availability of dry and unconsolidated soils (sand) is likely a limiting factor in nesting success for the subspecies across its range. Because these are cryptic and elusive animals, the availability of suitable habitat and soils, in total, is a vital factor for assessing population health and persistence of the Cedar Key mole skink.

3.2.2 Population Structure

Preliminary genetic research on the five mole skink subspecies, including the Cedar Key mole skink, has recently identified at least three distinct populations within the Cedar Key mole skink. Tail samples were collected from 22 skinks captured during recent surveys of North Key, Seahorse Key, and Scale Key (Mercier, pers. comm. 2017b) (**Figure 2-3)**. A discrete genetic signature was identified at North Key, Seahorse Key, and Scale Key (Mercier pers. comm 2017); additional samples collected from other islands are still to be processed. It is important to note that these are only preliminary findings using very small samples sizes, and these are the only three locations from where samples have been processed. While the confidence level in identifying these populations is high, it is not the full picture of population structure. At this time, an inference cannot be made that these are the only populations or that individuals of these three populations only occur on these islands alone. The abundance and extent of these populations are unknown and there are other islands on which individuals occur that have not been associated with a population (Mercier, pers. comm. 2017b). Similar island population characteristics have been identified for the FL Keys mole skink.

Preliminary genetic evidence indicates that little to no connectivity or breeding is taking place between the identified Cedar Key mole skink populations, suggesting that the population structure of the subspecies is that of discrete, non-interbreeding populations (Parkinson et al. 2016, entire; Technical Team Working Group 2016; Mercier, pers. comm. 2017b). This population structure is supported by the relatively limited dispersal and small home ranges assumed for the Cedar Key mole skink.

Lizards have a history of being able to passively disperse by rafting (carried by floating debris and wrack) or floating from islands in the Caribbean and Pacific (Adler et al. 1995, pp. 535-537; Loso and Ricklefs 2010, p. 63), and experts think it is likely that some level of stochastic passive dispersal of individuals, primarily via rafting is occurring for this subspecies (Branch et al. p. 2003 p. 207). Possible stochastic events leading to rafting or passive movement of skinks include a) inundation and flooding of inland areas from strong seasonal storms and hurricanes that move debris or soils, and b) high tides and coastal storm surge that collect and carry wrack and vegetative debris (**Figure 3-1**). Distances between these identified populations are relatively close: North Key to Scale Key (4.0 miles), North Key to Seahorse Key (2.0 miles), and Seahorse

Key to Scale Key (4.0 miles). Distances between all islands that have Cedar Key mole skinks range from 0.05 miles between Cedar Key and Way Key to 6.0 miles between Way Key and Deer Island. Individuals may be rafting from one island to another with enough frequency to maintain some interaction among the populations but still at a level low enough that the populations remain distinct (Cronin, 2003, p. 1186; Smith and Green 2005, pp. 111-113). It should be noted that several of the occupied islands are within 1.5 to 2.5 miles of sandy-soil habitat on the mainland of Florida, thus providing a potential path for rafting or passive movement of Cedar Key mole skinks to the mainland (**Figure 3-2)**. Additional surveys and genetic research are needed for this area to determine if there is a genetic transgression zone between the Cedar Key and peninsular mole skink subspecies.

Rafting as a dispersal mechanism is known to play an important role for immigration of individuals to other islands but the degree and success to which this plays in establishing new populations on unoccupied islands is uncertain (Adler et al. 1995, p. 535-537; Branch et al. 2003, entire). In the Cedar Keys, there are numerous islands in relative close proximity to one another so that distance is not a huge barrier to reaching new ground. However, successful colonization of an unoccupied island would require a mating pair or a gravid female to reach and become established. The level to which the subspecies can rely on this strategy to assure or even contribute to future persistence is uncertain and believed to be low.

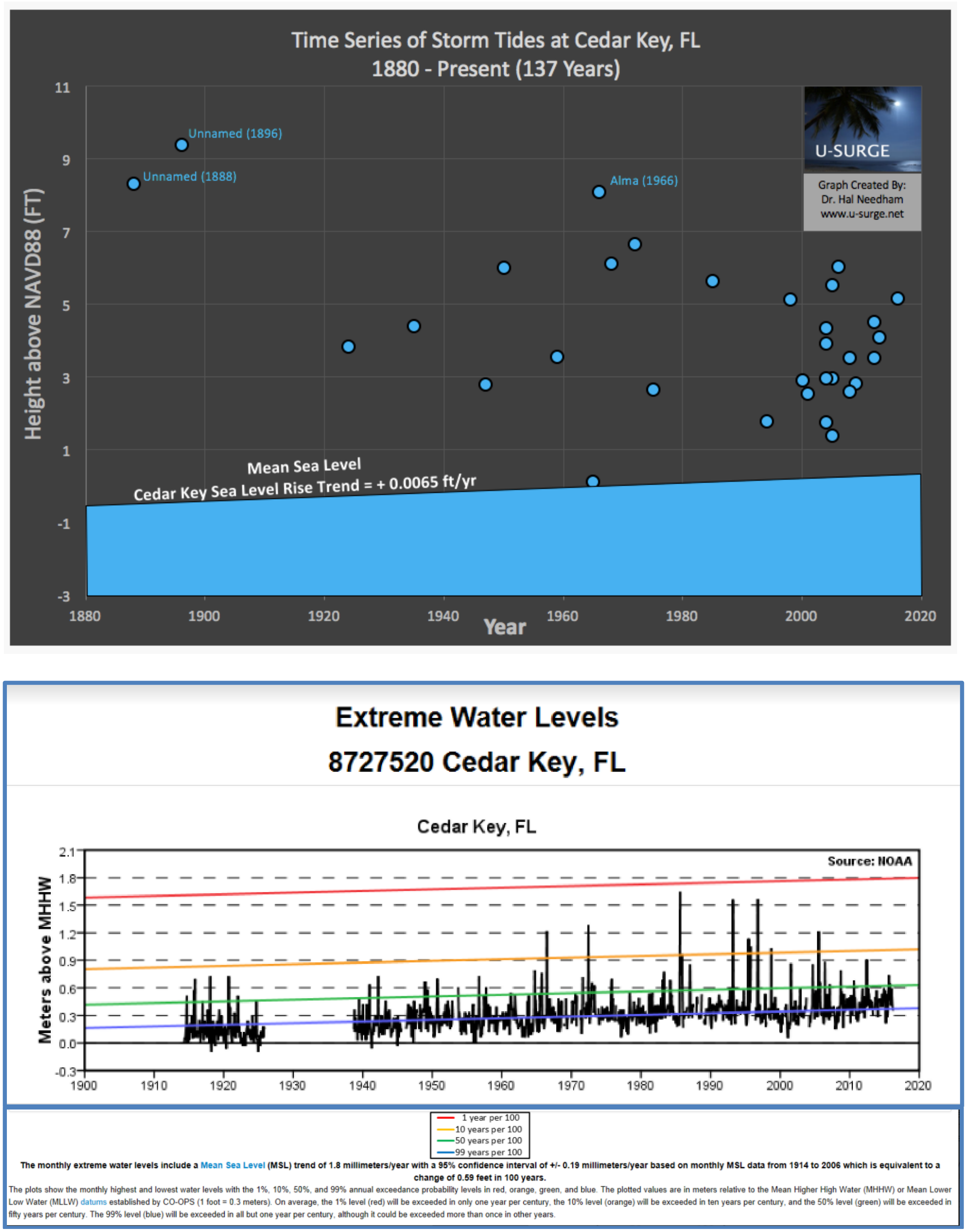


Figure 3-1. Storm surge events associated with storm events at Cedar Key since 1880. (https://www.u-surge.net/cedar-key.html) and Cedar Key (1900-2017) NOAA tidal gauges (NOAA 2017a).

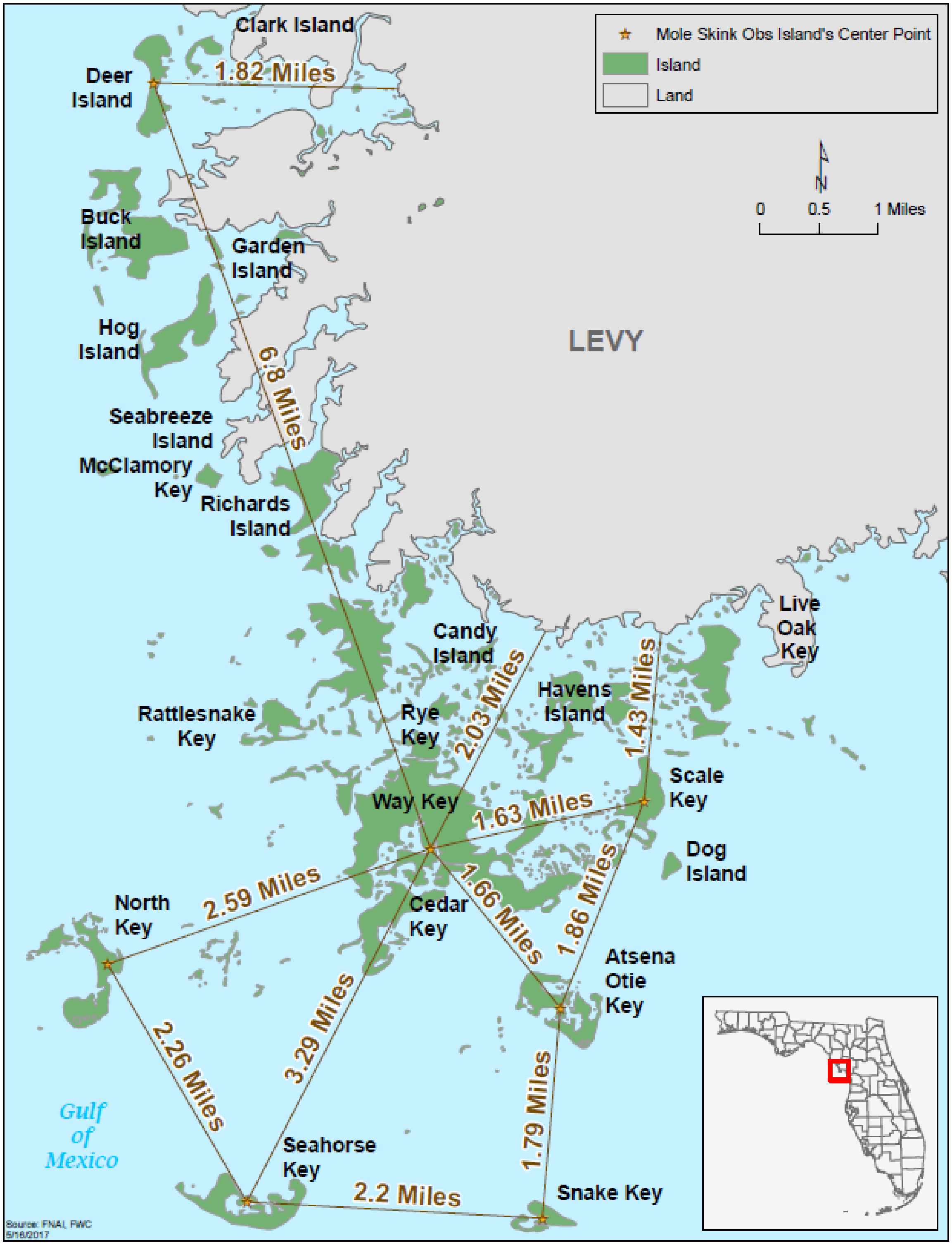


Figure 3-2. Distances between islands occupied by Cedar Key mole skinks and also distances to the mainland.

Based on preliminary genetic evidence, the Cedar Key mole skink's population structure is a set of multiple, non-interacting populations on separate islands. Additional information may find that its structure is some form of a classic metapopulation – with population extinctions and recolonization of new immigrants – to the degree that there are interactions (immigration and emigration of individuals) between islands.

The following are descriptions of the islands in which genetically distinct populations have been identified:

North Key – With approximately (49 ac) of upland habitat, North Key is the northern offshore island of the Cedar Keys and is one of the thirteen islands that make up the Cedar Keys National Wildlife Refuge. It is located 2.0 miles southwest of Cedar Key, Levy County, Florida and is undeveloped. Suitable habitat for the Cedar Key mole skink on North Key consists of nearly (1.5 mi) of undeveloped beach shorelines and (48.5 ac) of hammock habitat. The highest elevation is 16 feet. There are approximately (34.5 ac) of sandy soils (**Table 2-1**).

Seahorse Key – Located 2 miles offshore of Cedar Key, Seahorse Key is the southernmost island of the Cedar Keys and is also one of thirteen islands that make up the Cedar Keys National Wildlife Refuge. There is a historic lighthouse and other associated structures which are located on the highest section of Seahorse Key which reaches 52 feet in elevation but the remainder of the island is undeveloped. Suitable mole skink habitat consists of nearly (1.6 mi) of undeveloped beach shorelines with 3.0 ac of dry sand beach 3.9 ac of beach dune, and 48.5 ac of maritime hammock. There are approximately (60.1 ac) of sandy soils (**Table 2-1**).

Scale Key – Located approximately a half mile northeast of Cedar Key separated by salt marsh and tidal creeks, Scale Key is one of thirteen islands that make up the Cedar Keys National Wildlife Refuge. Suitable mole skink habitat consists of nearly (1.6 mi) of undeveloped beach shorelines with 2.4 ac of dry sand beach, 0.25 ac of beach dune, 10.1 ac of coastal upland and scrub, 19.8 ac of maritime hammock, 7.2 ac of scrubby flatwoods and 2.8 ac of xeric hammock. There are approximately (6.0 ac) of sandy soils (**Table 2-1**).

3.2.3 Current Population Uncertainties and Unknowns

The following is a list of uncertainties for the Cedar Key mole skink populations:

- Current survey efforts are not throughout the subspecies' range. Many smaller and less accessible islands have not been surveyed.
- Population abundance and minimum viable populations; population trends (birth rate); sex ratio (may be 1:1); fecundity; nesting success; nest success (number of eggs which hatch out of total laid); minimum viable population; adult survival rates; carrying capacity.
- Level of connectivity between islands of the Cedar Keys and also to the mainland of Florida; relationship between distance and immigration; preliminary genetic evidence suggests more or less distinct, non-interbreeding populations despite some level of stochastic dispersal that takes place from rafting.

- Home range is unknown; Individual dispersal occurs but is considered limited (see earlier discussion in Individual needs).
- Juvenile dispersal is believed to occur in order to establish their own home range from adult but uncertain on movement distances. Lack of information on resource sharing or if any level of overlapping ranges take place on the landscape.
- Quantity or quality of cover needed to maintain optimum temperature range and other microhabitat conditions is undefined.
- Quantity or metric for insects (food source) needed in the landscape is undefined.

3.2.4 Cedar Key Mole Skink Subspecies Needs

The subspecies needs are similar to those that are identified at a population level: available suitable habitat, soils, ground cover, and food source. As well, at the subspecies level, there needs to be multiple healthy populations or a single abundant population occurring across the subspecies' range. There may be distinct, non-interbreeding populations at each island, or there may be some level of dispersal from rafting between some islands providing at least a small level of connectivity between individual of populations. Preliminary genetic sampling has identified at least three discrete (non-interbreeding) populations as described above but sampling on other islands in between or adjacent to these three islands has not been completed and may show some mixing or variation of genetics. The minimum number of viable (resilient) populations necessary to sustain the subspecies is unknown. As an island subspecies, the relatively small, patchily distributed islands can each support only a small number of individuals (or separate populations). The distribution of suitable habitat and soils across the subspecies' range are necessary to support skink populations. The level of redundancy (distribution) operating within a subspecies is determined by the resiliency (abundance and health) of its populations.

CHAPTER 4 – FACTORS INFLUENCING VIABILITY AND CURRENT CONDITION OF THE SUBSPECIES

After identifying the most influential individual, population, and subspecies needs for the Cedar Key mole skink, the current condition of the subspecies is evaluated. To determine the Cedar Key mole skink current condition, the existing stressors have first been identified. Each stressor is considered in terms of the scale, intensity, and duration and the impacts it is having on the subspecies and habitat across its life history stages. Some stressors may be affecting the subspecies at all life stages or all individuals or populations across the subspecies' range while others may be specifically affecting a single resilience factor, such as the amount of suitable habitat, or a specific life stage. Some stressors, while present and acting on individuals of the subspecies, may not rise to the level of affecting the subspecies or even population(s). Factors influencing current condition included both negative stressors as well as beneficial conservation actions. Consideration and analysis was also given to the cumulative effects of these factors on viability. The overall current condition is expressed in terms of population resilience, and subspecies redundancy and representation.

4.1 Methods

The most influential population resiliency factors were identified earlier under Section **3.2 Needs of the Cedar Key Mole Skink Subspecies**. Stressors and their cause and effect upon these factors and the subspecies as a whole were identified through 1) Technical Team Working Group discussion (December 2016), 2) published literature, and 3) unpublished reports.

The primary stressors (in order from greatest to least current effect on the subspecies) identified for the Cedar Key mole skink include:

- Sea Level Rise due to the effects of climate change
- Climate driven shifts in seasonal timing and amounts of precipitation and rainfall;
- Loss of habitat (due to development, conversion);
- Displacement or disturbance from human activities (tourism);
- Change in habitat characteristics (vegetative; mangrove);
- Direct impact – displacement or removal by predators (feral cats; fire ants);
- Hurricanes; stochastic events (high tidal inundation from storm surge; oil spills);
- Pesticides (primarily mosquito prevention spraying);
- Collection.

The identification of stressors and assessment of the current effect level of each stressor on the Cedar Key mole skink was accomplished through a specific Technical Team Working Group Workshop on Life History and Current Conditions in 2016, through continued discussions with Technical Team Working Group members, and through a Species Status Assessment Workshop exercise in 2017. The individual expertise of the Technical Team Working Group members including herpetology, coastal ecosystems, reptilian genetics, Florida meteorology and climate change, and ecosystem mapping contributed to identifying and addressing the current effects of these stressors on the Cedar Key mole skink. An influence diagram was developed to illustrate the stressors and their influence on habitat and demography (**Figure 4-1**). An exposure table was also produced to further examine the exposure of each stressor (or activity) on the skinks biology and habitat and the consequences (or effect) upon the skinks (Appendix C).

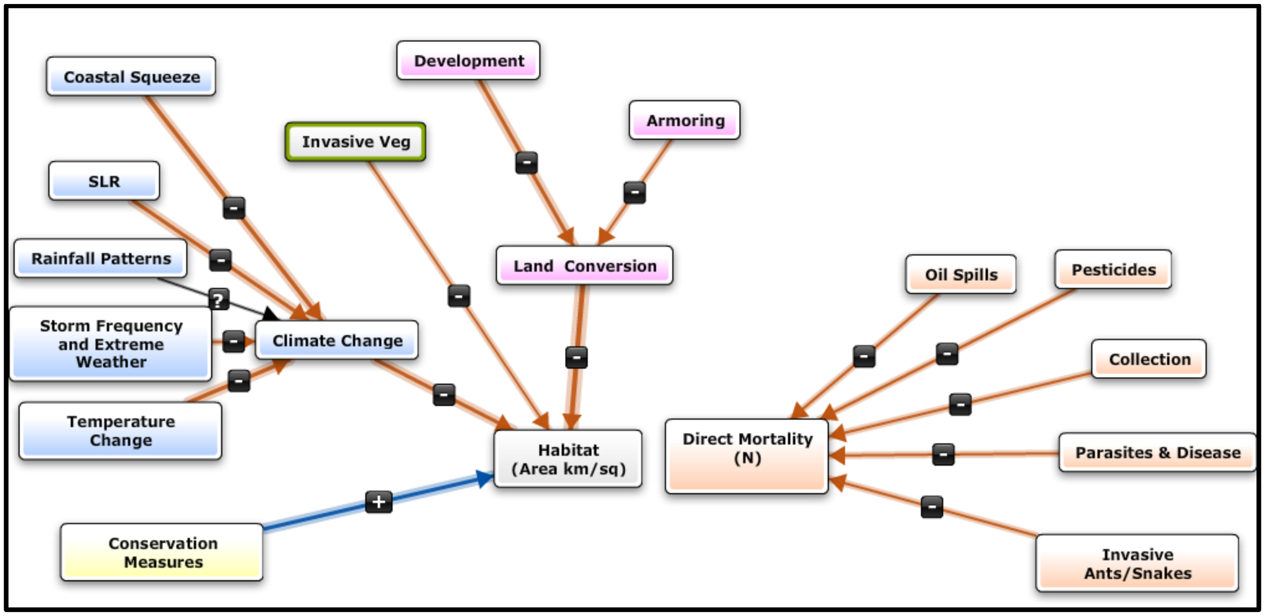


Figure 4-1. Influence diagram: factors influencing Cedar Key mole skink habitat and demographics.

4.2 Factors Influencing Viability

The Cedar Key and FL Keys mole skinks are both island subspecies of mole skinks and occur within island ecosystems. Detailed descriptions of some of the stressors for the FL Keys mole skink can be found in the biological status review (FWC 2011, p. 5) and species action plan (FWC 2013, pp. 3-5) and most hold true for the Cedar Key mole skink.

4.2.1 Climate Change

The predominant stressors currently affecting the Cedar Key mole skink and its habitat are the shifts in climate occurring as a result of increasing greenhouse gas emissions (GHG). The long-term persistence of the Cedar Keys, Florida Keys, and Florida's barrier islands is being challenged by rising sea levels and shifts in seasonal climate patterns. The main stressors affecting the Cedar Key mole skink and its habitat are sea level rise, increased storm surges, and shifts in seasonal patterns of rainfall and temperature.

The following scientific and ecological information on climate change includes summarized work by the National Climate Team and staff of the United States Fish and Wildlife Service (USFWS) from the 2014 publication entitled *Climate Change Impacts in the United States: The Third National Climate Assessment* (NCA) (Carter et al. 2014, entire). This team also summarized the 2013 publication from the International Panel of Climate Change (IPCC) entitled *Highlights of the IPCC 5th Assessment Report: The Physical Science Basis of Climate*

Change (WGI); Summary for Policymakers (IPCC, 2013, entire). This information is being further condensed with a primary focus on Florida (USFWS 2017, entire).

Sea Level Rise

The Cedar Key mole skink inhabits the islands of the Cedar Keys and utilizes the transitional coastal zone of the upland beach habitat (50 to 80 cm (20 to 31 in) above sea level) into the upland coastal maritime hammock habitat during all of its life stages. It relies on these coastal habitats for food, nesting, and shelter and this makes the subspecies especially vulnerable to current and predicted sea level rise across its entire range. The Cedar Keys are a low-lying set of sandy islands on Florida's central Gulf Coast. Many of the islands are less than 10 ft. in elevation but several of the larger islands with known populations of mole skinks have elevations that range from 15 to 50 ft. (**Table 3-1)**. The Cedar Keys area susceptible to flooding; even the islands' uplands are at risk of inundation and saltwater intrusion. These effects of rising sea levels (higher tidal surges, coastal flooding, and saltwater intrusion) are currently being experienced along Florida's Gulf Coast and the Cedar Keys.

Since 1880, global sea level has increased by 0.20 to 0.23 m (8 to 9 in.), and the rate of increase over the past twenty years has doubled (USFWS 2017, p. 5). An average 0.08 m (3 in) increase in overall global SLR has occurred between 1992 and 2015 (National Aeronautics and Space Administration Jet Propulsion Laboratory 2015, p. 2). This rise is equivalent to the Florida coastline subsiding at a rate of 0.04 inches a year (USFWS 2017, p. 6). The long-term trend in SLR at the National Oceanic and Atmospheric Association (NOAA) Cedar Key Station shows a 2 centimeter (cm) (0.08 in) increase of the mean high water line (MHWL) per year from 1914 to 2016 (NOAA 2017a) (Figure 6). Mean high water line is defined as "The line on a chart or map which represents the intersection of the land with the water surface at the elevation of mean high water (NOAA NOS 2017).

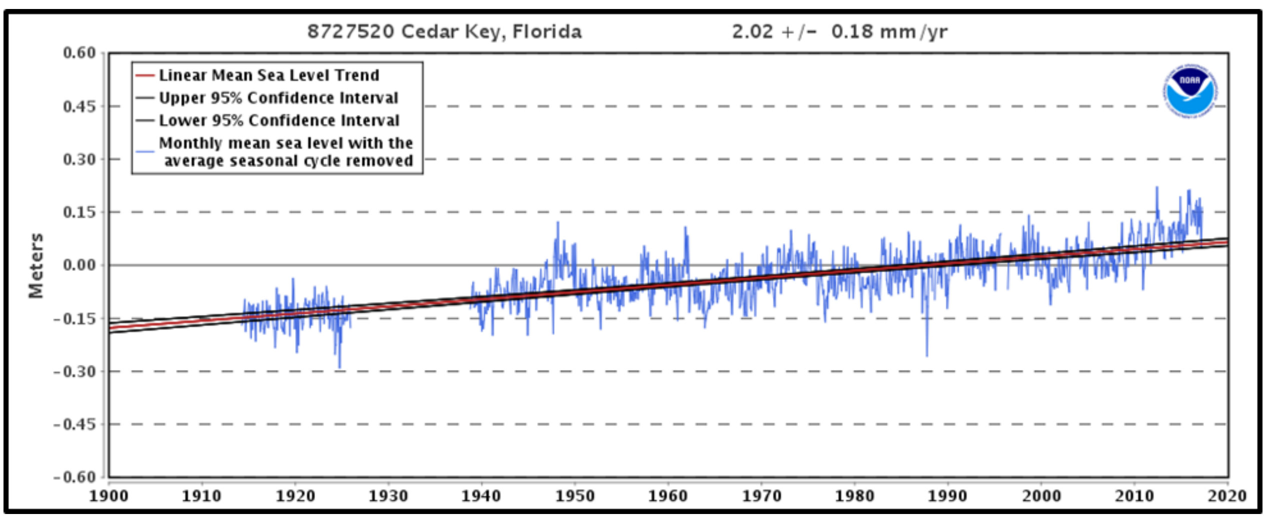


Figure 4-2. Mean sea level trend for Cedar Key (1900-2017) from NOAA tidal gauges (NOAA 2017a).

While the SLR rate for Florida has been equivalent to that experienced globally, recent analysis is now indicating an accelerated rate for the eastern United States and Gulf of Mexico above that of the global rate (NOAA 2017 b, p. 25; Carter et al. 2014, pp. 401-403; Park and Sweet 2015, entire). The global trend is currently on the higher-end trajectory of the scenarios, projecting a SLR of 2.5 to 3.0 m by 2100. NOAA (2017b, p. 21) is recommending the use of the higher end estimates for future projections. The accelerated sea level rise is being attributed to added ocean mass brought on by the melting Antarctic and Greenland ice packs, and thermal expansion from the warming ocean (Park and Sweet 2015, entire article; Rahmstorf et al. 2015, entire; NOAA 2017b, p14; Deconto and Pollard, 2016, p. 596). For this reason, it is now recommended to add approximately 15% to the earlier global mean SLR projections for the IPCC (2013, entire; Appendix D) when using projections for Florida if the projections used do not yet model the accelerated rate (Southeast FL Regional Climate Change Compact (Compact) 2012, p. 35; Park and Sweet, 2015, entire).

In 2011, the Cedar Key National Wildlife Refuge was 13% open water or tidal flat. By 2100, if 1 m of sea level rise occurs, 49% of the refuge will be tidal flat or open water. Also, 38% of beach habitat is predicted to be lost at the Cedar Keys Wildlife Refuge if 1 m (3.3 f) of sea level occurs by 2100 (Warren Pinnacle Consulting, Inc. 2011, p. 9).

Temperature

In the United States, the average temperatures have increased by 0.77 to 1.1 degrees C (1.3 to 1.9 degrees F) since record keeping began in 1895 (USFWS 2017, p. 2). The decade from 2000 to 2009 is documented as the warmest on record (since record keeping began in 1895) (USFWS 2017, p. 2). Temperature changes vary by region of Florida. Since 1991, average temperatures in south Florida have been greater than 1.5ºF; 1ºF to 1.5ºF in central Florida; 0.5ºF to 1ºF in northern Florida; and -0.5º to +0.5ºF over the Florida Panhandle (USFWS 2017, p. 2). Because of the current condition of human-induced emissions (that is, the pattern of continued release of GHGs added to those already occurring in the atmosphere), increases in surface air temperature continue to rise. Even if there was an immediate and aggressive reduction to all GHG emissions caused by humans, there would still be expected continued increases in surface air temperature due to the lag in response to GHGs by the Earth's system (IPCC 2013; pp. 19-20).

As mentioned in **Section 2.2 Description**, the optimum temperature range for the mole skink species (*Plestiodon egregius*), is from 26 to 34 degrees Celsius(C) (78.8 to 93.2 degrees Fahrenheit [F]) with a mean of 29.5 C (85.1 F) (Mount 1963 p. 363). Any continuously higher average number of hot days out of the skink's optimum range or a permanent shift in average air temperature out of this range, even by 0.28 degrees C (0.5 degrees F), can stress them physiologically or shift reproductive cues (Adolph and Porter 1993, p. 276). Increases in sand temperature (their surrounding habitat) would likely alter their movements and time spent under cover within the sands (Adolph and Porter 1993, p. 275-278, 290). It is uncertain about the level of specialization of the Cedar Key mole skink in its ability to accommodate to temperatures outside of its thermal range. This potential limiting coping ability to adjust to thermal stress outside of its temperature range increases the subspecies' susceptibility to the local and regional increases in temperature occurring with global warming (Gallagher et al. 2015, pp.61-63). The impacts from this stressor are based on the level and duration of thermal changes and the capacity for individual skinks to physiological or behaviorally accommodate these changes

Temperature-dependent sex determination (TSD) has been documented for most reptilian species but not all (a few reptiles have shown to not exhibit TSD or an environmentally determined sex ratio) (Bull 1980, p. 7). Recent work has indicated that both genetic and temperature-dependent sex-determination mechanisms co-occur and function interrelated in the lizard species *Pogona vitticeps* (Holleley et al. 2015, entire). The plasticity of this "dual system" implies a potential for this species to rapidly shift from what is a temperature- sensitive genetic mechanism (GSD) to a TSD mechanism under high incubation temperatures (Holleley et al 2015, p. 79-80). This transition or temperature override was found to evolve rapidly in response to high temperatures and resulted in the development of more females and the loss of mixed chromosomal offspring (Holleley 2015, pp. 80-81). How prevalent this rapid transition-response is in other reptilian species is uncertain. While no direct study of TSD or the transitioning of sex-determinant mechanisms in the mole skink exists, TSD has been identified in skink species in the same Family (Scicinidae) as the Cedar Key mole skink (Robert and Thompson 2009, entire; Ji et al. 2006, entire). Sarre et al. (2004, p. 640,642-643) proposed that the genetic and environmental sex determination mechanisms commonly co-occur and function as a continuum in reptile species. How the fluidity between these two mechanisms ultimately affects the fitness and genetic representation of a species is still unclear, but this mechanism is expected to be influenced by the increasing temperatures from climate change (Holleley et al 2015, p. 81; Bull 2015, p. 44).

Increased temperature above an optimal range and extreme high or low moisture conditions of sandy soils (a nesting substrate) will physically influence the environment of the Cedar Key mole skink nests in this substrate as well. It is likely that a shift to average higher sand temperatures would modify incubation periods, embryo temperatures, egg survival, hatching times, and possibly sex ratios of the Cedar Key mole skink (Packard et al. 1977, pp.75-82; Bull 1980, pp. 16-17; Warner and Shine 2008, pp.566-567; Van Damme et al. 1992, pp.224, 226).

Precipitation

Florida's precipitation patterns are changing (USFWS 2017, p. 4). The NCA reports that average precipitation in northeast and south Florida has increased by five to ten percent since 1900 and central and panhandle Florida regions have decreased by five to ten percent (Walsh et al. 2014, pp 32-35). Heavy downpours have increased over the last 30 to 50 years. There is currently a 27% increase in the frequency of heavy downpours in Florida since the 1970s (USFWS 2017, p. 4). Projections for central Florida are for wetter fall and winter seasons and dryer spring and summer seasons (Table 4-1). Impacts of wetter rainy seasons along with heavier rain events will include inundation, cohesion, and impaction of sandy soils which will impact the subspecies' ability to burrow and dig nests. While dry conditions are preferred, lack of rainfall could also be detrimental. Prolonged periods of drought could cause losses in vegetative cover and increase risk from desiccation.

Table 4-1: Climate model rainfall simulations using the CMIP5 models for regions within Florida, (USFWS 2017).

Florida Regions	Winter	Spring	Summer	Fall
Panhandle	0 to -10%	0 to +10%	0 to -10%	+10 to +20%
North Florida	0 to -10%	0 to +10%	-10 to -20%	+10 to +20%
Central Florida	0 to +10%	0 to -10%	-10 to -20%	+10 to +20%
South Florida	0 to +10%	0 to -10%	-20 to -30%	+10 to +20%

4.2.2 Land Development and Conversion

The habitat for the Cedar Key mole skink occurs as fragmented parcels on many of the islands of the Cedar Keys. The current amount of land mass, suitable habitat, and suitable soils for the Cedar Key mole skink was identified above in **Section 2.6 Habitat**. Two of the eight known to be occupied islands, Cedar Key and Way Key, are impacted by human development and are mostly developed. The remaining islands remain undeveloped and protected as part of the Cedar Keys National Wildlife Refuge. There are a couple of small islands that are privately owned or partially owned that remain undeveloped but could be developed. These areas provide habitat and soils for the Cedar Key mole skink (See **4.4 Conservation Actions** and **Table 2-1** for a more comprehensive list). While it is a relatively small coastal ecosystem of 30 or more islands of varying size and elevations, suitable habitat and soils remain which support the current known distribution of this subspecies on eight islands. There are an additional twelve islands that have been identified with potential habitat conditions that could support the Cedar Key mole skink and need to be surveyed. Also, several mainland Florida habitats, which are within 2 miles of currently occupied islands, have sandy soil habitats that should be surveyed and genetics assessed for an introgression zone between Cedar Key and peninsular mole skink subspecies.

Development

Levy County is rural with about 40,000 people living in the county's 1,412 square miles (Frank et al, 2014, pg. 47), or approximately 0.43 people per 0.4 ha (1 acre) (Carr and Zwick 2016, p. 29, 27). Relatively large areas of undeveloped land are projected to remain in Levy County (The 1000 Friends of Florida 2006, p.10). Levy County is expected to experience a "medium" growth in population, with an estimated 32% population increase (to 60,574 people) by 2070, from the 2010 estimates (40,473) in Levy County (Carr and Zwick 2016, p. 29).

There are close to 30 named islands in the Cedar Keys and only two are developed. Within Levy County, two of the eight islands known to be skink-occupied, Cedar Key and Way Key, have a combined population of approximately 700, which has remained the same for the past 30 years (Frank et al. 2014, pg. 81; Colson pers. comm. 2018). The two islands contain 42% (511 acres) of the approximate 1200 acres of suitable skink habitat in the Cedar Keys and are impacted by human development with more than half of the parcels already developed as residential and commercial units. Development and conversion of beach and coastal hammock habitat are capable of impacting all of the skink life stages. In addition to direct impacts from loss of soils for nesting and movement, ground cover and availability of the insect food sources found in the ground cover could be reduced. Of the 511 acres, the City of Cedar Key's inhabited areas encompass 411 acres of uplands, and the unincorporated areas of Cedar Key and Way Key occupy 100 acres. Of the 511 acres of suitable habitat on Cedar Key and Way Key, 308 acres contain 540 single family houses, 225 condominium units, 40 mobile homes, 5 multi-family parcels, 380 vacant residential parcels, and 34 commercial units/parcels; there are also 154 acres of roads and right of ways (utilities) including approximately 50 acres of an airport complex (Frank et al 2014, pg. 81, Service 2017, pg. 76). The airport complex on Cedar Key consists of a small private airport; individual skinks have been documented on the airport property along the beach berm areas and under dead grass adjacent to the runway. However, the airport management provides a level of protection to the habitat by restricting human access, so that normal airport activities will not greatly impact the Cedar Key mole skink (Service 2017, p. 27). Finally, approximately 50 acres of the 511 acres are public lands including the Cedar Key Cedar Key Museum State Park.

Deer Island, another known skink-occupied island (35 acres, or less than 1% of the approximate 1200 acres of suitable habitat in the Cedar Keys), is mostly privately owned and is currently undeveloped but could be developed in the future **(**FWC, unpublished data 2017**).**

The Cedar Key mole skink inhabits the same coastal beach berm and hammock habitat that is desirable for residential and commercial development on Cedar Key and Way Key. The FL Keys mole skink has shown some tolerance of habitat alteration and is occasionally documented in cemeteries, vacant lots, backyards and golf courses (Emerick pers. comm. 2017; FNAI 2011, entire; Mays and Enge 2016, p. 10). Further development and conversion of beach and coastal hammock habitat are capable of impacting all of the skink life stages. In addition to direct impacts from loss of soils for nesting and movement, ground cover and availability of the insect food sources found in the ground cover can be reduced. Loss of habitat reduces shelter and shade for adults. Indirectly, connectivity is further decreased, hindering population dynamics in finding mates and dispersal to new locations by juveniles.

Along the network of roads on the developed islands of Cedar Key and Way Key, direct mortality from vehicle strikes may be taking young and adult skink individuals. However, this is expected to be a minor impact to subspecies' populations based on the relatively limited home ranges of skinks within their habitat. Similarly, roads and other transportation structures can fragment habitat and populations leading to a reduction in population health and genetic diversity (Jochimsen et al. 2004, p. 40), but these structures are considered historical impacts to the subspecies since there is no information indicating current or future road construction on the two islands.

4.2.3 Disturbance

Disturbance of skinks and suitable habitat and soils from human activities have been identified as a potential stressor. Although the Cedar Keys National Wildlife Refuge is managed to enhance conservation of wildlife including the skink and its habitat (see discussion under Conservation Measures below), approximately 35,000 to 40,000 people visit the Refuge every year with approximately 26,250 to 30,000 visiting the Refuge islands (Gude pers. comm. 2018). However, as also discussed below, this Refuge is designated as a Wilderness Area, which limits the activities allowed on the islands to low impact activities including walking, paddling, and fishing (USFWS 2011, p. 1). In addition, many parts of the Refuge islands are not accessible to walking or other human activities due to dense vegetation (USFWS 2011, p. 1). The public can visit any of the beaches on the Refuge islands except areas closed during bird nesting season (Gude pers. comm. 2018). Atsena Otie Key is the only island managed by the Refuge that is fully open (beaches and interior areas of the island) to the public with a marked trail system; however, the dense vegetation occurring off the trail system deters the public from accessing those interior portions of the island (Gude pers. comm. 2018). Seahorse Key's interior is only accessible to the public 4 to 5 days per year (Gude pers. comm. 2018). The remaining Refuge islands' interior areas are all closed to public entry (Gude pers. comm. 2018). Still, for the Refuge islands' beaches, walking and launching kayaks or canoes along the beach berm could cause disturbance to the skink's behavior and habitat, but this activity is not likely to rise to a population level impact since the Cedar Key mole skink is mostly found under wrack litter above the high tide line on the beach berm and leaf litter in the interior. By limiting use of human activities on Refuge lands, negative impacts or loss to the skink and its habitat on these lands are minimized.

The Cedar Key Chamber of Commerce estimates that 100,000 people visit Cedar Key annually. Even with this number of visitors, the level of disturbance and the impacts are believed to be small because most of the focal activities are boating, fishing, and ecotourism, all of which mainly occur in the water and not within suitable habitat for the skink. Except for armoring of shorelines to protect existing structures, the Cedar Key community is unlikely to have much impact on the Cedar Key mole skink. As to the armoring, the City of Cedar Key Laws limit the use of vertical coastal armoring and promoting and incentivizing methods of maintaining the natural state and using living shorelines (City of Cedar Key 2016, pp. 182-183; Frank et al. 2014, pg. 116). Shoreline armoring could impact individual skinks and their habitat by hardening the beach berm and unconsolidated soils; however, given the City's preference of maintaining natural states and using living shorelines, the impact from shoreline armoring is expected to be a minor impact to populations.

4.2.4 Stochastic Events

Demographic stochasticity refers to random variability in survival or reproduction among individuals within a population (Shaffer 1981, p. 131). Demographic stochasticity can have a significant impact on population health, particularly for populations that are small, have low fecundity, and are short-lived. In small populations, reduced reproduction or temporary die-offs of a certain age-class will have a significant effect on the whole population. Although such impacts may have less of a consequence to a large population or to a (sub) species with many populations (high redundancy), this randomly occurring variation in individuals becomes an important issue for small populations.

Environmental stochasticity is the variation in birth and death rates from one season to the next in response to weather, disease, competition, predation, or other factors external to the population (Shaffer 1981, p. 131). For example, drought or predation, in combination with a low population year, could result in extirpation. The origin of the environmental stochastic event can be natural or human-caused. Extreme events are expected to increase in strength and frequency with accelerated climate change.

Storm Events

There has been a substantial increase in most measures of Atlantic hurricane activity since the early 1980s, the period during which high-quality satellite data are available. These include measures of intensity, frequency, and duration as well as the number of strongest (Category 4 and 5) storms (Walsh et.al. 2014, p. 20). The increases in storm strength are linked, in part, to higher sea surface temperatures occurring in the equatorial regions of the Atlantic Ocean where hurricanes form and move (USFWS 2017, pg. 7). Strong rainstorms, tropical storms, and hurricanes are all environmental factors that in part dictate Florida's climate and habitats. The health of the Cedar Key mole skink subspecies becomes vulnerable when the quantity and quality of their resources (food, cover, nesting beach) are compromised. This can particularly happen in the case of storm surges and with an increase in the number of incidences (being impacted repeatedly without time to recover).

Hurricane activity has been above normal since the Atlantic Multi-Decadal Oscillation (AMO) (the natural variability of the sea surface temperature in the Atlantic Ocean) went into its warm phase around 1992. The increased intensity of tropical storms and hurricanes result in higher storm surge and coastal flooding events and, thus greater impacts to coastal habitats than historically documented. Ecosystem resiliency is reduced when impacts by extreme and repetitive events occur (USFWS 2017, p. 7). Saltwater intrusion from storm surge and flood result in displacement landward to less suitable habitat and the loss of individual mole skinks. Flooding also affects the inland habitats as the unconsolidated dry soils become wet and compacted and thus affect Cedar Key mole skinks' ecological niche of swimming, burrowing, foraging and nesting. The recent increases in storm strength are linked, in part, to higher sea surface temperatures occurring in the equatorial regions of the Atlantic Ocean where hurricanes form and move. Numerous factors have been shown to influence these local sea surface temperatures, including natural variability of the AMO, human-induced emissions of heat-trapping gases, and particulate pollution.

Sufficient long-term monitoring of the Cedar Key mole skink subspecies and information on storm impacts to this subspecies are mostly lacking. Most surveys have been opportunistic to determine presence or absence. However, the storm impacts to habitats from Hurricane Hermine, which passed by the Cedar Keys in September 2016, were documented (Enge et al. 2017b, entire) (**Figure 4-3)**. Alternations from overwash and erosion to the beach and coastal hammock were widespread. Vegetation became buried and the ground cover was greatly reduced from the storm surge (**Figure 4-3**). The beachfront of North Key lost most of the vegetative cover required for the Cedar Key mole skinks.

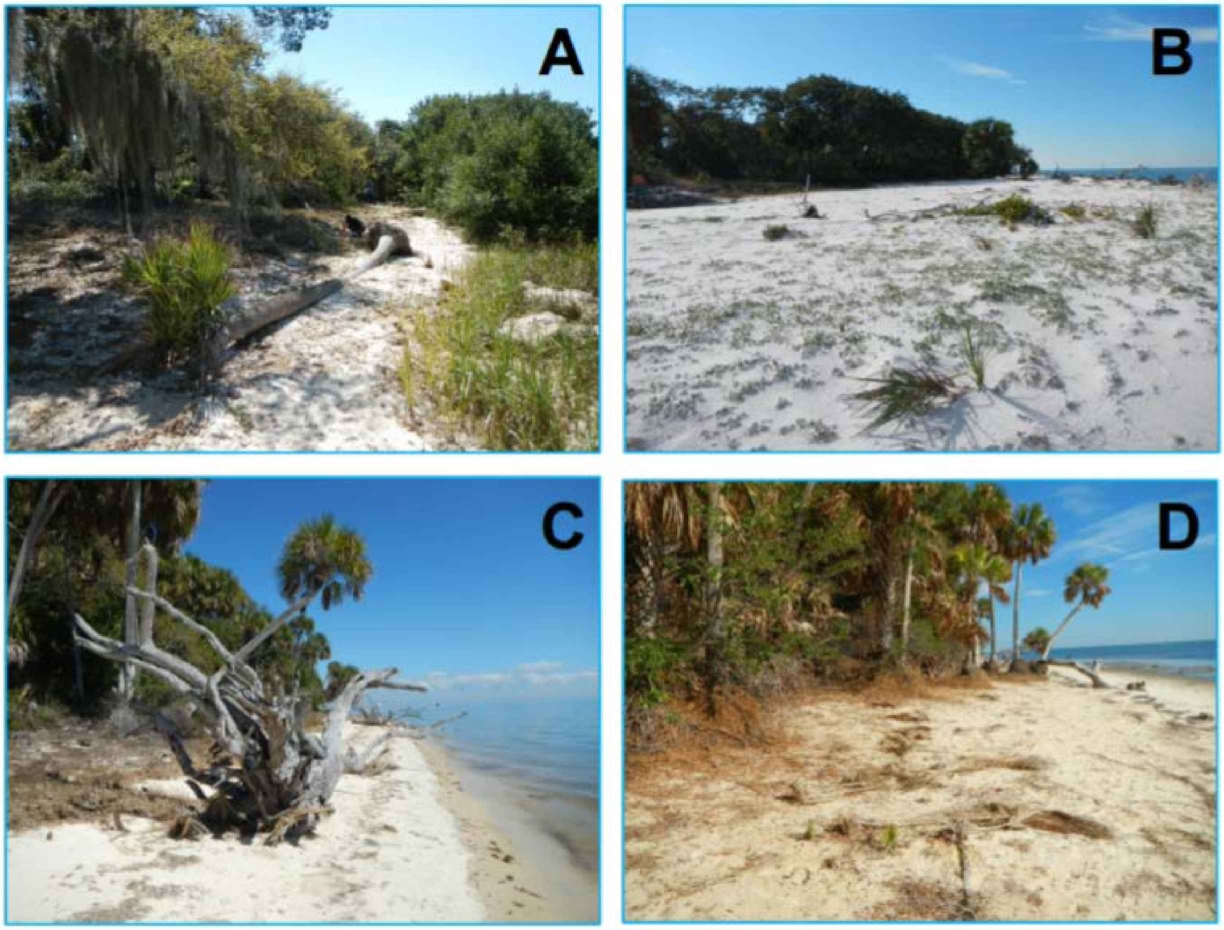


Figure 4-3. Hurricane Hermine impacted the area in September 2016. A) North Key (2015); B) North Key (Dec. 2016); C) Seahorse Key (2015); D) Seahorse Key (Dec. 2016). (Kevin Enge, FWC).

The heavy inundation and complete overwash of islands with lower elevations during hurricanes may provide some explanation for the lack of skinks being observed, even when the island has recovered and contains high quality suitable skink habitat. For example, Ohio Key in the Florida Keys is being regularly surveyed for FL Keys mole skinks and despite available high quality suitable habitat and numerous searches, no skinks have been located there.

Ecosystem resiliency and suitable habitat used by the Cedar Key mole skink is reduced with impacts by extreme events such as floods or storms. Saltwater storm surge and flood would likely result in displacement landward and the loss of individual mole skinks. These same events could trigger opportunities for skinks to become passively dispersed if carried on rafting debris. Also in cases when storms are not too destructive, vegetative material and wrack can also be deposited in localized areas high on the beach and ultimately provide habitat and increased insect food sources for mole skinks. The severity and duration of these impacts to the skink vary based on the intensity and scale of the events.

As mentioned, impacts from heavy rainstorms, tropical storms and hurricanes are part of the Florida coastal islands ecosystem. Over time, this process may be a factor towards reducing the persistence of Cedar Key mole skink populations and thereby reducing the redundancy available in the subspecies. Storm events are likely a contributing factor to the low historic and current abundance observed for this subspecies. Individual mole skinks may colonize and occupy smaller islands only temporarily until storm events impact that island. Eventual recolonization of impacted islands by skinks is also uncertain. Some of the Cedar Key mole skink populations are located in within a 2 mile proximity to the mainland of Florida, and thus, rafting and colonization on the mainland is possible and an avenue for mixing/ gene flow to the mainland peninsular mole skink subspecies.

Oil spills

Every year, thousands of oil spills occur in the United States, but most involve the spilling of less than one barrel of oil (NOAA 2017c). Since 1969, there are been at least forty-four oil spills greater than 10,000 barrels in U. S. waters including the largest to date, the 2010 Deepwater Horizon spill in the Gulf of Mexico (NOAA 2017c). There have been 16 oil spills recorded in the Gulf of Mexico responsible for the spilling of at least 0.05 million gallons (NOAA 2017c). There have been eight spills in the Caribbean Seas with at least 0.05 million gallons spilled (NOAA 2017c). Any large spill has the potential to reach the shore of the Cedar Keys.

Offshore oil tanker spills pose the same threat. Following the Deepwater Horizon spill, a study of contaminants in diamondback terrapins (*Malaclemys terrapin*) in Louisiana showed that turtles in areas with higher exposure to crude oil had higher levels of contaminants in their systems. Drabeck et al. (2014, pp. 132–133) found higher levels of toxic contaminants (2-ring aromatic hydrocarbon biphenyl, alkylated PAH dimethylnapthalene, and Biphenyl) in the reptiles' tissues sampled. These substances are most commonly associated with crude oil and gasoline (Drabeck et al. 2014, pp. 132–33). Depending on the location and severity of the incident, oil spills could affect all life stages of the Cedar Key mole skink which are found in the beach berm habitat under wrack material.

4.2.5 Predators

Native snakes have been documented as natural predators on mole skinks (Hamilton and Pollack 1958, p. 28, Mount 1963, p. 356). However, this predator-prey process has probably remained unchanged over time and therefore is currently not considered a stressor at the population or subspecies level for the Cedar Key mole skink.

Feral and free-roaming cats are instinctively natural predators and have been documented killing a variety of lizard species including: eastern fence lizard (*Sceloporus undulates*), five-lined skink (*Plestiodon fasciatus*), broad-headed skink (*Plestiodon laticeps)*, and ground skink (*Scincella lateralis*) (Mitchell and Beck 1992, p. 200). Cats present a threat to all life stages of the Cedar Key mole skink on the developed islands of Cedar Key and Way Key. Given the limited dispersal and possible clumped distribution, cat predation could negatively reduce or eliminate a skink population (FWC 2013, p.5). However, there is no direct evidence is lacking on the level of impacts that feral and free-roaming cats have a significant impact on the skink.

4.2.6 Invasive Species

The semi-fossorial nature and small size of the Cedar Key mole skink makes all life stages, particularly the eggs, susceptible to the red imported fire ant (*Solenopsis invicta*). Fire ants have been documented killing numerous reptile species' eggs, hatchlings, and adults (Allen et al. 2004, p. 90-92). Fire ants may also indirectly impact adults by affecting survival and weight gain, behavioral changes, changes in foraging patterns and habitat use, and reduced food availability (Allen et al. 2004, p. 90-91). A study conducted in the Florida Keys showed that transects closest to roads and that had the largest amount of development within a 150-m (492-ft) radius of a road had the highest probability of fire ants being present (Forys et al. 2002, p. 31). Similar results could be expected on the islands of Cedar Key and Way Key. Fire ants could also be a food source for these insect-eating generalists, but this has not been documented and is not expected to be a preferred food source given the stinging capability of the ants. Again, there is no direct evidence that fire ants have any significant impact on this subspecies.

The impact of other invasive species preying on Cedar Key mole skink is unknown (Hamilton and Pollack 1958, p. 28, Mount 1963, p. 356); at this time, it appears that invasive species are not a stressor at the population or subspecies level for the Cedar Key mole skink.

Nonnative, invasive plants can compete with native plants for space, light, water, and nutrients. At this time, nonnative, invasive plants are not considered a stressor at the population or subspecies level for the Cedar Key mole skink.

4.2.7 Collection

The collection of the Cedar Key mole skink is considered to be infrequent and an insignificant stressor on the subspecies. A four-year study on the commercial harvest of amphibians and reptiles in Florida documented the capture and sale of four FL Keys mole skinks (two in 1990-1991 and two in 1993-1994) (Enge 2005, p. 211). Small skinks are more often sold as snake food or captured incidentally during hunts for snakes (Enge 2005, pp. 198-211). Current internet searches for the sale of any *Plestiodon* skinks did not find any skinks for sale (Amazon 2017; Ebay 2017). Online searches by FWS staff biologists found two records of previously independent searches from 2013 and 2008 of consumers looking to purchase mole skinks (Fauna Classifieds 2017; Yahoo Answers 2017). No responses to these inquiries were found. The collection of mole skinks would primarily target the adult and juvenile life stage. Adult female skinks are expected to be particularly vulnerable when attending a nest.

4.2.8 Pesticides

Current broad use of pesticides for mosquito control occurs in Levy County. Methods used include spraying adulticide and larvicide spray. There is a specific "No-Spraying" zone across the range of the Cedar Key National Wildlife Refuge, and the Refuge can only be sprayed in events of public health emergencies. The region-wide range of the mosquito control program could possibly be having an unidentified direct impact to the Cedar Key mole skink. Indirect effects could be occurring via impacts to their insect food sources, ground cover, and through soil absorption. Because of its widespread nature, the impact of mosquito spraying would be at the population and subspecies level. At this time, no evidence exists to indicate that this activity is a negative stressor on the Cedar Key mole skink.

4.2.9 Disease

There is no sign or documentation of parasites or disease acting as stressors on the subspecies.

4.3 Cumulative Cause and Effect

Rarely do stressors act alone in the environment, and therefore their cumulative effects to the subspecies and habitat also need to be considered. Even minor stressors that impact just a few individuals in a population need to be considered for their additive effects. For example, the effects from invasive species, pesticide impacts, and collections may each be a low risk to individual skinks but cumulatively can become a moderate or severe stressor to the population abundance. Stressors were considered cumulatively for their effects on the Cedar Key mole skink and were currently found to not impose negative effects at the population or subspecies level.

Various stressors can originate from a similar cause but produce a set of interdependent effects on the subspecies. Global greenhouse gas emissions increase the rate and severity of climactic changes that act in combination as stressors on the subspecies. These include a) SLR, b) seasonal shifts in timing and amounts of precipitation, c) shifts in temperature patterns, d) and increased storm intensities that affect the subspecies. Increased mean (average) high water line resulting from SLR reduces available suitable habitat for the Cedar Key mole skink. Because the average high water line is now higher than historic levels, areas not typically flooded are now flooded on a more regular basis.

Increased incidence and intensity of storm surge is another stressor produced by the occurrence of more severe storms. This surge exacerbates the level of flooding and inundation. Increased rainfall, along with the stressors of SLR and higher than average storm surges, further reduces habitat quality through soil compaction and increased durations of wet soils. This negatively affects nesting ability, skink movement, and availability of insect food sources that rely on dry ground cover. Each of these stressors alone affects the overall viability of the subspecies and its habitat, but combined, they produce synergistic or worsening impacts on the subspecies.

4.4 Conservation Actions

The Cedar Key mole skink subspecies is not a state-listed species.

Levy County has several plans for coastal management, emergency management, and land use management, including a Comprehensive Plan which includes specific elements of Coastal, Conservation, and Future Land Use (Frank et al. 2014, p. 68; Levy County 2017). The County has policies to limit incompatible future growth and development in coastal areas subject to flooding (Frank et al. 2014, pp. 68-69), which are areas where the skink's habitat occurs. The Comprehensive Plan also contains coastal setback guidelines and standards for construction near or on the shoreline and policies for protecting environmentally sensitive land (Frank et al. 2014, p. 69).

The City of Cedar Key has a variety of land uses: residential, conservation, recreation, marsh, mixed use, commercial, and public (City of Cedar Key 2016, p. 161). City Code 4-3.2 states that "the City shall protect native vegetation, including but not limited to trees, mangroves, and marsh grasses, and cooperate with Levy County in identifying, conserving, protecting or preserving unique vegetative communities in contiguous areas to assure that development does not degrade the environment, impair aesthetics, damage coastal resources or deny reasonable property rights and uses" (City of Cedar Key 2016, p. 178). City code 4-8.1 states "a minimum coastal construction setback line of 50 feet from the mean high water line will be maintained on any land adjoining all surface waters. In addition to the 50-foot setback line, an additional setback may be required to protect water-dependent vegetation located landward of the coastal construction setback line" (City of Cedar Key 2016, p. 182). These setbacks from beach berm habitat allow skink habitat along the shoreline to remain intact. The city also has plans to manage and protect all ecological and wildlife communities (City of Cedar Key 2016, p. 180).

The USFWS Coastal Program is a conservation tool in the Cedar Keys. This program provides valuable technical and financial assistance to public and privately-owned coastal lands by supporting habitat conservation projects (USFWS 2012, entire).

The NOAA Coastal Zone Management (CZM) Program addresses the issues of climate change, ocean planning, and planning for energy facilities and development. The program was established by the CZM Act of 1972. This is a voluntary partnership between the federal government and the coastal states. This program funds coastal improvement projects in both aquatic and terrestrial habitats, which can improve and restore skink habitat and soils (NOAA 2017d).

4.4.1 Conservation Lands

As mentioned above, most of Levy County's coastline is protected in Federal and state conservation lands. Not only are the Cedar Keys surrounded by conservation lands, a significant number of the islands and coastal habitats within the Cedar Keys are protected as conservation lands (**Figure 4-5)**. Bordering the north of the Cedar Keys is the Lower Suwanee National Wildlife Refuge; to the east along the coast is the Waccasassa Bay Preserve State Park; to the northeast on the mainland is the Cedar Key Scrub State Reserve; and within, is the Cedar Keys National Wildlife Refuge that includes five of the eight islands where Cedar Key mole skinks have been documented.

These areas are all managed for conservation purposes and have similar beach berm and coastal hammock habitats which may be suitable for the Cedar Key mole skink currently or in the future. Cedar Keys NWR does allow for recreational use of the island habitats; however, these areas provide complete protection from development and urbanization and allow for the persistence of sandy soil habitats. A comprehensive list of these lands is provided in **Table 4-2**. These areas provide all or some of the following conservation benefits to the Cedar Key mole skink:

- Management of natural habitat including the maintenance and restoration of functioning beach berm and coastal hammock systems.
- "Leave no trace" practices and principles that are designed to reduce or eliminate impacts by humans visiting or using the lands.

- Prevention or minimization of the collection/removal of mole skinks.
- Prohibition or limited-use of activities aimed at preventing disruptions, impacts or losses to natural habitats and the species. These include such things as no motorized vehicles, no ORVs, human exclusion of sensitive environmental sites, reduction of noise and light pollution, no dumping, no searching for antiquities, and no release of exotic species.
- Provide environmental education and interpretive services to the public on natural habitat and species: "Good stewardship" practices.
- Aquatic sanctuary and preserve lands provide buffers on coastal habitat by minimizing high-impact coastal recreational use and development of these areas.
- "Conservation in perpetuity". Commitment of the conservation land owner to the long-term conservation and management of native habitat and species.

By limiting use of human activities, negative impacts or loss to the skink and its habitat as well as skink collection is or could be minimized on public lands. In addition, the long-term passive management for natural environmental processes of coastal public lands adjacent to the current range of the subspecies provides some future benefit to the Cedar Key mole skink and its habitat; by allowing natural environmental processes such as habitat transition to occur, the Cedar Key mole skink may benefit by dispersing via rafting during storm or flooding events to suitable beach berm and coastal hammock habitats on some of these public lands that are now outside, but adjacent to, the current range of the subspecies.

The collection of Cedar Key mole skinks on any State, Federal, or public land is currently prohibited by state statute Rule 68A-27-.001 (4), F.A.C. (FWC 2016, p. 15). The Florida State Parks also have specific rules prohibiting the collection, destruction, or disturbance of all plants and animals within state park properties (Florida State Parks 2017).

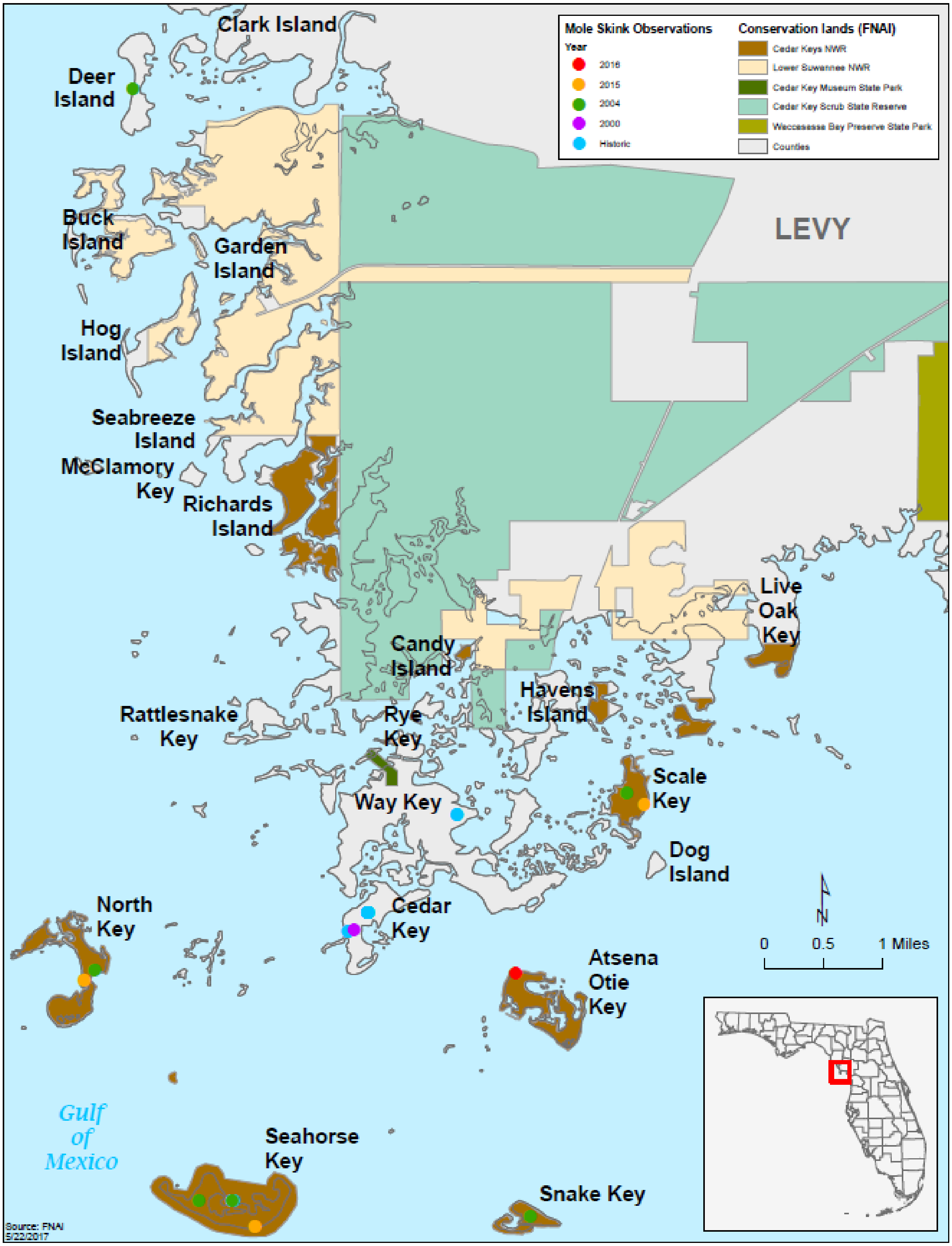


Figure 4-4. Publically owned and managed lands of the Cedar Keys, Levy County, Florida.

Table 4-2. Federal and State conservation lands within and adjacent to the Cedar Keys.

Conservation Land	Location	Acres (ac)	Management Plan
Federal			
Cedar Keys NWR	13 Islands of the Cedar Keys	762 ac	USFWS CCP (2002)
Lower Suwanee NWR	Coastal Levy County	53,000 ac	USFWS CCP (2002)
State			
Cedar Key Scrub State Reserve	Central Coastal Levy County	5023 ac	Florida DEP State Reserve (2005) - FWC Wildlife WMA
Waccasassa Bay Preserve State Park	Southern Coastal Levy County	34,064 ac	Florida DEP State Parks (2015b)
Cedar Key Museum State Park	Cedar Key	18.6 ac	Florida DEP State Parks (2015a)

The Cedar Keys National Wildlife Refuge protects and manages occupied and potentially occupied suitable habitat of the Cedar Key mole skink. The refuge is comprised of thirteen islands ranging in size from 1 to 120 acres and totaling 762 acres (USFWS 2002, p. 35). Five (Atsena Otie Key, North Key, Scale Key, Seahorse Key, Snake Key) of the eight islands where the Cedar Key mole skink is known to occur are part of the Refuge. The National Wildlife Refuge Improvement Act of October 9, 1997 recognizes as law that the primary function of a National Wildlife Refuge is to conserve fish, wildlife, plants and their habitat for the benefit of the American people. Public use of a refuge may be allowed only when the activity is compatible with the mission of the System and does not negatively affect the flora and fauna of the refuge (USFWS 2002, p. 39). Further, within the Refuge, Congress designated Seahorse Key, Snake Key, North Key, and Deadman’s Key as National Wilderness Areas (USFWS 2002, p. 35). Some of the conservation benefits of wilderness stewardship include: managing the use of resources and activities within wilderness; allowing natural processes to operate freely within wilderness; preserving wilderness air and water quality; controlling and reducing the adverse physical and social impacts of human use in wilderness; and harmonizing wilderness and adjacent land management activities. As discussed above (see Other Stressors), all of these activities are beneficial to the skink and its habitat by providing protections to habitat in which the skink occurs.

4.5 Current Condition

4.5.1 Population Resilience

Due to the semi-fossorial and cryptic nature of the Cedar Key mole skink and limited research on all of the mole skink subspecies, there is limited information about the population structure and demographics of the Cedar Key mole skink. Three genetically discreet populations have been identified from preliminary genetic research with very small sample sizes (22) and samples from only 3 of the eight islands of known occurrence. Of the three islands sampled by geneticists, each was identified with a unique genetic identification. One of the islands, Seahorse Key also has historical records which suggest a level of resiliency for individuals (or a population) at this site. North Key and Scale Key have no historical observations documented (refer to **3.3.2 Population Structure**). The three identified genetic populations do not constitute the entire Cedar Key mole skink subspecies population.

Little information exists on the abundance or growth rate of these populations. Therefore, a full picture on the health and resilience of these populations is uncertain. The capture data is limited; only 52 records since 1951, most of which were prior to 2000. There are 10 records since 2000; however this includes documenting Cedar Key mole skinks at five additional islands than previously known. The presence and distribution of skinks being documented is highly reflective of the presence and effort of searches taking place at these locations, and opportunistic surveys have resulted in detecting presence on unsurveyed islands. That is, individual skinks, and possibly more populations are present on the numerous other islands which have not yet been searched.

Population resiliency for the Cedar Key mole skink populations is supported by the existence of suitable available habitat across the range of the subspecies. A strong correlation between habitat availability and population resilience is inferred but not at a certainty level where habitat can be used as a surrogate for skink presence. The current total acreage of the available suitable habitat in the Cedar Keys is approximately 480 ha (1,173.5 ac), and the current suitable soils identified total approximately 315 ha (778.3 acres). Of this available suitable habitat, the eight islands where Cedar Key mole skink has been documented encompass 305 ha (752.9 ac). There are an additional 19 islands totaling 170 ha (420.6 ac) that have not been surveyed. Of the 480 ha (approximately 1,200 acres) of available suitable habitat in the Cedar Keys, approximately 42% is located on two mostly developed islands (Cedar Key and Way Key), approximately 8% on undeveloped, privately-owned islands, and the remaining 50% on islands in public ownership including the Cedar Keys National Wildlife Refuge. Of the approximately 305 ha (752.9 ac) of available suitable habitat on skink occupied islands, approximately 60% is located on the two mostly developed islands, approximately 36% on islands in public ownership, and approximately 4% on undeveloped, privately-owned islands.

Suitable coastal maritime hammock, coastal dune, and beach berm habitat provides ground vegetation and wrack material that mole skinks depend on for nesting, insect food sources, and cover. Mole skink abundance, distribution and life history behaviors (nesting, breeding) are limited to the availability of these resources in the remaining areas of high beach and coastal hammock. While ground cover and insect food sources are apparently sufficient and occur in adequate amounts, there have been no quantitative studies completed on these factors. Valuable characteristics that contribute to population resilience are their generalist behavior in use of a) various ground covers and b) insect food sources.

Factors reducing population resiliency are the limited and patchily distributed suitable habitat and unconsolidated sandy soils available across the subspecies' range. The islands of the Cedar Keys are limited naturally in their land mass. Much of the undeveloped coastal beach and maritime hammock habitat remains intact and hard to access by humans. The availability of unconsolidated, dry soils is likely a limiting factor in the nesting success of the populations (**Table 2-1 and 3-1**). Currently there are approximately 750 acres of sandy soil habitats on the eight islands where they are known to occur. There is an additional 420.3 acres on 20 islands that have not been surveyed. The habitat and soils are still believed to be in a quantity and quality enough to support the Cedar Key mole skinks populations. However, stressors primarily from climate change and SLR are currently adversely impacting these habitats and soils required by Cedar Key mole skink populations.

Stochastic, low levels of passive dispersal of individual skinks among the islands of the Cedar Keys is likely to be occurring, but is expected on a limited and random basis. Due to proximity of the mainland (1-2 miles in some locations), dispersal of individual skinks to the mainland from the Cedar Keys is also likely to be occurring. The level at which immigration and emigration via dispersal acts as a factor towards population resilience and prevention against extinction for this subspecies is unknown. The small size of many of the islands and the distance of water and salt marsh between them makes the likelihood of dispersal appear limited in its influence on the population dynamics; however, it cannot be completely ruled out as a contributing factor. Many of the islands have yet to be searched, including some of the hammock islands surrounded by salt marsh. These islands could be occupied and they could also act as “stepping stones” in the random dispersal of individual skinks. Genetic research on the Cedar Key mole skink (including the other four subspecies) is currently underway, with a goal of furthering our understanding of population dynamics, genetic relatedness within the subspecies, and the degree of separation of this subspecies from the Florida mainland.

Heavy rainstorms, tropical storms and hurricanes are part of the Florida environment and this process can be a factor that reduces the resilience (persistence) of skink populations. It may be one reason that the numbers of individuals across the Cedar Keys is historically and currently documented in low abundance. Individual skinks may colonize and occupy smaller islands only temporarily until storm events impact that island. Eventual recolonization of impacted islands by skinks is also uncertain. The larger islands likely provide more persistent habitat and populations of skinks due to: larger island size, available habitat that can buffer flooding effects, and/or elevation. The larger islands include Atsena Otie Key, Cedar Key, North Key, Seahorse Key and Way Key.

Because of the lack of available information on the extent of individual populations in the subspecies and the uncertainty of population structure, the assessment of population resiliency is incomplete. Resilient small numbers of skinks (most are sightings of a single skink) dispersed across the Cedar Keys are documented in historical and current records. Recent survey data from North Key found hatchlings, which shows that breeding and some level of hatch success is taking place at this site. Available beach and coastal maritime hammock habitat, ground cover, and insect food sources are patchily distributed across the range and are providing the resources necessary to support skink populations; however, the Cedar Key mole skink is still experiencing moderate to high stressors across its range from loss of habitat due to sea level rise (SLR). Environmental stressors from climate change pose a risk to the resilience of this subspecies as a result of habitat conversion or loss caused by inundation. The current limitation at the local level to directly manage, minimize or eliminate the causes of these global, climate-induced stressors contributes to this level of risk.

4.5.2 Subspecies Redundancy

For the Cedar Key mole skink, similar stressors with similar timing and intensity is experienced by the entire subspecies because of the very narrow geographic range (10 miles of coast occupying ~50 mile^2 of coastal habitat). For example, the entire subspecies is vulnerable to the effects of a hurricane passing over the Cedar Keys. Climactic shifts taking place in regional precipitation and temperature patterns affect the subspecies as a whole.

Subspecies redundancy for the Cedar Key mole skink can be provided by individuals being distributed across many islands and across the subspecies' known range. While there are currently only three genetically identified populations, species experts believe that low numbers of individuals (which may represent separate populations) do exist across the range of the subspecies (Technical Team Working Group 2016; **Tables 3-1** and **3-2**). Cedar Key mole skinks have been documented on eight of the 30 named islands of the Cedar Keys. These islands range in size from 1 to 380 acres of sandy soil upland habitats. Limited acreage of beach, coastal maritime hammock habitat, and other unconsolidated soil habitats exists in the Cedar Keys (1,200 acres). As the Cedar Keys are a small chain of islands, land mass in general is limited, and thus there is little redundancy or "backup" for the available habitat and natural expansion is not possible. However, it should be noted that there is potential for immigration to the mainland due to its close proximity (**Figure 4.5**) and further assessment of mole skinks on the mainland in the immediate vicinity of the Cedar Keys is needed.

Recent surveys have documented individual skinks on five additional islands that do not have historical records of mole skink occurrence. These skinks are not believed to be new recruits to these sites. It is more than likely that these are persistent individuals or groups of skinks on islands that had never before been searched for skinks. The true spatial distribution of populations throughout the islands of the Cedar Keys is unclear, and our current image of the subspecies distribution is based on the limited survey data. It is strongly believed that individual skinks occurring on islands other than North Key, Scale Key and Seahorse Key (those with genetically identified populations) either belong to one of the three identified populations, or more likely are additional genetically-distinct populations.

Dispersal of individuals across islands is unclear and likely an uncommon occurrence. Genetic evidence shows little to no sign of interbreeding between the identified island populations. During surveys, researchers generally observe or collect just a single skink or small numbers and it is likely that skinks do occur on other islands but in low numbers. The importance of the other islands (other than those with identified populations) to the overall population resiliency for the subspecies is unclear.

Despite a level of redundancy provided by the discrete populations and individuals that are found dispersed across several islands, the Cedar Key mole skink lacks a level of redundancy geographically because of its small endemic range. For some large scale stressors that affect the entire Cedar Keys, the entire subspecies is vulnerable to the timing and intensity of impacts. Large scale habitat loss is quite feasible in a strong hurricane as is direct mortality of skinks via drowning. On a localized, on-the-ground level, individual skinks would be expected to survive. Not all would drown, and some could opportunistically burrow under the soil or seek shelter in very small and protected areas. The occurrence of skinks on many of the Keys, even though in low abundance, provides some redundancy to the subspecies. Current stressors that impact the entire range of the subspecies are a) naturally occurring tropical storms and hurricanes and b) climate change stressors that include SLR, higher average hot temperatures, increased number of hotter days per year, more pronounced rainfall, shifts in seasonal precipitation patterns, increased flooding and storm surge events, and more intense major storms.

4.5.3 Subspecies Representation

The genetic and environmental diversity within the subspecies is low (Technical Team Working Group 2016; Mercier, Pers. Comm. 2017b; Branch et al. 2003, p.202). Branch et al. (2003, p. 202) found lowest haplotype diversity for the Cedar Key mole skink as compared to the other mole skinks subspecies, as well as low nucleotide diversity within the Cedar Key mole skink; it also has the smallest/narrowest range of all the subspecies. As mentioned, the subspecies is a unique genetic lineage and is genetically distinct from the other mole skink subspecies. Evidence indicates that it is an isolated subspecies and not a population of the mainland (Parkinson et. al. 2016, pp. 12-13; Branch et al. 2003, pp. 202-205). There are no genetic signs of interbreeding between the other subspecies of mole skinks (Technical Team Working Group 2016; Mercier, pers. comm. 2017b). At this time, preliminary information suggests that the Cedar Key mole skink subspecies is represented by at least three distinct populations, each on separate islands, but as a whole, there is low genetic diversity within the subspecies. There is no sign of morphological or behavioral differences between skinks on different islands.

The Cedar Key mole skink occurs across a very narrow geographic and ecological range; there is no variation in habitat types across distance or elevation as there is for larger-ranging and more abundant species. The entire subspecies is represented within the same chain of coastal islands within approximately 50 mi^2 range. Populations or individuals are represented across only slight elevation differences across the separate islands. The amount of coastal sandy substrate and hammock habitat is limited in the Cedar Keys. The Cedar Key mole skink does not occur across different ecotones and does not have access to different ecotones or systems in which to adapt.

This lack of breadth in the subspecies makes is susceptible to stochastic events such as genetic mutations, diseases, or broad scale loss of habitat types. For example in the case of disease or parasites, one individual or population may spread disease or parasites to the entire subspecies if there is no variation that may protect some from being affected. No part (populations) of the subspecies is immune. The same case may occur environmentally, because the subspecies only occurs in a small range of tropical habitat. All individuals of this subspecies exist in the same system, and there are no other individuals or populations that exists in other ecosystems or varied environment (such as in a more temperate landscape). Therefore, if the tropical system is impacted, the entire subspecies is highly likely to be susceptible to impacts.

4.6 Summary of Subspecies - Overall Current Condition

The Cedar Key mole skink subspecies has limited genetic and environmental variation (representation) within the Cedar Keys. The subspecies lives in this limited ecological setting, and there is no behavioral or morphological variation within the subspecies. Recent searches (since 2000) have added five additional islands to the three historical islands where Cedar Key mole skinks are documented to occur. Despite the subspecies' distribution across many islands, it should be noted that the overall distribution (redundancy) for this subspecies only occurs within the Cedar Keys. The Cedar Key mole skink is a very narrow-ranging endemic. It should be noted that the mainland of Florida is in close proximity, within 1.5 to 3 miles of several occupied islands, and it is not known if the Cedar Key mole skink occurs on the mainland or if there is a genetic intergradation zone with the adjacent mainland subspecies.

There are three identified populations and additional individuals (not yet identified into populations) occurring across separate islands; however, little information exists on the abundance or growth rate of these populations (resiliency). Observation data indicates low numbers within populations. The longest and most consistently surveyed area (1951 to present), Seahorse Key, indicates that all life stages and breeding and nesting are occurring in this area. Populations or low numbers of individuals across the Cedar Keys have persisted through many hurricanes and severe storms that are part of this coastal ecosystem. Although available suitable habitat and soils that offer cover, nesting habitat, and food sources for the skinks exist across the range of the Keys, the Cedar Key mole skink is still experiencing stressors from SLR, storms, storm surge and flooding.

CHAPTER 5 – FUTURE CONDITION

We have considered what the Cedar Key mole skink needs for viability and the current condition of those needs, and we reviewed the factors that are driving the historical and current conditions of the subspecies. We now consider what the subspecies' future conditions are likely to be. We apply our future forecasts to the concepts of resiliency, representation, and redundancy, to describe the future viability of the Cedar Key mole skink.

5.1 Introduction

The low-lying archipelago of the Cedar Keys has experienced a SLR increase of approximately 0.08 m (3 in) between 1992 and 2015 (NASA 2015, p. 2; NOAA 2017a). The primary stressors affecting the future condition of the Cedar Key mole skink is SLR and associated climate change shifts in rainfall, temperature and storm intensities. These stressors account for indirect and direct effects at some level to all life stages and the habitat across the subspecies' range. Additive climate change stressors projected for the future include: a) increased number and intensity of strong storms with associated storm surge, saltwater intrusion, and inland flooding, b) increased temperatures, c) shifts in the timing and amounts of seasonal precipitation patterns, and d) accelerated rates of SLR due to ice cap melt contributing to the Atlantic ocean current's influence on the Gulf coast of the United States. The habitat of the Cedar Keys is being inundated and based on SLR projections coastal beach and low-lying areas will either be lost to the sea or converted to predominantly saltwater habitat. However, adjacent mainland upland and freshwater marsh habitats will be converted to coastal sandy islands, salt marshes, bays and tidal creeks.

As presented in **Chapter 4 – Current Condition**, the rate of global SLR has been measured at approximately 0.003 m (0.12 in)/year since 1993 (NOAA 2017b, p. 8). Southeast and Gulf of Mexico coasts of Florida have shown a similar rate (Hall et al. 2016, entire: Compact 2012, p.1). However, under future scenarios, the projected increase in SLR is not expected to continue on this same rate or trend. Recent information indicates that the rate of global and regional SLR is beginning to accelerate (Park and Sweet 2015, entire; NOAA 2017b, entire; Rahmstorf et al. 2015, entire; Zhang et al. 2011, entire). Both accelerated rates and higher inundation levels of SLR than previously projected are now expected to occur. Two main reasons for this are the: Antarctica and Greenland ice melt adding ocean mass to the Atlantic Ocean, and thermal expansion of the oceans produced by warming seas (NOAA 2017b, pp. 7,16; Deconto and Pollard 2016, p. 596; Park and Sweet, 2015, entire).

The current and ongoing climate change stressors are the most influential threat to the subspecies future condition and status (Pearson et al. 2014, p. 217). Vital life history factors of Cedar Key mole skink subspecies which makes it vulnerable to climate change stressors are its small occupied areas, low population sizes, and short generation length (Pearson et al. 2014, pp. 218-219). Global climate change is a natural process; however, the uncontrolled and continued release of large quantities of GHG emissions into our global atmosphere is also affecting the planet's oceans. The rate and intensity of these global atmospheric warming processes have increased to a point that on a regional and local scale they have become negative stressors affecting the habitat of the Cedar Keys.

5.2 Scenario Development

To examine the potential future condition of the Cedar Key mole skink, three future scenarios were developed. The scenarios focus on a range of conditions based on climate change scenarios and projections for land development. The range of what is likely to happen in each scenario will be described based on the current condition and how resilience, representation and redundancy would be expected to change. The levels of certainty or uncertainty are addressed in each scenario.

Observed and projected changes in climate at the regional level vary from global average conditions. The SLR projections used in this assessment were “downscaled” from the global scale projections. Regionalized projections provided higher resolution information that is more relevant to spatial scales used for analyses of the Cedar Key mole skink and the conditions influencing it and its habitat. Minor stressors were determined to remain relatively stable and not expected to change from current condition. These stressors include predation, collection, disease, pesticides, human disruption from human activities, and oil spills. If however any one of these stressors would begin to increase and place pressure on the subspecies, it will need to be assessed. For example if it is found in the near future that individual mole skinks begin to experience symptoms of disease, a reassessment of the condition would need to be reviewed.

The “Big Bend” Region of Florida’s Gulf Coast (Regional District 2 West) SLR projections, which do not include the accelerated projections, were used to develop GIS shapefiles to view and run computer scenarios of the projected SLR over time (UF 2015). This mapping also provided an illustrative view of inundation on the Cedar Keys landscape based on these projections. The projections include a Low, Medium, and High scenario of SLR for 2020, 2040, 2060 and 2100 at this regional level. Further information on the development of these projections can be found in UF (2015).

These regional projections were used to define the future scenarios of this assessment. They were adjusted (downscaled to a regional level) from the Global “worst”, “moderate”, and “best” case SLR scenarios (IPCC 2013, entire; NOAA 2017b, entire). There are numerous SLR modeling projections developed to reflect the range in of the “worst”, “moderate, and “best” case GHG scenarios. The “worst” case represents a “global business as usual” scenario. The “moderate case” represents a scenario that “begins global moderate reduction in GHG concentrations by 2015, then decreasing”, and the “best” case scenario is to “begin aggressive global GHG reductions now” (IPCC 2013, entire; NOAA 2017b, entire; Hall et al. 2016, entire; Jevrejeva et al. 2014, entire; Parris et al 2012, entire). Appendix D provides a summarized list of some of the published SLR projection curves.

In Florida, SLR by 2100 is projected to have increased to between 0.3 m (1 ft.)(low) to 2.5m (8.4 ft.) (high) (NOAA 2017b, p.40). The regional projection which do not yet account for the accelerated rates predict a 0.1 m (4 in) to 1.96 m (77 in) SLR by 2100 for the “Big Bend” of Florida (UF 2015). The Low, Medium, and High SLR scenarios of the Big Bend of Florida, including the Cedar Keys, for 2040, 2060, and 2100 (UF 2015) were used in the description of three future scenarios for the Cedar Key mole skink (**Table 5-1**) (U.S. Army Corps of Engineers (USACE), 2014). A 2020 curve was not used in the future scenarios for the Cedar Key mole skink, because this near-future scenario is not reflecting a large enough difference between the current conditions.

Information for the future conditions assessment was compiled and analyzed. These projections do not yet reflect modeling based on new increased rate estimates (which are approximately 15% higher based on the NOAA 2017b, entire). However, GIS mapping shapefiles were available from the Geoplan (UF 2015) data which allowed for viewing of inundation levels of the Cedar Keys in time lapse images. The spatial information was able to be used to visually observe and calculate changes to land area, habitat, soils, and Cedar Key mole skink observation data based on various levels of inundation. Suitable habitat for the eight islands with documented occurrence of the Cedar Key mole skink was analyzed to predict inundation from the three projections.

Table 5-1. Regional Estimated Cedar Keys – Big Bend Region of Florida Relative SLR projections used for the Cedar Key mole skink future scenarios. See **Figure 5-1** for graphical depiction (UF 2015).

	Cedar Keys - Big Bend Florida Regional Estimated Relative Sea Level Change Projections. Mean High Water –MHW meters (in)				
Year	**2020**	**2040**	**2060**	**2080**	**2100**
Low	0.48 (19)	0.53 (21)	0.56 (22)	0.59 (23)	0.64 (25)
Medium	0.50 (20)	0.61 (24)	0.69 (27)	0.80 (32)	0.94 (37)
High	0.57 (22)	0.79 (32)	1.09 (43)	1.46 (58)	1.96 (77)

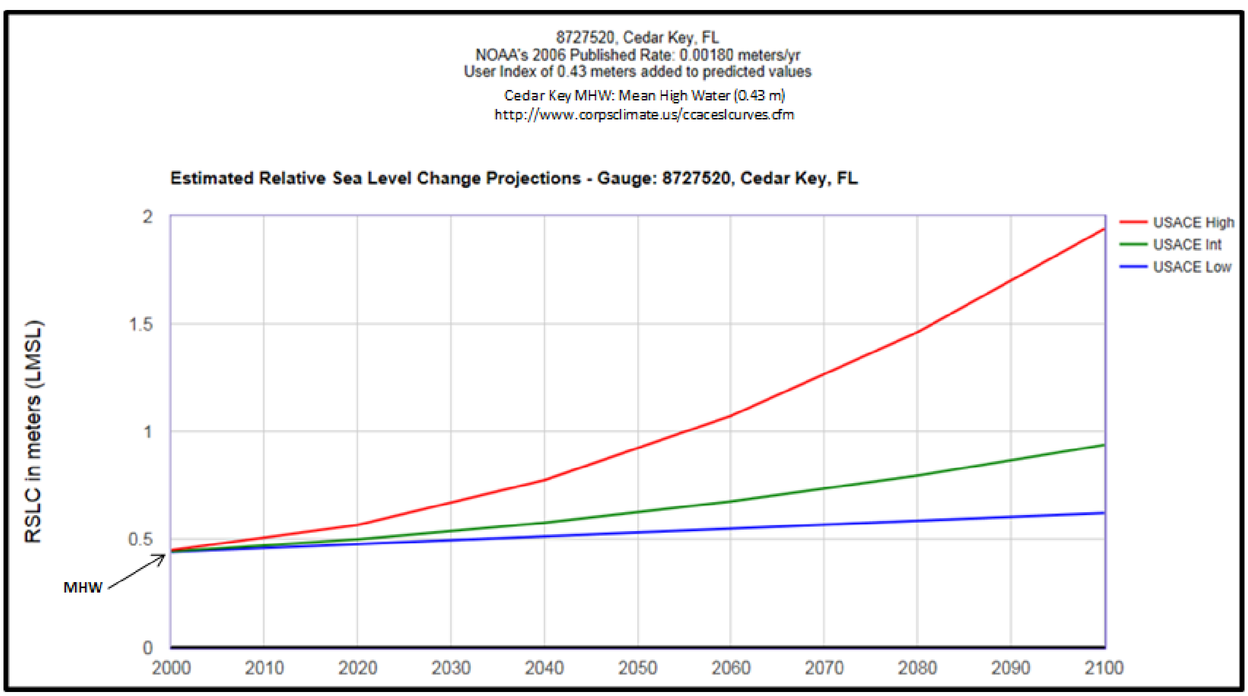


Figure 5-1. Estimated Big Bend of Florida region SLR projections used for Cedar Key mole sink Future Scenarios (U.S. Army Corps of Engineers; UF 2015).

The work of Pearson et al. (2014, entire) was also considered in assessing future scenarios. Pearson et al. (2014, entire) used life history, spatial, and demographic variables (such as population size and connectivity) in models used to predict the extinction risk due to climate change of thirty six reptile and amphibian species. The two variables found to be most influential in predicting extinction risk due to climate change were “occupied area” and “population size” (Pearson et al. 204, pp. 18-19). The interaction of specific variables was also a determinant in the risk of extinction. For example, the effect a population size (small populations with higher risk than larger populations) from climate change was found to be magnified for species with small occupied areas (Pearson et al. 2014, p. 218). This work indicated that the same life history and population variables (such as population size and connectivity) typically used to predict effects of the stressors to the species can be used in the same manner for reviewing effects of climate change stressors on a species.

Three feasible future scenarios representing Best, Medium and Worst case scenarios for the Cedar Key mole skink followed the Low, Medium, and High regional SLR projection developed by the USACE and used by the University of Florida (2015) (**Table 5-4**). Also, for all three future scenarios, the IPCC’s description and likelihood of occurrence in the 21st century of extreme weather and climate events including changes in temperature, precipitation, and storm intensity was used (**Table 5-2**) (IPCC 2013, p. 7). The level of occurrence or trends of these events are generally presented as positively occurring or not, and are not shown in a low, medium, and worst case scenario; therefore this same set of projected weather events and their likelihood trends was used in each of the future scenarios for the Cedar Key mole skink. In addition, most of these events most directly associated with the Cedar Keys (more hot days, increase in precipitation events, and increase in storm intensity) are already being documented, and there is a high confidence in their occurrence into the late 21st century. The IPCC terms used to describe the likelihood of the event are described in **Table 5-3**.

Table 5-2. IPCC global scale assessment of extreme weather and climate events and likelihood of further changes in the 21st Century (IPCC 2013, p. 7 Table SPM.1 summarized).

Weather and climate events and trend	**Likelihood of further changes**	
	Early 21st Century	**Late 21st Century**
Warmer and/or fewer cold days and nights over most land areas	Likely	Virtually certain
Warm spells/heat waves. Frequency and/or duration increases over most land areas	Not formally assessed[a]	Very likely
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation.	Likely over many land areas	Very likely over wet tropical regions.
Increases in intensity and/or duration of drought	Low confidence[b]	Likely on a regional to global scale
Increases in intense tropical cyclone activity	Low confidence	More likely than not
Increased incidence of extreme high sea level	Likely	Very Likely

[a]Models project near-term increases in the duration, intensity, and spatial extent of heat waves and warm spells.
[b]There is low confidence in projected changes in soil moisture.

Table 5-3. IPCC Fifth Assessment Report (AR5) Likelihood Terms (IPCC 2013, p. 142).

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

*Additional terms that were used in limited circumstances in the Fourth Assessment Report (AR4) (*extremely likely* = 95-100% probability, *more likely than not* = > 50% -100% probability, and *extremely unlikely* = 0-5% probability) may also be used in the AR5 when appropriate.

In each of the following scenarios, population growth and development possibilities were considered. While there are differing future options for development, the highest (or worst) level of projected development even in the positive growth scenario does not act as a major stressor as compared to the climate change stressors. Two reasons for this are the 1) amount of protected lands and 2) county building regulations which currently exist in the Cedar Keys. The minor stressors discussed in **Chapter 4 - Current Condition** were considered, and it was determined that these stressors will remain at the same or similar level similar to the current under the future conditions. That is, these stressors will not increase or rise to the level of impacting the 3Rs for the Cedar Key mole skink.

The future scenarios are based on the projected inundations presented in **Table 5-4** (I. Best Case Scenario, II. Moderate Case Scenario, and III. Worst Case Scenario). **Figure 5-2** illustrates the Low, Medium and High 2040 to 2100 projected sea level rise curves used, respectively, in describing the “Best”, “Medium” and “Worst” case scenarios for the Cedar Key mole skink (University of Florida 2015) (**Table 5-4** I, II, and III). Additional illustrations of habitat change under these three scenarios of these same Keys are provided in **Appendix D**.

Table 5-4. Future Scenarios.

I. Best Case Scenario

BEST CASE SCENARIO			
Climate change	**Land Development/Habitat Conversion**	**Other Stressors**	**Likelihood of modified GHG emissions (IPCC Guidance)**
Low emission. Strong mitigation to decrease emissions by end of the 21st century Low SLR curve – 0.53m (21 in) to 0.64 m (25 in) from 2040 to 2100 **Table 5-1**; University of Florida 2015. NOAA (2017b) Low 0.3 m (11.8 in) SLR by 2100 Likelihood of exceeding by 2100 is 100%. Per IPCC (2013) for all scenarios: • Precipitation – Increased number of consecutive dry days. (*likely*) and wetter in rainy season (very likely). • Stronger storms (increased magnitude) and with heavier downpours (very likely). • Temperature: More days higher than 95 degrees F (virtually certain). For coastal FL, this means an additional 30-50 days/ year above 95 degrees F. • Temperature: Increase in the average temperature 3-8 degrees F by 2100 (likely; already taking place under observed trend)	Reduced trend or remains the same as current trend but increased densities are only approved in already developed urban. Lower rate of SLR is expected to keep growth rate up or the same. Or, as SLR effects are noticed, a "flattened" or a lowered population growth is expected. More likely best case is the lower rate of SLR and the same or higher increase in population.	Likely at same level Disruption, destruction of habitat from tourism, recreational activities is maintained at current level (status quo) Effectiveness of management on existing protected lands is improved to assure persistence of subspecies and habitat Presence of exotics (fire ants, veg;, feral cats, snakes)	Very unlikely – Will likely exceed these projections. This scenario is similar to the IPCC RCP2.6 * (low curve). (Appendix C) *RCP is Representative Concentration Pathways (= GHG concentrations)

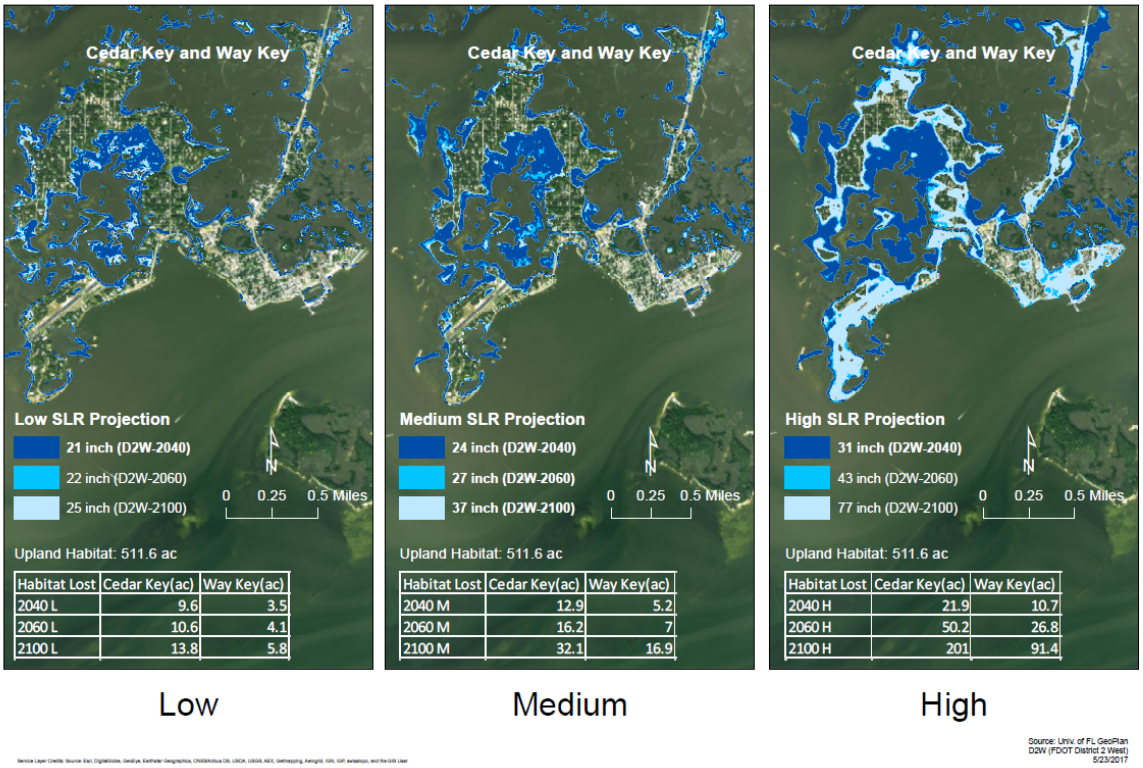
II. Moderate Case Scenario

MODERATE CASE SCENARIO			
Climate change	**Land Development/Habitat Conversion**	**Other Stressors**	**Likelihood of modified GHG emissions (IPCC Guidance)**
Moderate emissions Moderate mitigation GHG emissions stabilized by 2050, then decreasing Medium SLR curve: 0.61m (24 in) to 0.94m (37 in) from 2040 to 2100 (**Table 5-1**; University of Florida 2015). NOAA (2017b) Medium SLR - Likelihood of exceeding 1.49m (58.8 in) by 2100 is 50 percent. **see Best case for precipitation and rainfall	Current trend with no redevelopment densities (accommodation of new populations through an increase in development of existing urban areas) Status quo	Likely at same level Disruption, destruction of habitat from tourism, recreational activities is maintained at current level (status quo) Effectiveness of management on existing protected lands is improved to assure persistence of subspecies and habitat Presence of exotics (fire ants, veg;, feral cats, snakes	Likely as not This scenario is similar to the IPCC RCP 4.5 (Intermediate -low curve). (Appendix C)

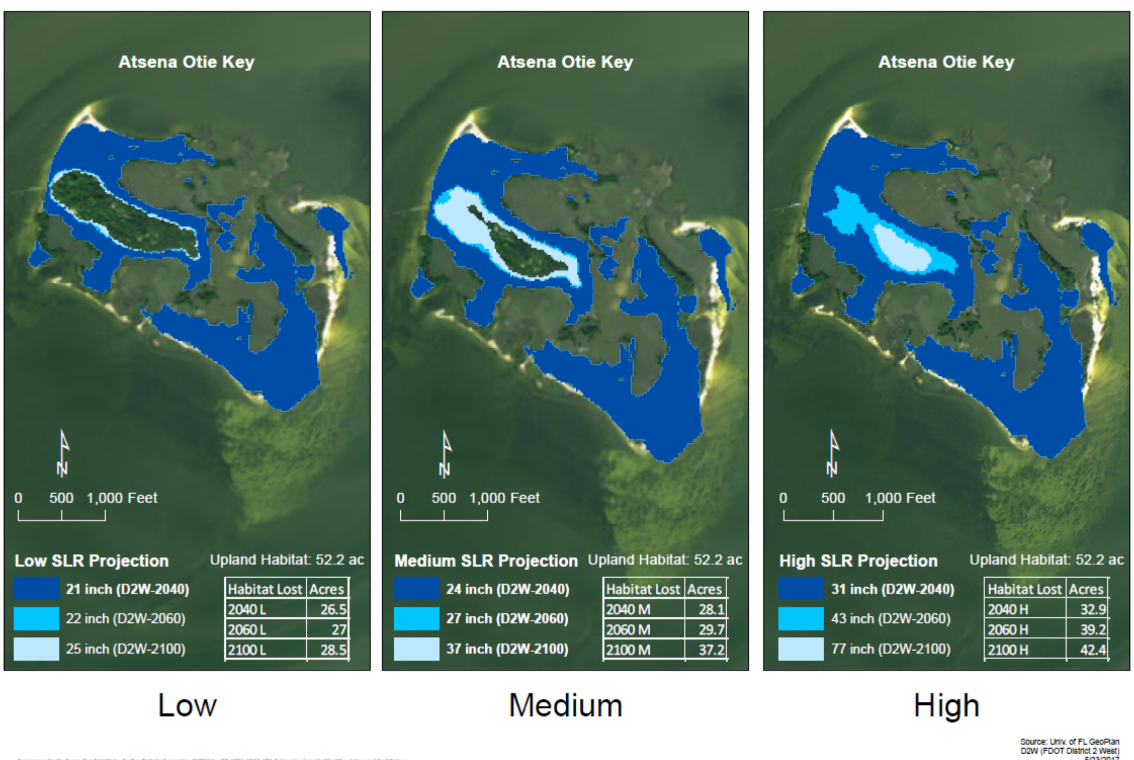
III. Worst Case Scenario

WORST CASE SCENARIO			
Climate change	**Land Development/Habitat Conversion**	**Other Stressors**	**Likelihood of modified GHG emissions (IPCC Guidance)**
High emission temperature, precipitation, SLR Business as Usual High SLR curve: 0.79 m (31 in.) to 1.96 m (77 in) from 2040 to 2100 -- without accelerated rates modeled.* (**Table 5-1**; University of Florida 2015) *At this time, 0.05 to 0.1 percent likelihood chance of exceeding Extreme 2.5 m (8.2 ft) by 2100 from NOAA (2017b, p. 21). Using current accelerated rates. Lower Probability but High Risk/Consequences to this scenario. **see Best case for precipitation and rainfall.	Increase in current population trend and no redevelopment densities (full build-out of available lands)	Disruption, destruction of habitat from tourism, recreational activities is maintained at current level (status quo) Effectiveness of management on existing protected lands is improved to assure persistence of subspecies and habitat Presence of exotics (fire ants, veg;, feral cats, snakes)	Not as likely to exceed this by 2100. Current future projection gives a 0.05 to 0.1 percent likelihood of being exceeded by 2100. Does not rule out reaching it beyond 2100. This scenario is similar to the IPCC RCP8.5 (High curve). (Appendix C)

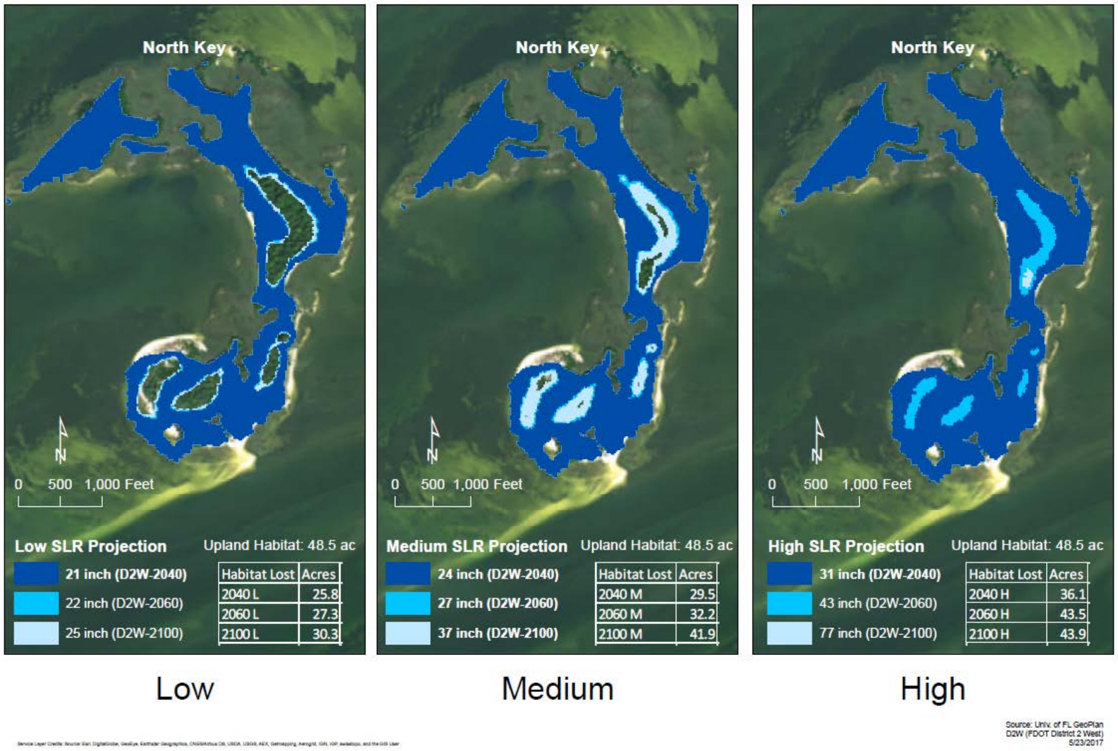
Low, Medium and High 2040 to 2100 SLR Projections for Cedar Key and Way Key (Univ. of FL 2015)



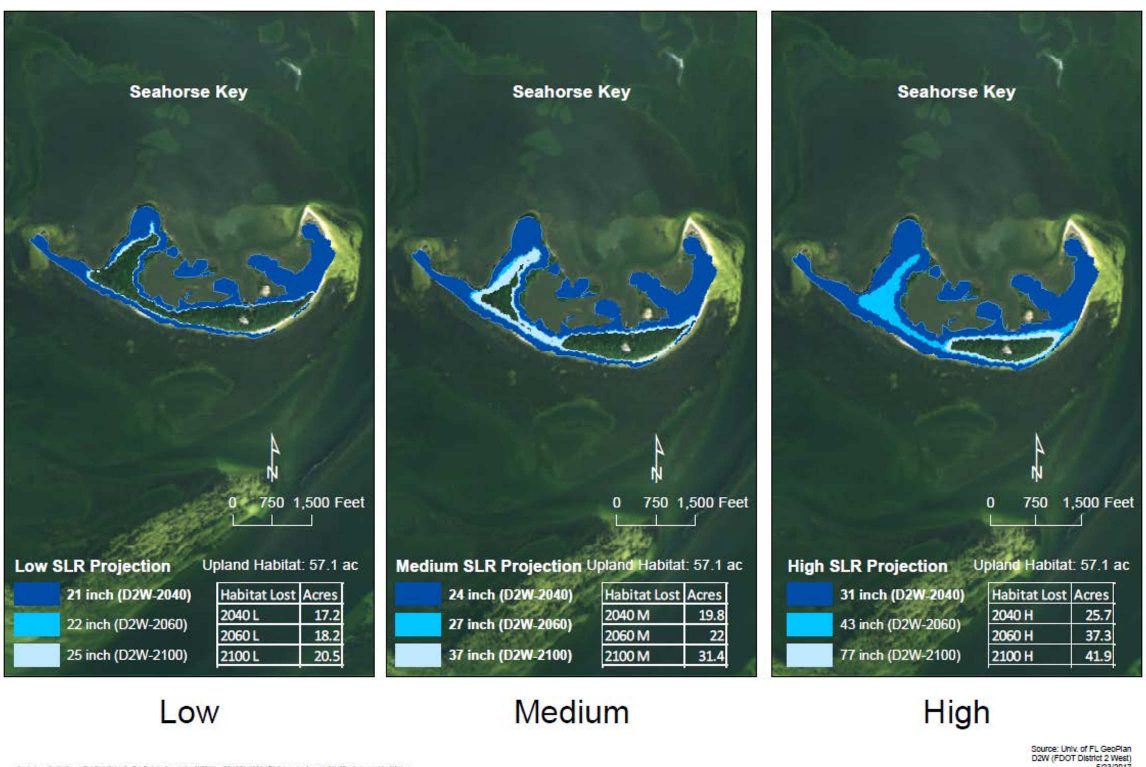
Low, Medium and High 2040 to 2100 SLR Projections for Atsena Otie Key (Univ. of FL 2015)



Low, Medium and High 2040 to 2100 SLR Projections for North Key (Univ. of FL 2015)



Low, Medium and High 2040 to 2100 SLR Projections for Seahorse Key (Univ. of FL 2015)



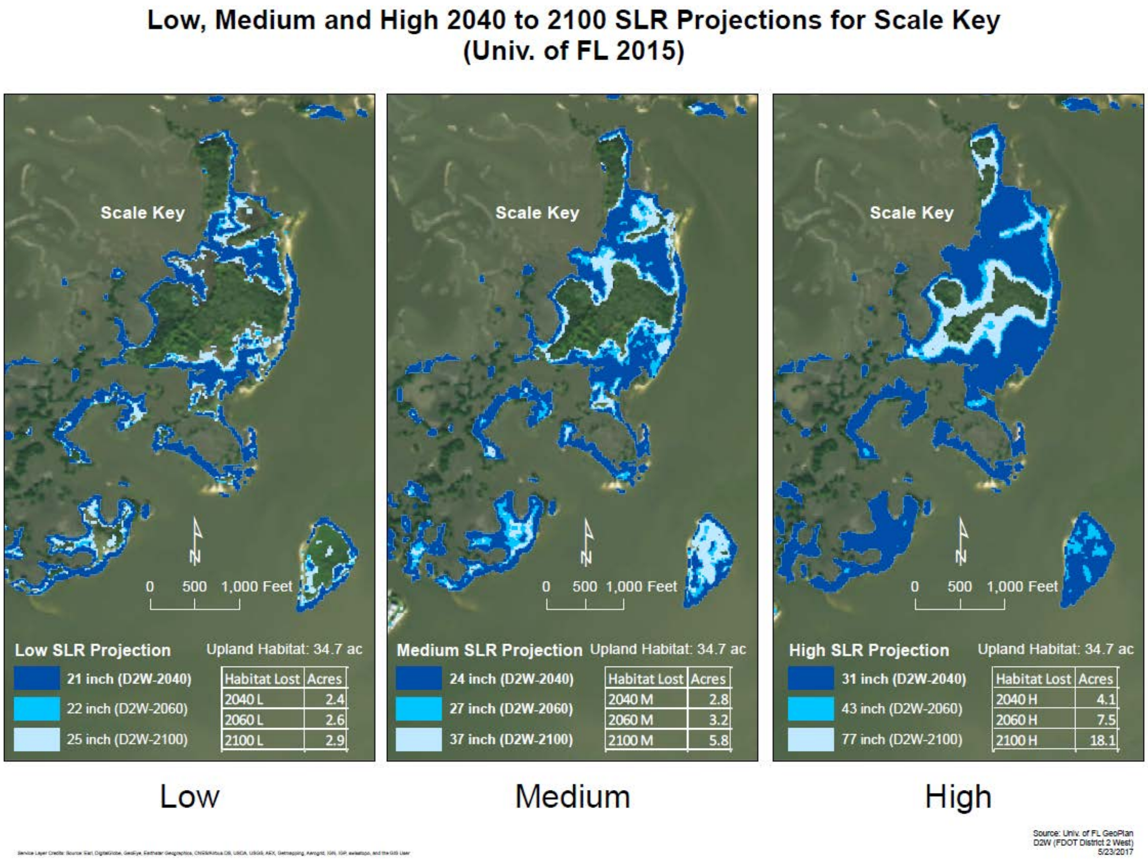


Figure 5-2. Low, Medium and High 2040 to 2100 projected sea level rise curves used, respectively, in describing the "Best", "Medium" and "Worst" case scenarios for Cedar Key/Way Key, Seahorse Key, North Key, Atsena Otie Key, and Scale Key.

5.2.1 Projected Changes in Temperature and Precipitation

The future scenarios include the projected changes in temperature and precipitation from climate change in the central FL region. The projected increases in average annual temperature by the late 21st century (compared to the late 20th century) vary from +3 to +7° F (statewide depending on location and the emissions scenario used). Extreme heat events in FL are projected to increase relative to 1986-2005. By the late 21st century, the average temperatures on the hottest days will be 3° F to 8° F hotter. Due to the already released, human-induced emissions of GHGs present in the environment, another +0.5° F increase in surface air temperature would be expected, even if there was a sudden end to all human-induced GHG emissions (Carter et al. 2014, p. 25). From 2041 to 2070, the FL coastal area is projected to experience approximately 30 to 40 more days/year with temperatures above 95° F compared to recent historic levels (1971-2000) (**Figure 5-3**).

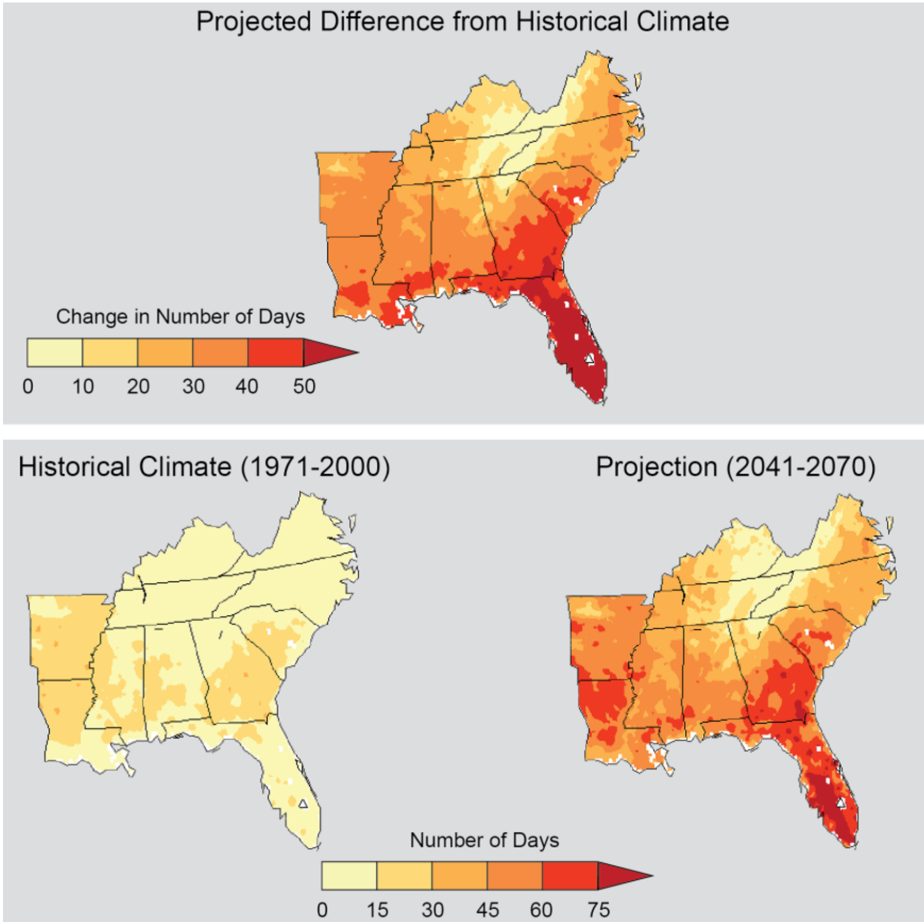


Figure 5-3. Projected average number of days/year with temperatures above 95° F for 2041-2070 compared to 1971-2000. (Carter et al. 2014, Figure 17.4, p. 399).

Precipitation projections are less certain, but many models project increases in precipitation during the fall and winter across central FL (USFWS 2017, pp.2-5). Projections of future changes in precipitation show substantial shifts in where and how precipitation will fall. Models are in agreement regarding changes in tropical storm and hurricane rainfall events. Greater rainfall rates are expected with about a 20 percent increase near the center of storms. Scientists continue to research the expectation of precipitation changes in other severe storms (USFWS 2017, pp 4-5). Dry consecutive days are expected to increase up to 20 percent in central Florida by 2100. While dry conditions are preferred for the Cedar Key mole skink, extreme conditions (lack of rainfall and increased temperatures) are detrimental. For example, prolonged periods of drought or decreased precipitation across a coastal ecosystem create losses in vegetative cover and an increased risk to mole skinks due to desiccation.

Storm Events

Models are in agreement regarding changes in tropical storm and hurricane rainfall events. Greater rainfall rates are expected with about a 20 percent increase near the center of storms. Scientists continue to research the expectation of precipitation changes in other severe storms (USFWS 2017, pp 4-5). Tropical storms and hurricanes are projected to be fewer in number but stronger in force, with more Category 4 and 5 hurricanes (Walsh et.al. 2014, p. 20). Almost all existing studies project greater rainfall rates in hurricanes in a warmer climate, with projected increases of about 20 percent average near the center of hurricanes (USFWS 2017, p. 7). Stronger storms (increased magnitude) and with heavier downpours are considered "*very likely*" based on the IPCC (2013, p. 7).

5.2.2 Population Growth and Development

The July 2016 estimated human population of Levy County, FL was 39,961 individuals, a 2.1% decrease from the April 2010 population estimate of 40,801 (United States Census Bureau [U.S. Census Bureau] 2017). The estimated density from 2010, the most recent census, was 94.5 people per km^2 (approximately 36.5 people per mi^2) (U.S. Census Bureau 2017). The current estimated population is 31% less than the estimated 2060 population of 57,139 people made by Carr and Zwick (2016, p.28).

The inhabited areas of the Cedar Keys are comprised of 525 acres of incorporated and unincorporated uplands on four of the 25 upland islands (1,200 upland acres). Cedar Key, Way Key, Havens Key, and Rye Key have an estimated population of 700 (Frank et al 2014, p. 47). There are 540 single family houses, 225 condominium units, 40 mobile homes, 5 multi-family parcels, 34 commercial units, an airport complex and 380 remaining undeveloped residential parcels (Frank et al 2014, pg. 81).

The current growth rate for Levy County is considered "medium" compared to other Florida counties (Carr and Zwick 2016, p.28). The population grew 15.6 %, from 34,450 in 2000 to 39,832 in 2016 (U.S. Census Bureau 2017). As described above, there was a 2.1% decrease between 2010 and 2016. An assessment of the FL Keys by Hoegh-Guldberg (2010, p. 14) assumed the population is directly related to the remaining land area and, as land area is reduced, the number of persons would be expected to decline. A similar scenario is expected for the Cedar Keys and other Florida island communities.

Based on this information, feasible population growth scenarios include the 1) continued increase in population, 2) no change in current population (increases and reductions maintain current population), or a 3) decline in the population. In terms of population increases, Carr and Zwick (2016, p. 9) presented two alternatives. One is the current trend in which new populations are not accommodated to the existing urban areas. That is, growth has some capability of moving into new areas because of the density limitations in the existing urban areas. The alternative is the use of "redevelopment areas". This is the accommodation of new populations "through an increase in the densities of existing urban areas" (Carr and Zwick, 2016. p. 9). This 2070 alternative allows more people in already existing, urban areas, reducing new development into undeveloped areas. Despite the alternatives to increasing density in some areas to reduce development in more undeveloped areas, the Cedar Keys still has a limited carrying capacity, 380 remaining undeveloped residential parcels.

It is possible with the predicted population growth in Levy County; no vacant land in the Cedar Keys would remain. This information does not consider the thousands of people who visit the Cedar Keys as tourists and temporary visitors each year. The increase in the human population and consequent development and pressures this exerts on the developed islands of the Cedar Keys is expected to intensify as inundation and increased flooding events occur. Inundation and increased incidences of flooding events will trigger people to move to higher ground. At some point, the population could be expected to decline in order to accommodate the loss of land mass and consequential negative effects on property values and the economy (Hino et al. 2017, entire; Zhang et al. 2011, pp. 9-17). While population increase is a stressor on the natural habitats needed by the Cedar Key mole skink, this affects the developed islands of the Cedar Keys, approximately half of the upland habitats. The remaining islands and the other half of the available habitat are conservation lands that are managed as natural islands. The unchecked stressor is the impact of SLR and loss of habitat for the subspecies across the range.

5.3 Expected Changes; Implications to Resiliency – Redundancy - Representation

The islands of the Cedar Keys are of sand origin. The total land area of sandy soil uplands is approximately 1,200 acres; the eight islands where Cedar Key mole skinks have been documented encompass 752.9 acres of those sandy soil upland habitats. There are an additional 19 islands (generally smaller with lower elevations) that have not been surveyed, 420.3 acres.

The preferred habitats for the Cedar Key mole skink have been identified as beach berm and coastal maritime hammock and the sandy soils in the Cedar Keys are identified as Orsino Fine, Paola Fine, Pompano Fine, Zolfo, and Immokalee Fine sands. The eight islands documented with Cedar Key mole skinks were analyzed according to expected losses from projected sea level rise using the University of Florida (2015) Low, Medium and High SLR scenarios (**Table 5-3 and 5-5**). These SLR projections are in the mid-range of existing modeled SLR projections (see **Appendix D**), but the scenarios are specific for the Big Bend coast of Florida that includes the Cedar Keys. In the remainder of this section, calculations of land loss within the Cedar Keys are of the islands where Cedar Key mole skinks have been documented, approximately two thirds of the total upland habitat of the Cedar Keys.

Table 5-5. Cedar Key mole skink sandy soil upland habitat (islands of occurrence) under the Low (2040), Medium (2060) and High (2100) projected inundation curves for the Cedar Keys – Big Bend of Florida.

Projected SLR Low(L),Medium(M), High (H)		**Total Sandy Soil Upland Habitats acres**	**Inundated acres**	**Percent Inundated**
		752.9		
0.53 m (21 in)	2040L		100.6	13%
0.61 (24)	2040M		113.0	15%
0.79 (32)	2040H		148.9	20%
0.56 (22)	2060L		105.4	14%
0.69 (27)	2060M		127.9	17%
1.09 (43)	2060H		222.0	29%
0.64 (25)	2100L		117.4	16%
0.94 (37)	2100M		191.0	25%
1.96 (77)	2100H		464.4	62%

Low-Medium-High SLR inundation projections

To reiterate, the University of Florida (2015) SLR curves are in the mid-range of existing modeled SLR projections (**Appendix D; i.e.** NOAA (2017b) SLR projections downscaled regionally curves is higher). In the best case future scenario, the Low SLR, for the Cedar Key mole skink, 13 to16 percent (100.6-119.3 acres) of the total sandy soil upland habitats are expected to be inundated in from 2040 to 2100 (**Table 5-5**). The Medium SLR projects a 15 to 24 percent (113.0-182.8 acres) of the land is inundated between 2040 and 2100 and the High SLR scenario project a 20 to 62 percent (148.9-464.4) of land inundation between 2040 and 2100.

Under all future scenarios, except for the 2100 High, 31 percent of the uplands will be inundated (**Table 5-5**). Under all scenarios, except the 2100 High, more than 50 percent of upland habitat becomes inundated on four of the eight islands of occurrence (**Appendix D**). Under the 2100 High SLR scenario, all but one of the islands loses more than 50 percent of the uplands. **Figure 5-2** provides maps illustrating each trajectory scenario of inundation for each island where Cedar Key mole skinks have been documented and includes acreages of inundation under each scenario. There is some uncertainty on the timing of inundation levels as they are projected into the future. A 21 to 77 inch inundation may be experienced from 2040 to 2100, depending on the rate of SLR (**Table 5-1 and Figure 5-1).** Therefore, despite some uncertainty on the timing of the inundation, it is important to understand these implications between different levels of SLR to the land mass, upland habitat, and sandy soils.

The Low SLR curve is considered to have a near one hundred percent probability of being exceeded (NOAA 2017b, p. 33). The best case scenario would be to not reach or have no more than this expected inundation. These projections may be conservative as they do not yet incorporate recent adjustments in the modeling for the accelerating rate of global and regional SLR. Under the NOAA (2017b) projections which do account for the accelerated SLR rate (Appendix D), the best case scenario projects a higher range of inundations, during this same time. To reiterate, the observed SLR is currently trending on the high end of the curves (University of Florida 2015) (Compact 2002, p. vii). It has been noted that SLR may occur in rapid pulses rather than gradually (Compact 2012, p.13) and that SLR inundation curves show a non-linear behavior (Zhang et al. 2011, p. 18). Prior to the acceleration tipping point, “direct and dramatic evidence” of SLR may not be evident but beyond which the rates of inundation accelerate rapidly (Zhang et al. 2011, pp.14-15, 18).

The SLR projections predict inundation only and do not model the complex set of shifts in habitats that are anticipated to be triggered over time as the effects of SLR are experienced. Vegetation is expected to convert more towards tidal and salt tolerant species with fewer hammock and buttonwood species. Habitat and human relocation “upland” and inward is projected as everything living is pushed by a rising sea and its impacts to higher and drier grounds. Four of the islands where Cedar Key mole skinks have been documented are within 2 miles of the mainland of Florida. With recognized potential for rafting to new locations due to storm events and SLR, investigations into the potential of a genetic introgression between the Cedar Key and peninsular mole skink subspecies on the mainland is a high priority exercise to understand the long-term status.

To provide perspective on the direct impacts of SLR on the three genetically- identified populations on Seahorse Key, North Key, and Scale Key (all undeveloped islands and protected as conservation lands within the Cedar Keys NWR), the land area and percentage of area lost at each of these Keys under each of the scenarios are provided in Appendix F. Seahorse Key (57.1 ac) is projected to lose 36 and 73 percent of its land mass at the 2100 Low and High SLR trajectory of 43 and 77 inches of inundation, respectively . Approximately 30 and 45 percent of the key is projected to be inundated with a 2040 Low and High SLR, respectively. North Key (48.5 ac) is projected to lose 62 and 91 percent with 2100 Low and High SLR trajectory of 43 and 77 inches of inundation; and 61 and 74 percent of the key is projected to be inundated with a 2040 Low and High SLR, respectively. Scale Key (34.7 ac) is projected to lose 17 and 52 percent with 2100 Low and High SLR trajectory of 43 and 77 inches of inundation; and 7 and 12 percent of the key is projected to be inundated with a 2040 Low and High SLR, respectively. Slight differences in elevation and topography are two factors which account for these differences in inundation. Models of SLR inundations generally indicate the Cedar Keys islands that persist longer are larger in size that also have larger areas with high elevations which includes Cedar Key and Way Key.

5.3.1 Recorded Observations and Inundations

There are a total of 52 vouchered and unvouchered records that total less than 100 individuals documented. Forty-two records are historical (1951-1988) and 10 have been during surveys of beaches since 2000. Most of the records that have location information state similar collection locations: was on the beach; at the edge of beach; under debris at high waterline on beach; and under tidal wrack. One outlier is the collection at the Cedar Key Airport under dead grass adjacent to the runway.

Inundations of the historical and current skink data points under the various SLR projections are expected under all scenarios as the Cedar Key mole skink documentations have almost entirely been in the transition zone from the high tide beach to the adjacent upland habitat. The only vouchered specimens collected in inland island habitats were those collected under dead grass adjacent to the runway at the Cedar Key Airport. This explicitly points out the need for further surveys of Cedar Key mole skinks to gather a better understanding of their use sandy soil island habitats such as the maritime hammock.

Increased SLR and inundation may increase the incidence of possible random dispersal from rafting, to other islands or the mainland and assist in survivability of some skinks when their habitat becomes inundated. However, the effectiveness of this dispersal mechanism would ultimately be expected to worsen with inundation as land mass decreases and the distance between land increases.

5.3.2 Level of Certainty or Uncertainty

As mentioned earlier, there is a high level of certainty in exceeding the low projections of SLR (near 100%). Under the global likelihoods of SLR, (IPCC (2013, p.7) states the “increased incidence and/or magnitude of extreme high sea level” is very likely. Heavy precipitation events are “very likely” over mid-latitude and wet tropical regions. Warmer days and nights and over most land and fewer cold days and more frequent hot days are "Virtually Certain" (IPCC (2013, p.7). The increase in the frequency and duration of warm spells/heat waves over most land areas is "very likely" (IPCC (2013, p.7).

5.3.3 Key Considerations of Future Condition

a) Lag time on SLR - It is not possible to reverse what trend is already underway based on the levels of GHG emissions already released into the atmosphere (Deconto and Pollard, 2016, entire). This is why there is a high certainty in the exceedance of the low curve (NOAA 2017, p.33; Compact 2012, p. 5).
b) An accelerated rate of SLR is being observed and is expected to increase. This is why NOAA increased the low and high expected ranges
c) Tipping points in inundation are expected and have been predicted to occur around 2035-2060 (Zhang et al. 2011, p. 15). Increases in SL are occurring gradually and then the projected curves steepen which indicates that the inundation rate experiences an abrupt increase.

Table 5-6. Cedar Key mole skink population resilience, and subspecies redundancy and representation under future scenarios**.**

Population Resilience	**Redundancy**	**Representation**
Reduced resiliency expected to occur across all future scenarios. The level of reduced resiliency becomes a matter of scale in timing and intensity of SLR. Reduction or loss of suitable habitat and dry soils are main reason for reduced skink abundance and population resiliency under future scenarios. Abundance numbers are low; expected to remain low or become reduced. High variations between islands exist in the projected inundation levels and timing of inundations to beach habitat and lower elevations. When ground cover is washed out, the insect abundance may	Reduced redundancy expected with all scenarios. Generally expect loss of habitat and inundation impacting all the islands of the Cedar Keys. Have yet to survey 19 additional islands of the Cedar Keys. Most of these islands are smaller with low elevations. Have yet to survey the adjacent mainland as some occupied islands are within 2 miles of the sandy soil mainland habitats. Generally, larger islands retain habitat longer than smaller ones. Not at all times the case: offshore islands of the Cedar Keys may be impacted by storm events than those that are surrounded by salt marsh and oyster bars or are in	Current condition of low genetic and environmental diversity. Little breadth to rely on if some lost. Not a large difference in genetic diversity, habitat types, elevation. No significant "movement to higher ground". Any inland movement or movement to drier/higher areas is temporary. Several of the islands of the Cedar Keys are surrounded by water so inundation can occur along all locations (not just along a coast). Low genetics does not assist in sustainability. If a stressor impacts one, will likely affect all. Stochastic events: For

decrease. When ground cover is washed out, the ability for skink to find cover, nest, and forage is reduced or compromised. The extent and duration of this impact is based on increases to flooding and storm surge and the rate of SLR.	closer proximity to the mainland. A level of redundancy is retained because of the existence of the protected and conversation lands across the range. Although these habitat as well will be impacted by loss due to inundations Shifts in vegetation from drier hammock and beach to tidal vegetation will be expected to reduce the quality and quantity of suitable habitat as SLR continues. Greater storm surge – overwash – is expected to reduce redundancy. Increased occurrence of storm surge and floods with increasing inundations is expected to reduce redundancy as occupied areas become flooded. There will be a decrease in recovery time for habitat and populations from the impacts of hurricanes and strong storms as storm intensity and occurrence of storms increases as predicted. Expect loss of populations and further loss of connectivity. Decreased ability to reach new island if are passively rafting, however the potential for landfall on the mainland would be possible due to the close proximity.	example drought or long term decrease in precipitation levels causes loss of upland island habitats and/or insect food source. This is likely to be a loss experienced across the range of the Cedar Keys. All skinks are susceptible.

5.4 Summary: Resilience, Representation and Redundancy under Future Scenarios

The subspecies future condition is most influenced by the unmanaged and persistent upward trend in SLR. The observed trend in SLR is currently meeting the high curve projected in 2009 global models, and the rate of SLR is also found to be accelerating (NOAA 2017b, p. 25; Carter et al. 2014, pp. 401-403; Park and Sweet 2015, entire). At this time, any global management actions currently in place towards the control of GHG emissions will not curb or reverse the ongoing trend. Even if stringent and immediate reductions in GHG emissions were underway, there is still a lag in response such that there is 100 percent chance of exceeding the SLR projected under the current "Low" (best case) scenarios (NOAA 2017b, p. 33).

Given the subspecies' current condition (3Rs) and the impacts that the subspecies is expected to experience under the future scenarios, reductions in population resiliency, subspecies redundancy, and subspecies representation are expected. Even under the best future scenario, that would include the low curve of SLR and a reduction in population on the Cedar Keys, adverse impacts in the form of patchily-distributed habitat or the loss of suitable habitat and soil losses are expected. A further lack of connectivity and dispersal capabilities of individuals between the islands is expected. It is possible that this has already occurred and that there is a genetic introgression zone with the peninsular mole skink. These impacts are based on projected inundation of the land. It is extremely likely that impacts in the form of storm surges and flooding events (saltwater intrusion) will be taking place prior to the loss of the land from SLR. However, due to the close proximity to the mainland of Florida, several islands within 2 miles, Cedar Key mole skinks have similar probabilities to raft to sandy soil habitats on the adjacent mainland.

Based on the analysis that incorporated regional SLR projections, we expect loss of 13 to 20 percent (2040), 14 to 29 percent (2060), and 16 to 62 percent (2100) of the 305 ha (752.9 ac) estimated to be suitable habitat on the eight islands of occurrence. However, land mass reduction may be offset with island creation due to inundation of the adjacent mainland. Abundance numbers are likely to decrease on occupied islands according to the severity of inundation and loss of habitat and soils. Even in the low SLR curve (best case scenario), a loss of about 13 percent of the suitable habitat for the Cedar Key mole skink are projected to be loss to inundation. This scenario is imminent according to the projections, current trend and lack of intervening management actions (NOAA 2017b, p. 21).

Habitat loss occurs exponentially across the Low, Medium and High SLR scenarios. At 21-22-25 inches of SLR (2040 Low-Medium-High), approximately 13-15-20 percent of beach berm and coastal hammock habitat can be expected to be inundated; however, more than fifty percent of uplands of three of the occupied islands will be inundated. By 37 inches of inundation (2060 Medium), 25 percent of the skinks' suitable habitat is projected to be inundated, but the three previously mentioned islands may not exist. This loss and consequent fragmentation of habitat is expected to decrease population size (Dubey and Shine 2010, p. 886). As mentioned, the worse-case scenario has an approximately 0.05 to 1.0 percent chance of being exceeded by 2100 according to the present models (NOAA 2017b, p. 21 This low occurrence probability is based on the uncertainty of what will occur in the future as SLR is projected to reach a tipping point and rapidly accelerate. However, loss of existing islands may be offset with the creation of new islands due to inundation of the adjacent mainland.

The probabilities of the moderate and worst case scenario from occurring are lower compared to the best case scenario. There is a 50 percent chance the moderate scenario, and a 0.05 to 0.1 percent chance the worst case scenario will be exceeded by 2100. The probabilities may be low, but the consequences for the Cedar Key mole skink are high under these scenarios. While the scenarios appear to only gradually (over many years) impose impacts to the Cedar Key mole skink, an abrupt acceleration in SLR are expected. Most importantly, no mechanisms are currently in place, globally or regionally, which indicate an aggressive or immediate reduction in global GHG emissions. Regardless of the time frames used in the modeled projections, SLR and other climactic changes will continue to progress and further impact the Cedar Key mole skink until interventions are in place to minimize or reverse these stressors.

To assess Cedar Key mole skink viability, we used the three conservation biology principles of resiliency, representation, and redundancy (Shaffer and Stein 2000, pp. 306–310). Briefly, resiliency supports the ability of the species to withstand environmental and demographic stochasticity; representation supports the ability of the species to adapt over time to long-term changes in the environment (for example, climate changes); and redundancy supports the ability of the species to withstand catastrophic events (for example, droughts, hurricanes). In general, the more redundant and resilient a species is and the more representation it has, the more likely it is to sustain populations over time, even under changing environmental conditions.

Resiliency
The Cedar Key mole skink may experience reductions in population resiliency across all future scenarios due to SLR and climate change-associated factors. During historical and current survey efforts, the Cedar Key mole skink has been found in low numbers on eight islands in the Cedar Keys, and future occurrence data are expected to show similar (or reduced) numbers and distribution on these islands. However, there are an additional 19 islands with suitable habitat that have not been surveyed, and future survey efforts could find additional individuals or populations on these islands. Based on preliminary research, there are at least three genetically distinct populations and additional individuals (not yet identified into populations) occurring across separate islands; however, little information currently exists on the abundance or growth rate of these populations. When considering the subspecies' needs, there will be a reduction in suitable habitat from inundation which may lead to a reduction in population abundance and distribution. As ground cover becomes inundated or washed away, the Cedar Key mole skinks' ability to find cover, forage for insects, and nest in dry, unconsolidated soils will be reduced.

Redundancy
Despite the subspecies' occurrence across multiple islands, there are data gaps on the subspecies' actual range-wide distribution and abundance. Historically, the Cedar Key mole skink has been found in low numbers on three islands: Cedar Key, Seahorse Key, and Way Key. Recent surveys documented the subspecies from Cedar Key and Seahorse Key and from five new island locations: Atsena Otie Key, Deer Island, North Key, Scale Key, and Snake Key; Way Key has not been recently surveyed. As previously mentioned, there are multiple islands that have not been surveyed for the Cedar Key mole skink, and future surveys efforts could provide certainty

into the actual range-wide distribution of the subspecies. Across all future scenarios, the Cedar Key mole skink may experience reduced redundancy. Due to SLR and climate change-associated factors, we expect some habitat loss and inundation across the known range of the Cedar Key mole skink, but we expect some level of redundancy to be retained due to the continued existence of 71 to 87 percent of the suitable habitat (under all except the 2100 SLR high projection (38% habitat) on the eight islands into the future.

Representation

The Cedar Key mole skink has limited genetic and environmental variation within the Cedar Keys, and there is no behavioral or morphological variation within the subspecies. The entire subspecies is represented from a chain of coastal islands within approximately 50 mi^2 range. The Cedar Key mole skink may experience reductions in subspecies representation across all future scenarios as suitable habitat on islands becomes inundated. This island subspecies occurs across a narrow geographic and ecological range, and there is no variation in habitat types. The Cedar Key mole skink is represented across only slight elevation differences across the separate islands. Many of the islands are less than 10 ft. in elevation but several of the larger islands with known populations of mole skinks have elevations that range from 15 to 50 ft. The larger islands may provide more persistent habitat due to larger island size, available habitat that can buffer flooding effects, and increased elevation.

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APPENDICES

Appendix A. Florida Keys and Cedar Key Mole Skink Technical Team Working Group

Florida Keys and Cedar Key Mole Skinks Life History Needs and Current Conditions Technical Team Working Group
Alphabetical Order:

Layne Bolen – USFWS biologist; Florida Keys mole skink Team Lead
Billy Brooks – USFWS biologist; Cedar Key mole skink Team Lead

Shana DiPalma – USFWS biologist; cartographer
Adam Emerick – USFWS biologist; Florida Keys Refuge Complex
Kevin Enge – Herpetological expert; Florida Fish and Wildlife Conservation Commission
Andrew Gude – USFWS Cedar Key National Wildlife Refuge Manager
Jonathan Mays – Herpetological expert; Florida Fish and Wildlife Conservation Commission
Katie Mercier – Master's graduate student; University of Central Florida, Department of Biology
Lori Miller – USFWS biologist; meteorologist; climate change specialist
Paul Moler – Herpetological expert; mole skink species expert; Retired Florida Fish and Wildlife Conservation Commission
Dr. Henry Mushinsky – Herpetological expert; mole skink species expert; Retired University of South Florida
Lindsay Nester – USFWS biologist
Dr. Christopher Parkinson – Professor; University of Central Florida, Department of Biology

Florida Keys and Cedar Key Mole Skinks Life History Needs and Current Conditions Technical Team Working Group Workshop held on December 8, 2016.

Appendix B. Current Condition Exposure Table

Activity	Exposure		Biology			Consequences: Individuals		Consequences: Populations	Consequences: Species	A/M/M
Terminal Activity	DIRECT Interaction	INDIRECT Interaction	Resources or Individuals Exposed	Life Stage Affected	Resource Functions	Responses to Exposure	Effects	Effects to Reproduction, Numbers, Distribution	Representation Resiliency Redundancy	
Armoring	crushing	erosion of beach habitat	ind. skinks, sandy beaches	all	shelter	trauma, dispersal	death, E expenditure	decline in #'s	decline in viability	
Development (Commercial/Residential)	crushing	permanent habitat loss, alterations predator/prey	ind. skinks, habitat	all	shelter	trauma, dispersal	death, E expenditure	decline in #'s	decline in viability	
Few, Small, Isolated Pops			ind. skinks	adults		decline in repro.		decline in repro. and distribution	decline in viability	
Dispersal										
Fire Ants	depredation		habitat	eggs?		trauma	death	decline in repro.	decline in viability	
Invasive Vegetation	habitat loss		habitat	all	shelter	dispersal	E expenditure	decline in distribution	decline in viability	
Extreme Weather Events	inundation of habitat, death	decline in habitat suitability, predator/prey/ disease transitions, vegetation shifts	ind. skinks, habitat	all	shelter	sex ratios, thermoregulation, trauma	skewed sex ratios, death	decline in repro and #'s	decline in viability	
Oil Spills	oiling	decline in habitat suitability, alterations predator/prey, loss of habitat	ind. skinks	all	shelter	trauma	death	decline in repro, #'s, and distribution	decline in viability	
Disease/Predators/Parasites	death		ind. skinks	all		disease, infection, trauma	death	decline in repro, #'s, and distribution	decline in viability	
Climate Change/SLR	inundation of habitat	Changes in temp., rainfall, storm frequency/severity, vegetation shifts, salinization of soils, soil type transitions, habitat loss	ind. skinks, habitat	all	shelter	trauma, dispersal	death, E expenditure	decline in repro, #'s, and distribution	decline in viability	
Temperature Change		predator/prey/ disease transitions,	ind. skinks, sand	all	shelter	sex ratios, thermoregulation	skewed sex ratios	decline in repro and #'s	decline in viability	
Change in Rainfall Patterns		vegetation shifts	ind. skinks, sand	all	shelter	sex rations, thermoregulation	skewed sex ratios	decline in repro and #'s	decline in viability	
Storm frequency/severity	inundation of habitat	decline in habitat suitability, alterations predator/prey, loss of habitat, vegetation shifts	ind. skinks and habitat	all	shelter	trauma, dispersal	death, loss of habitat	decline in repro., #'s, and distribution	decline in viability	
Pesticides	reduced fitness, death	reduction in prey availability, 2ndary exposure thru prey	ind. Skinks	adults, eggs?	shelter	trauma, loss of prey availability	death, E expenditure	decline in repro., #'s, and distribution	decline in viability	

Appendix C. Global and regional sea level rise projections used for assessment of future scenarios.

NOAA 2017b						
	Low	Intermediate-low	Intermediate	Intermediate-high	High	Extreme
2020	0.06 m (0.2 ft.)	0.08 m (0.26 ft.)	0.1 m (0.33 ft.)	0.1 m (0.33 ft.)	0.11 m (0.36 ft.)	0.11 m (0.36 ft.)
2030	0.09 m (0.3 ft.)	0.13 m (0.43 ft.)	0.16 m (0.52 ft.)	0.19 m (0.62 ft.)	0.21 m (0.69 ft.	0.24 m (0.79 ft.)
2040	0.13 m (.43 ft.)	0.18 m (0.59 ft.)	0.25 m (0.82 ft.)	0.3 m (0.98 ft.)	0.36 m (1.18 ft.)	0.41 m (1.35 ft.)
2050	0.16 m (0.52 ft.)	0.24 m (0.79 ft.)	0.34 m (1.12 ft.)	0.44 m (1.44 ft.)	0.54 m (1.77 ft.)	0.63 m (2.07 ft.)
2060	0.19 m (0.62 ft.)	0.29 m (0.95 m)	0.45 m (1.48 ft.)	0.6 m (1.97 ft.)	0.77 m (2.53 ft.)	0.9 m (0.3 ft.)
2070	0.22 m (0.72 ft.)	0.35 m (1.15 ft.)	0.57 m (1.87 ft.)	0.79 m (2.59 ft.)	1 m (3.28 ft.)	1.2 m (3.94 ft.)
2080	0.25 m (0.82 ft.)	0.4 m (1.31 ft.)	0.71 m (2.33 ft.)	1 m (3.28 ft.)	1.3 m (4.27 ft.)	1.6 m (5.25 ft.)
2090	0.28 m (0.91 ft.)	0.45 m (1.48 ft.)	0.85 m (2.79 ft.)	1.2 m (3.93 ft.)	1.7 m (5.58 ft.)	2 m (6.56 ft.)
2100	0.3 m (0.98 ft.)	0.5 m (1.6 ft.)	1 m (3.28 ft.)	1.5 m (1.92 ft.)	2 m (6.56 ft.)	2.5 m (8.20 ft.)

Parris et al. 2012				
	Low	Intermediate-low	Intermediate-high	High
2100	0.3 m (0.66 ft.)	0.6 m (1.64 ft.)	1.2 m (3.94 ft.)	2 m (6.56 ft.)

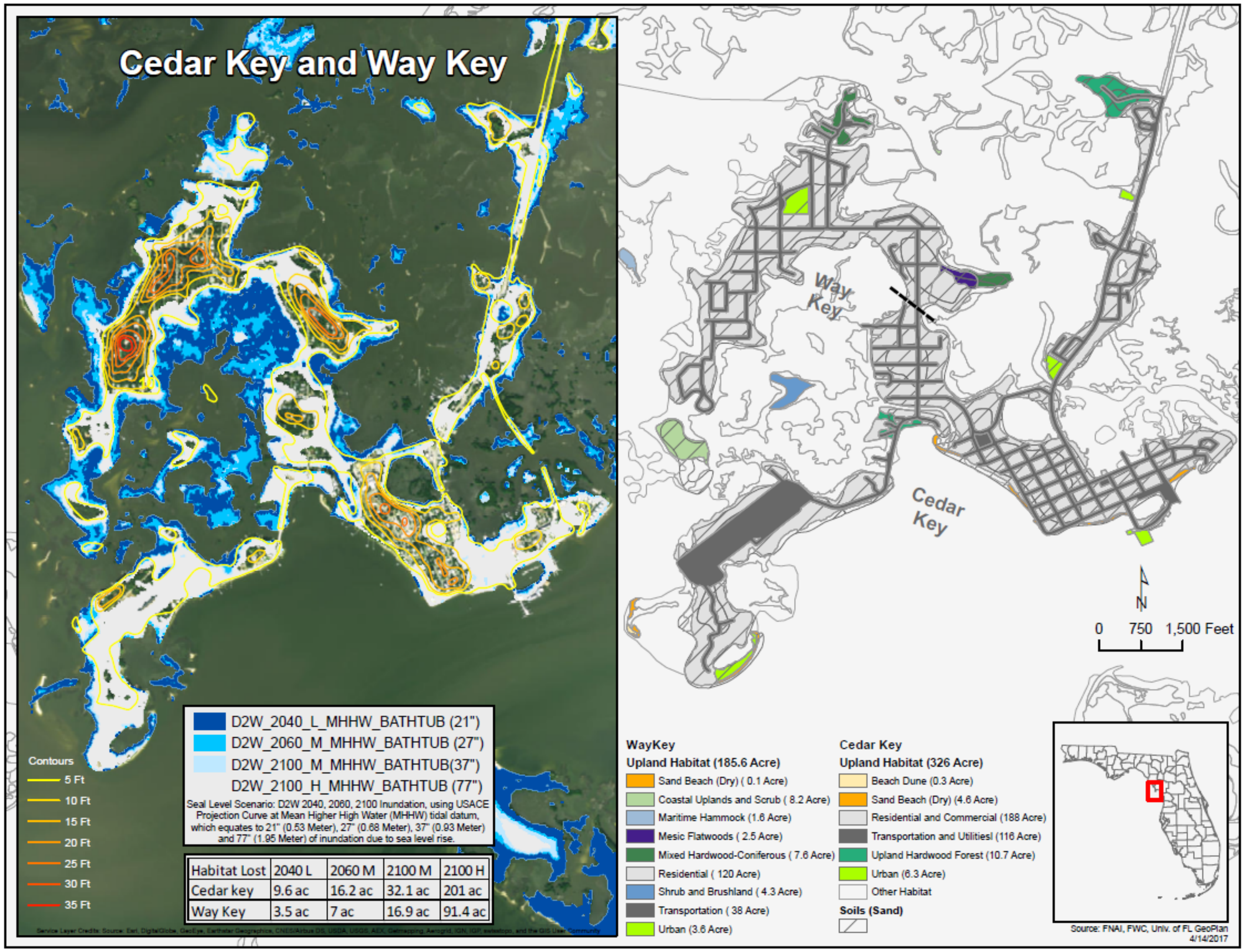
IPCC 2013 RCP – Representative Concentration Pathways (GHG concentrations)				
	Low (RCP2.6)	Intermediate-low (RCP4.5)	Intermediate-high (RCP6.0)	High (RCP8.5)
2046-2065	0.24 m (0.79 ft.)	0.26 m (0.85 ft.)	0.25 m (0.82 ft.)	0.3 m (0.98 ft.)
2081-2100	0.4 m (1.31 ft.)	0.47 m (1.54 ft.)	0.48 m (1.57 ft.)	0.63 m (2.067 ft.)

University of Florida 2015 Using Army Corps of Engineers SLR Projection Curves Estimated Relative Cedar Keys - Big Bend Florida Regional Sea Level Change Projections. meters (in)				
Year	2020	2040	2060	2100
Low	0.1 (4)	0.53 (21)	0.56 (22)	0.64 (25)
Medium	0.1 (4)	0.61 (24)	0.69 (27)	0.94 (37)
High	0.1 (4)	0.79 (32)	1.09 (43)	1.96 (77)

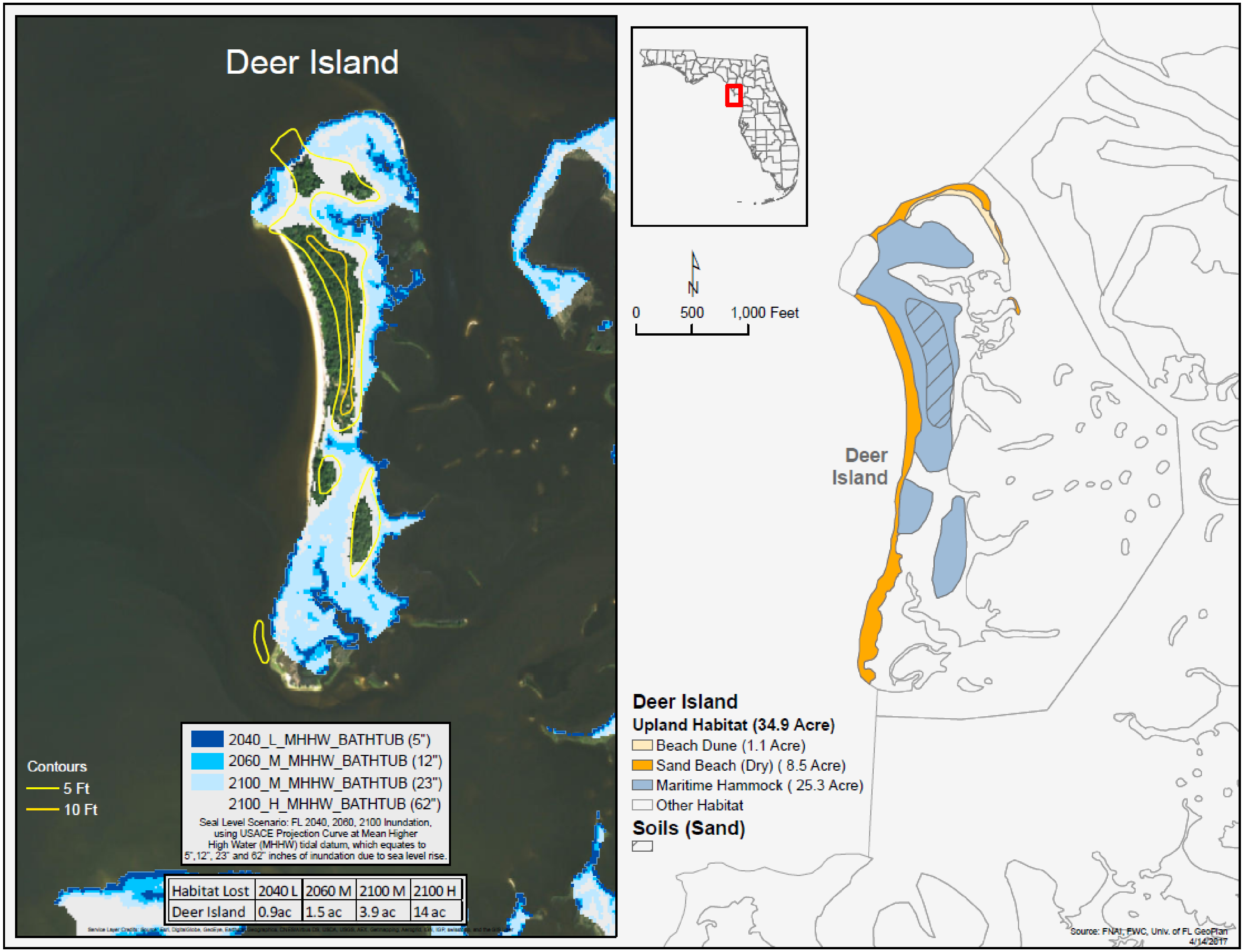
Hall et al. 2016				
	Low	Intermediate-low	Intermediate-high	High
2100	0.4 m (1.31 ft.)	0.7 m (2.3 ft.)	1.3 m (4.27 ft.)	2.1 m (6.89 ft.)

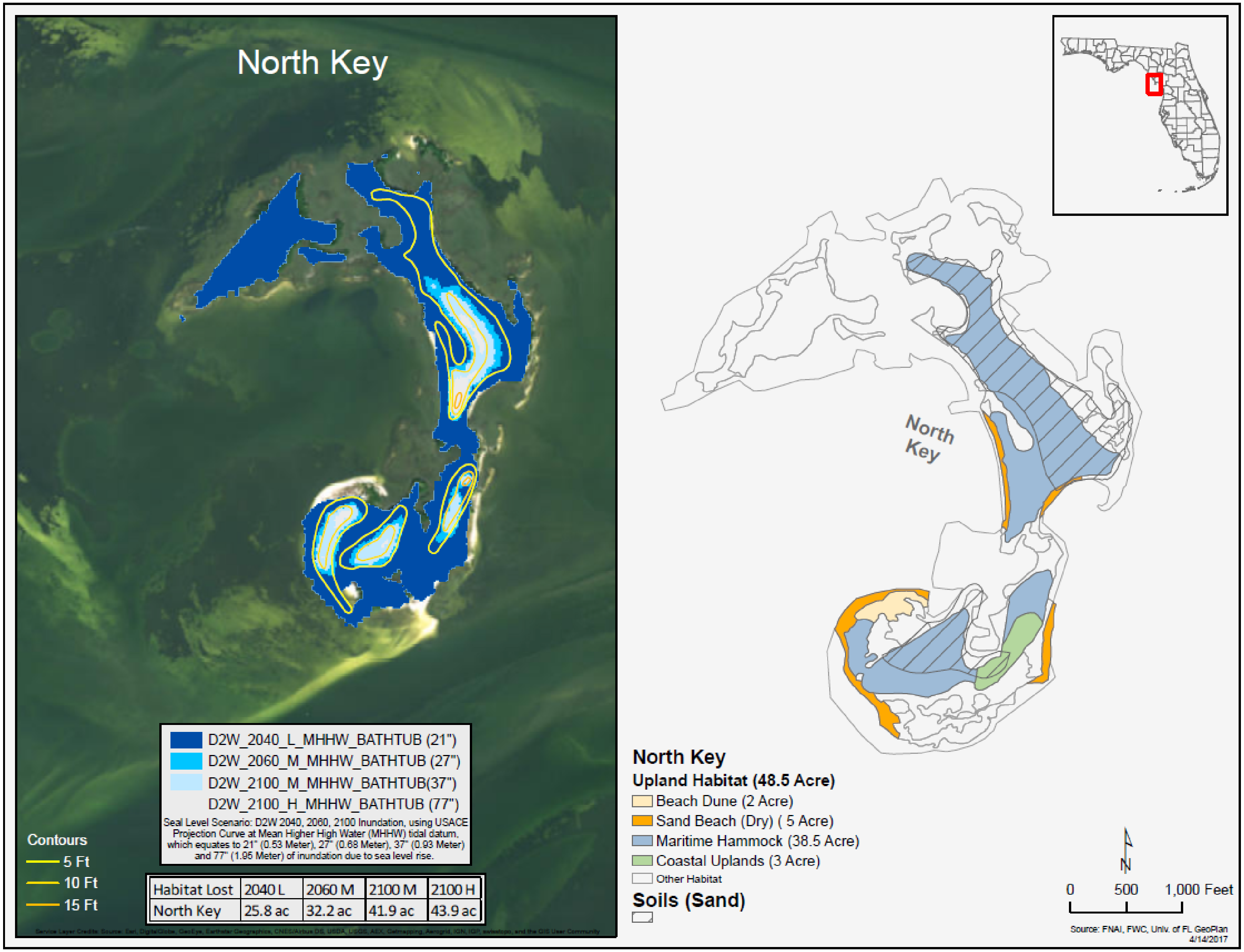
Compact 2015, p. 5			
	IPCC AR5 (median)	USACE High	NOAA High
2030	0.15 m (6 in)	0.25 m (10 in)	0.30m (12 in)
2060	0.36 m (14 in)	0.66 m (26 in)	0.86 m (34 in)
2100	0.79 (31in)	1.5 m (61 in)	2.1 m (81 in)

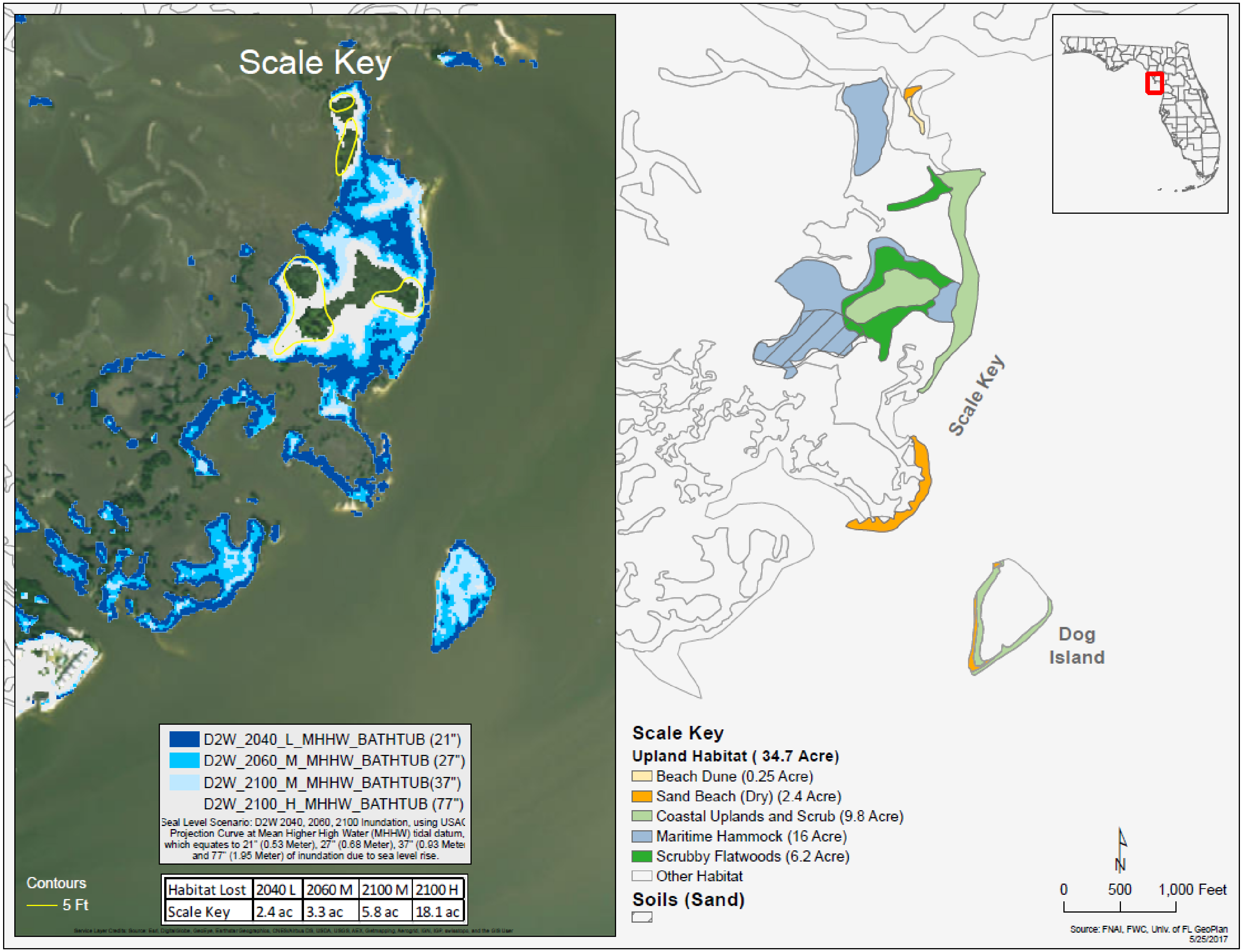
Appendix D. Best, Moderate, and Worst Case SLR projections from 2040 (21”), 2060 (27”), 2100 (37”), and 2100 (77”); upland acreages inundated; elevation contours; and suitable habitats and soils for the Cedar Key mole skink on Cedar Key, Way Key, Deer Island, North Key, Scale Key, Seahorse Key, Snake Key, and Atsena Otie Key.



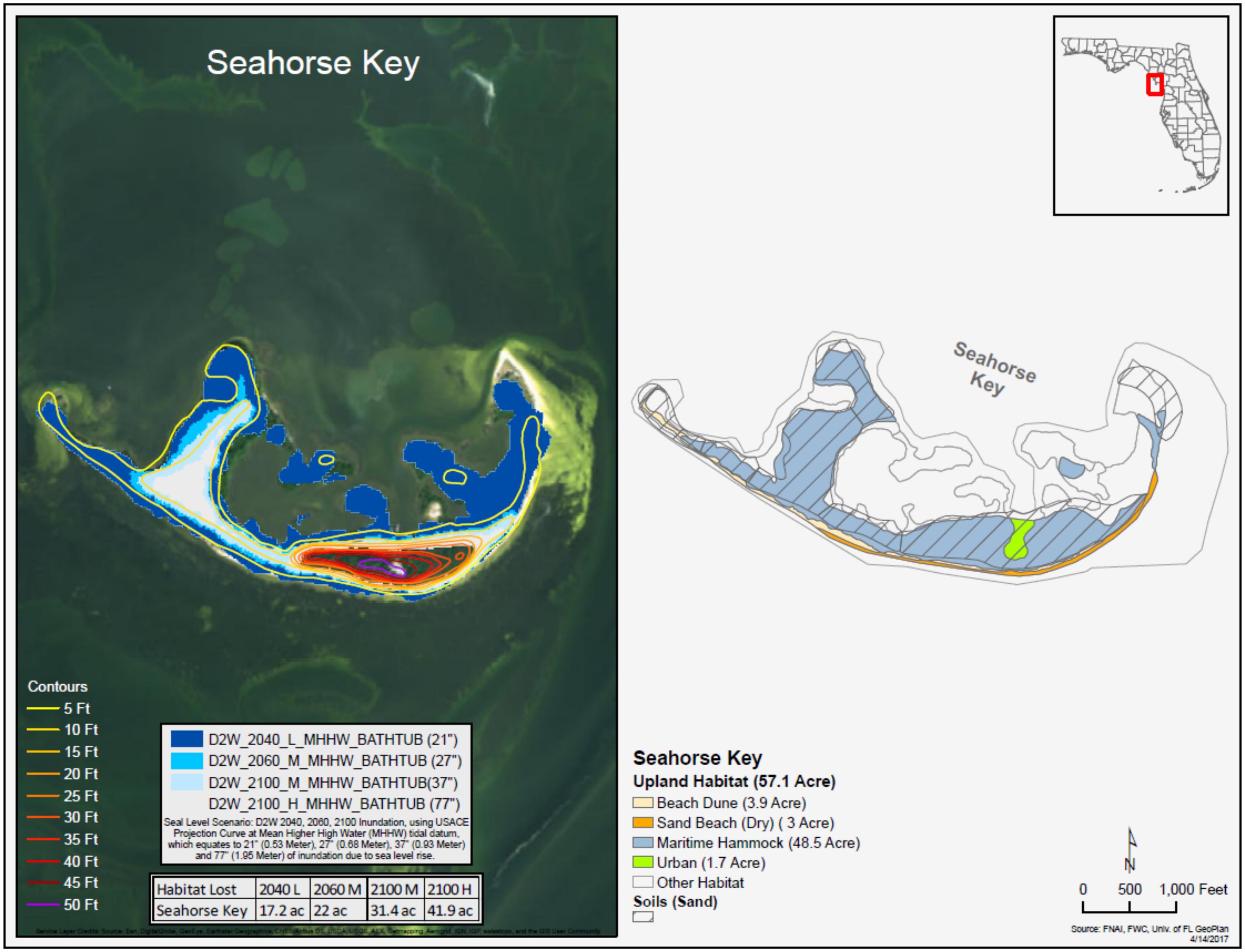
Habitat Lost	2040 L	2060 M	2100 M	2100 H
Cedar key	9.6 ac	16.2 ac	32.1 ac	201 ac
Way Key	3.5 ac	7 ac	16.9 ac	91.4 ac


Deer Island
2040_L_MHHW_BATHTUB (5")
2060_M_MHHW_BATHTUB (12")
2100_M_MHHW_BATHTUB (23")
2100_H_MHHW_BATHTUB (62")
Seal Level Scenario: FL 2040, 2060, 2100 Inundation, using USACE Projection Curve at Mean Higher High Water (MHHW) tidal datum, which equates to 5", 12", 23" and 62" inches of inundation due to sea level rise.
Contours
5 Ft
10 Ft
Habitat Lost | 2040 L | 2060 M | 2100 M | 2100 H
Deer Island | 0.9ac | 1.5 ac | 3.9 ac | 14 ac
N
0
500
1,000 Feet
Deer Island
Deer Island
Upland Habitat (34.9 Acre)
Beach Dune (1.1 Acre)
Sand Beach (Dry) (8.5 Acre)
Maritime Hammock (25.3 Acre)
Other Habitat
Soils (Sand)
Source: FNAI, FWC, Univ. of FL GeoPlan
4/14/2017

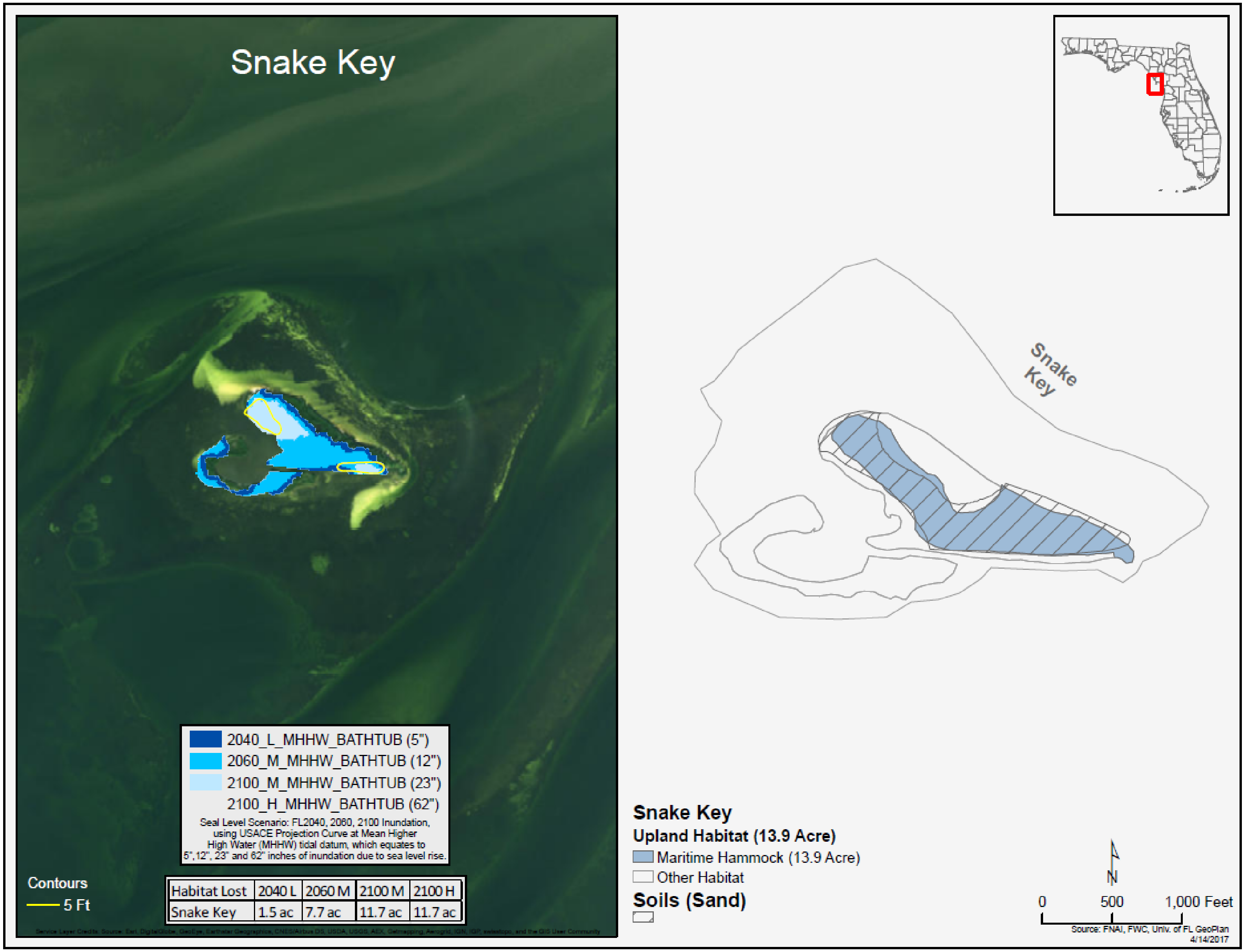

North Key
D2W_2040_L_MHHW_BATHTUB (21")
D2W_2060_M_MHHW_BATHTUB (27")
D2W_2100_M_MHHW_BATHTUB(37")
D2W_2100_H_MHHW_BATHTUB (77")
Seal Level Scenario: D2W 2040, 2060, 2100 Inundation, using USACE Projection Curve at Mean Higher High Water (MHHW) tidal datum, which equates to 21" (0.53 Meter), 27" (0.68 Meter), 37" (0.93 Meter) and 77" (1.95 Meter) of inundation due to sea level rise.
Contours
5 Ft
10 Ft
15 Ft
Habitat Lost | 2040 L | 2060 M | 2100 M | 2100 H
North Key | 25.8 ac | 32.2 ac | 41.9 ac | 43.9 ac
North Key
North Key
Upland Habitat (48.5 Acre)
Beach Dune (2 Acre)
Sand Beach (Dry) (5 Acre)
Maritime Hammock (38.5 Acre)
Coastal Uplands (3 Acre)
Other Habitat
Soils (Sand)
N
0 500 1,000 Feet
Source: FNAI, FWC, Univ. of FL GeoPlan
4/14/2017

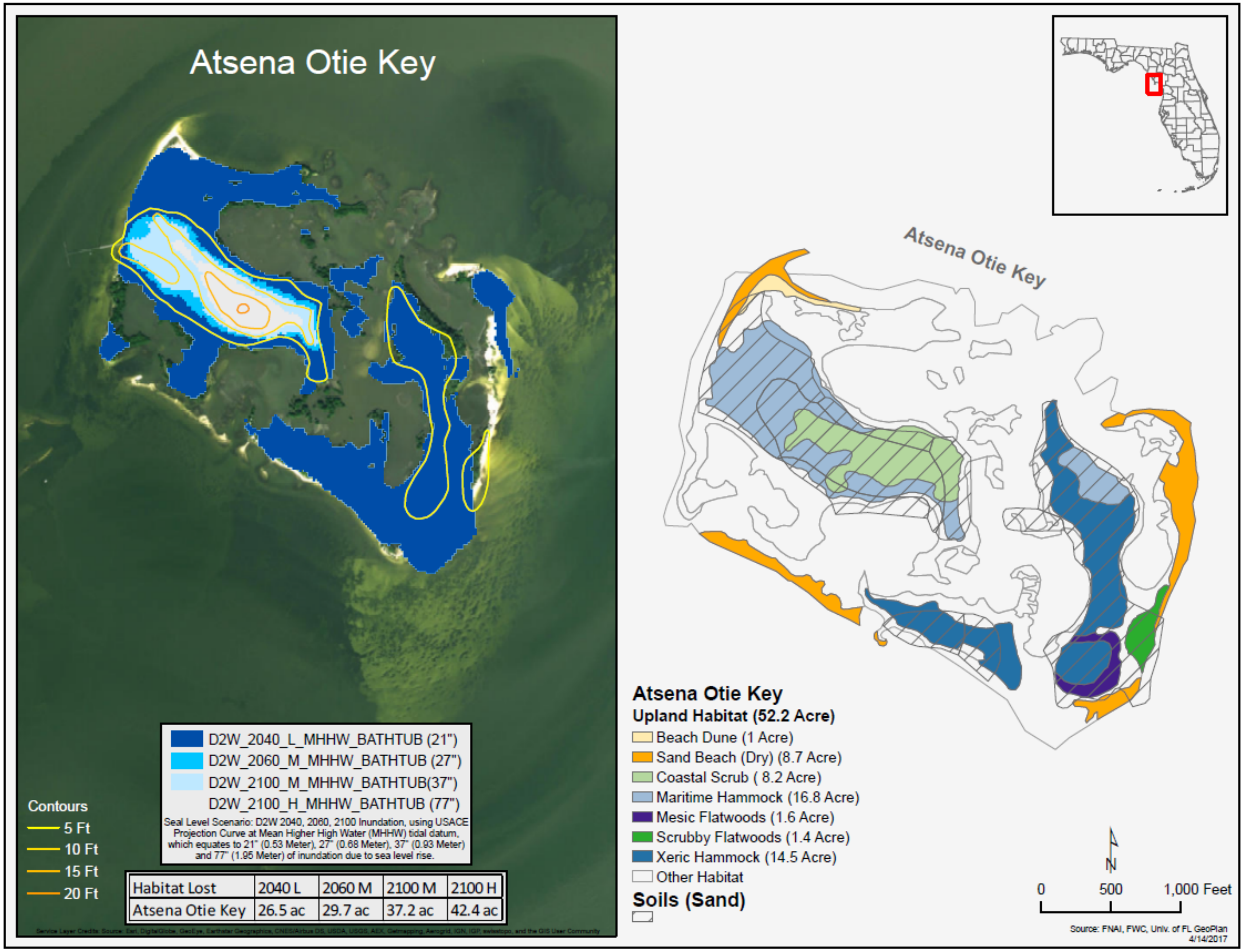


Scale Key
D2W_2040_L_MHHW_BATHTUB (21")
D2W_2060_M_MHHW_BATHTUB (27")
D2W_2100_M_MHHW_BATHTUB(37")
D2W_2100_H_MHHW_BATHTUB (77")
Seal Level Scenario: D2W 2040, 2060, 2100 Inundation, using USAC Projection Curve at Mean Higher High Water (MHHW) tidal datum, which equates to 21" (0.53 Meter), 27" (0.68 Meter), 37" (0.93 Mete and 77" (1.95 Meter) of inundation due to sea level rise.
Habitat Lost | 2040 L | 2060 M | 2100 M | 2100 H
Scale Key | 2.4 ac | 3.3 ac | 5.8 ac | 18.1 ac
Contours
5 Ft
Scale Key
Dog Island
Scale Key
Upland Habitat (34.7 Acre)
Beach Dune (0.25 Acre)
Sand Beach (Dry) (2.4 Acre)
Coastal Uplands and Scrub (9.8 Acre)
Maritime Hammock (16 Acre)
Scrubby Flatwoods (6.2 Acre)
Other Habitat
Soils (Sand)
N
0 500 1,000 Feet
Source: FNAI, FWC, Univ. of FL GeoPlan
5/25/2017



Seahorse Key
Contours
5 Ft
10 Ft
15 Ft
20 Ft
25 Ft
30 Ft
35 Ft
40 Ft
45 Ft
50 Ft
D2W_2040_L_MHHW_BATHTUB (21")
D2W_2060_M_MHHW_BATHTUB (27")
D2W_2100_M_MHHW_BATHTUB(37")
D2W_2100_H_MHHW_BATHTUB (77")
Seal Level Scenario: D2W 2040, 2060, 2100 Inundation, using USACE Projection Curve at Mean Higher High Water (MHHW) tidal datum, which equates to 21" (0.53 Meter), 27" (0.68 Meter), 37" (0.93 Meter) and 77" (1.95 Meter) of inundation due to sea level rise.
Habitat Lost | 2040 L | 2060 M | 2100 M | 2100 H
Seahorse Key | 17.2 ac | 22 ac | 31.4 ac | 41.9 ac
Seahorse Key
Seahorse Key
Upland Habitat (57.1 Acre)
Beach Dune (3.9 Acre)
Sand Beach (Dry) (3 Acre)
Maritime Hammock (48.5 Acre)
Urban (1.7 Acre)
Other Habitat
Soils (Sand)
N
0
500
1,000 Feet
Source: FNAI, FWC, Univ. of FL GeoPlan
4/14/2017


Snake Key
2040_L_MHHW_BATHTUB (5")
2060_M_MHHW_BATHTUB (12")
2100_M_MHHW_BATHTUB (23")
2100_H_MHHW_BATHTUB (62")
Seal Level Scenario: FL2040, 2060, 2100 Inundation, using USACE Projection Curve at Mean Higher High Water (MHHW) tidal datum, which equates to 5",12", 23" and 62" inches of inundation due to sea level rise.
Contours
5 Ft
Habitat Lost | 2040 L | 2060 M | 2100 M | 2100 H
Snake Key | 1.5 ac | 7.7 ac | 11.7 ac | 11.7 ac
Snake Key
Snake Key
Upland Habitat (13.9 Acre)
Maritime Hammock (13.9 Acre)
Other Habitat
Soils (Sand)
N
0
500
1,000 Feet
Source: FNAI, FWC, Univ. of FL GeoPlan
4/14/2017


Atsena Otie Key
D2W_2040_L_MHHW_BATHTUB (21")
D2W_2060_M_MHHW_BATHTUB (27")
D2W_2100_M_MHHW_BATHTUB(37")
D2W_2100_H_MHHW_BATHTUB (77")
Seal Level Scenario: D2W 2040, 2060, 2100 Inundation, using USACE Projection Curve at Mean Higher High Water (MHHW) tidal datum, which equates to 21" (0.53 Meter), 27" (0.68 Meter), 37" (0.93 Meter) and 77" (1.95 Meter) of inundation due to sea level rise.
Contours
5 Ft
10 Ft
15 Ft
20 Ft
Habitat Lost | 2040 L | 2060 M | 2100 M | 2100 H
Atsena Otie Key | 26.5 ac | 29.7 ac | 37.2 ac | 42.4 ac
Atsena Otie Key
Atsena Otie Key
Upland Habitat (52.2 Acre)
Beach Dune (1 Acre)
Sand Beach (Dry) (8.7 Acre)
Coastal Scrub (8.2 Acre)
Maritime Hammock (16.8 Acre)
Mesic Flatwoods (1.6 Acre)
Scrubby Flatwoods (1.4 Acre)
Xeric Hammock (14.5 Acre)
Other Habitat
Soils (Sand)
N
0
500
1,000 Feet
Source: FNAI, FWC, Univ. of FL GeoPlan
4/14/2017

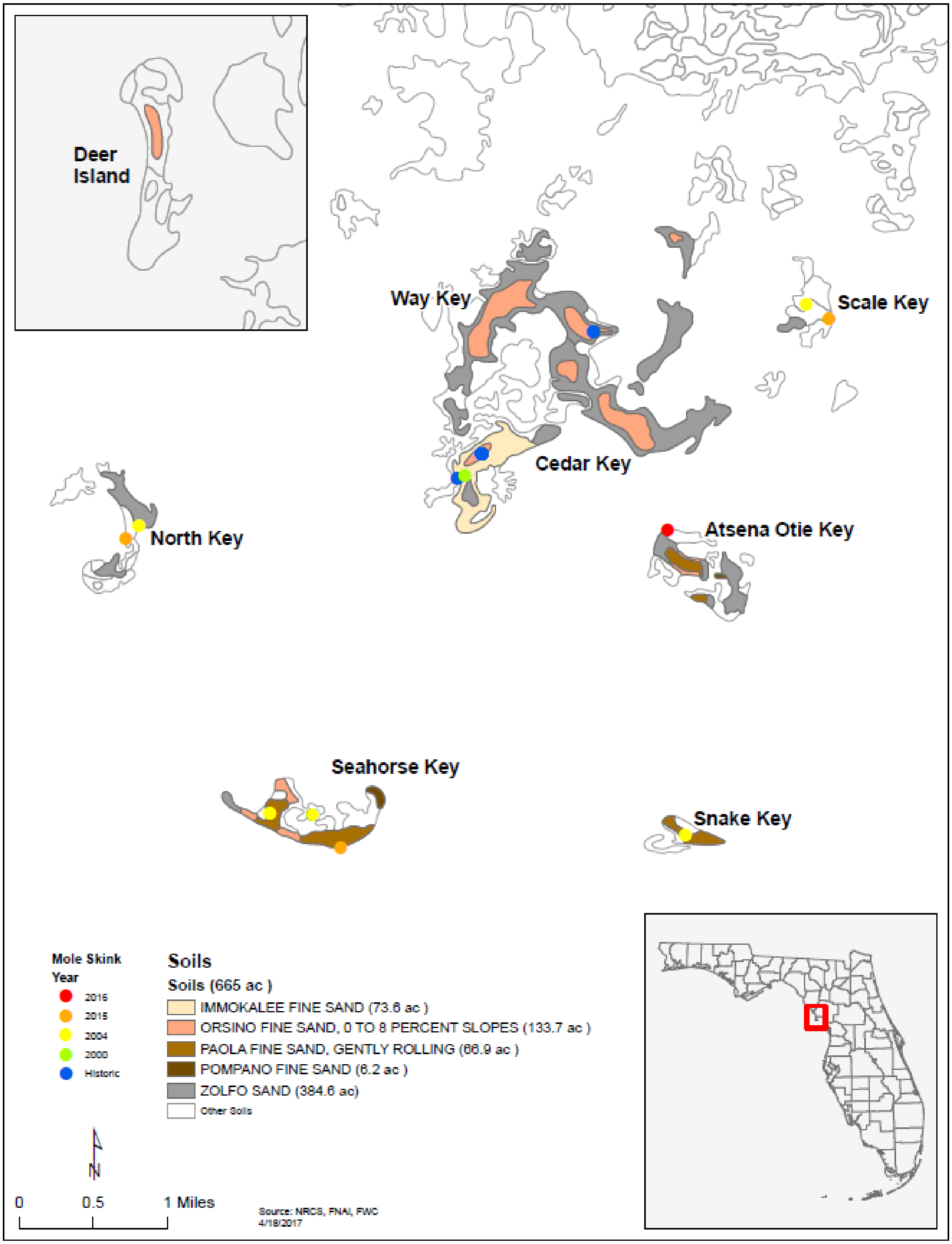
Appendix E. Sea Level Rise projections for eight islands with identified Cedar Key mole skink populations.

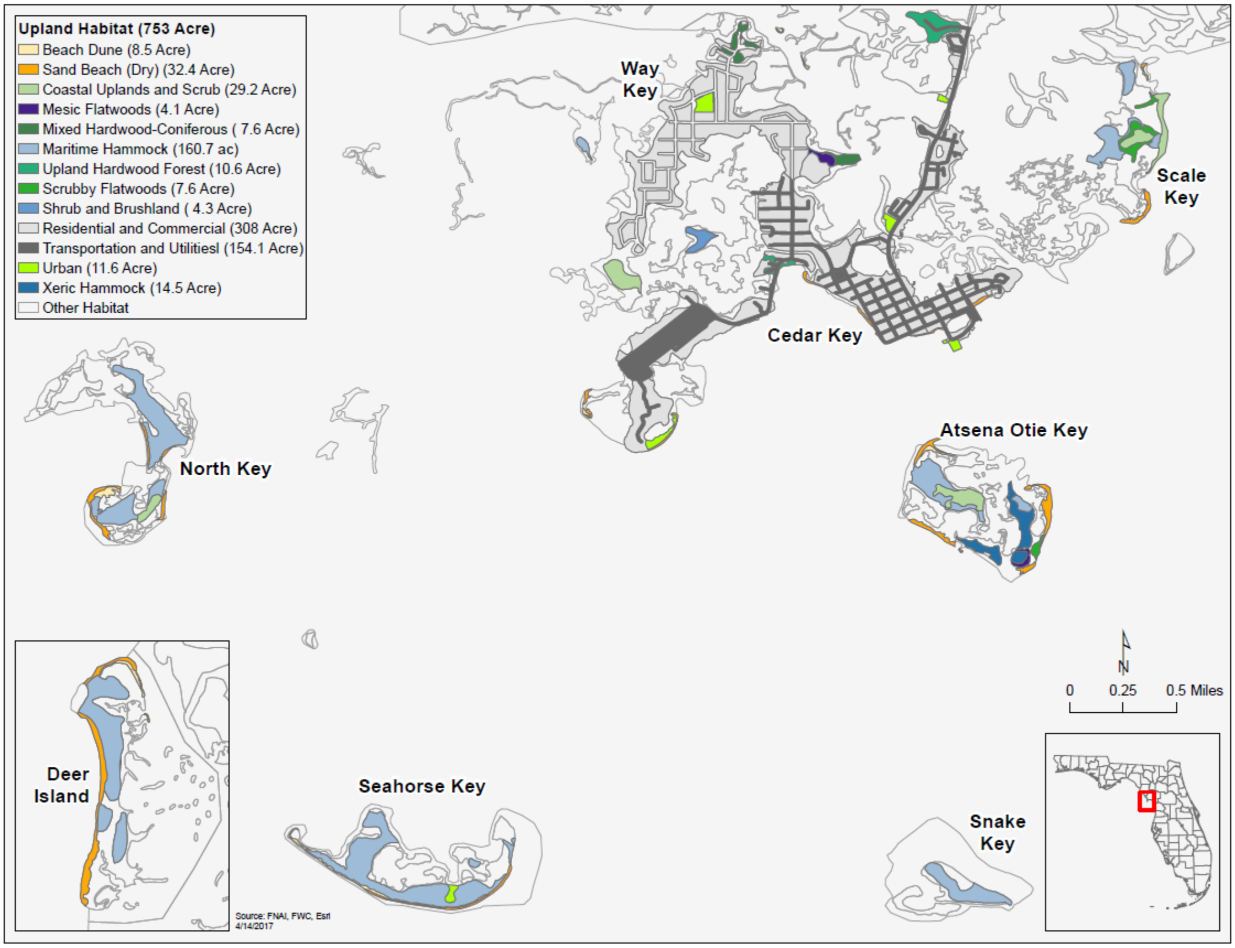
SLR Projected Low(L),Medium(M), High (H)		Total Upland (ac)	Inundated (ac)	Inundated Percent (ac)
	Cedar key Area (Inch)			
21	**2040L**			
	Cedar key	326	9.6	3%
	Way Key	185.6	3.5	2%
	North Key	48.5	25.8	53%
	Seahorse Key	57.1	17.2	30%
	Atsena Otie Key	52.2	26.5	51%
	Scale Key	34.7	2.4	7%
23	Deer Island	34.9	3.9	11%
23	Snake Key	13.9	11.7	84%
Total		**752.9**	**100.6**	**13%**
24	**2040M**			
	Cedar key	326	12.9	4%
	Way Key	185.6	5.2	3%
	North Key	48.5	29.5	61%
	Seahorse Key	57.1	19.8	35%
	Atsena Otie Key	52.2	28.1	54%
	Scale Key	34.7	2.8	8%
23	Deer Island	34.9	3.9	11%
23	Snake Key	13.9	11.7	84%
Total		**752.9**	**113.9**	**15%**
31	**2040H**			
	Cedar key	326	21.9	7%
	Way Key	185.6	10.7	6%
	North Key	48.5	36.1	74%
	Seahorse Key	57.1	25.7	45%
	Atsena Otie Key	52.2	32.9	63%
	Scale Key	34.7	4.1	12%
28	Deer Island	34.9	5.8	17%
28	Snake Key	13.9	11.7	84%
Total		**752.9**	**148.9**	**20%**
22	**2060L**			
	Cedar key	326	10.6	3%
	Way Key	185.6	4.1	2%
	North Key	48.5	27.3	56%
	Seahorse Key	57.1	18.2	32%
	Atsena Otie Key	52.2	27	52%
	Scale Key	34.7	2.6	7%

23	Deer Island	34.9	3.9	11%
23	Snake Key	13.9	11.7	84%
Total		**752.9**	**105.4**	**14%**
27	**2060M**			
	Cedar key	326	16.2	5%
	Way Key	185.6	7	4%
	North Key	48.5	32.3	67%
	Seahorse Key	57.1	22	39%
	Atsena Otie Key	52.2	29.7	57%
	Scale Key	34.7	3.2	9%
28	Deer Island	34.9	5.8	17%
28	Snake Key	13.9	11.7	84%
Total		**752.9**	**127.9**	**17%**
43	**2060H**			
	Cedar key	326	50.2	15%
	Way Key	185.6	26.8	14%
	North Key	48.5	43.5	90%
	Seahorse Key	57.1	37.3	65%
	Atsena Otie Key	52.2	39.2	75%
	Scale Key	34.7	7.5	22%
28	Deer Island	34.9	5.8	17%
28	Snake Key	13.9	11.7	84%
Total		**752.9**	**222**	**29%**
25	**2100L**			
	Cedar key	326	13.8	4%
	Way Key	185.6	5.8	3%
	North Key	48.5	30.3	62%
	Seahorse Key	57.1	20.5	36%
	Atsena Otie Key	52.2	28.5	55%
	Scale Key	34.7	2.9	8%
23	Deer Island	34.9	3.9	11%
23	Snake Key	13.9	11.7	84%
Total		**752.9**	**117.4**	**16%**
37	**2100M**			
	Cedar key	326	32.1	10%
	Way Key	185.6	16.9	9%
	North Key	48.5	41.9	86%
	Seahorse Key	57.1	31.4	55%
	Atsena Otie Key	52.2	37.2	71%
	Scale Key	34.7	5.8	17%
62	Deer Island	34.9	14	40%
62	Snake Key	13.9	11.7	84%
Total		**752.9**	**191**	**25%**

77	**2100H**			
	Cedar key	326	201	62%
	Way Key	185.6	91.4	49%
	North Key	48.5	43.9	91%
	Seahorse Key	57.1	41.9	73%
	Atsena Otie Key	52.2	42.4	81%
	Scale Key	34.7	18.1	52%
62	Deer Island	34.9	14	40%
62	Snake Key	13.9	11.7	84%
Total		**752.9**	**464.4**	**62%**

Appendix F. Soils and Habitats for eight islands with identified Cedar Key mole skink populations.




Upland Habitat (753 Acre)
Beach Dune (8.5 Acre)
Sand Beach (Dry) (32.4 Acre)
Coastal Uplands and Scrub (29.2 Acre)
Mesic Flatwoods (4.1 Acre)
Mixed Hardwood-Coniferous (7.6 Acre)
Maritime Hammock (160.7 ac)
Upland Hardwood Forest (10.6 Acre)
Scrubby Flatwoods (7.6 Acre)
Shrub and Brushland (4.3 Acre)
Residential and Commercial (308 Acre)
Transportation and Utilitiesl (154.1 Acre)
Urban (11.6 Acre)
Xeric Hammock (14.5 Acre)
Other Habitat
Way Key
Scale Key
Cedar Key
North Key
Atsena Otie Key
N
0 0.25 0.5 Miles
Deer Island
Seahorse Key
Snake Key
Source: FNAI, FWC, Esri
4/14/2017

Appendix G. SLR Projections for the Cedar Keys, Levy County, Florida.