# Ten-year management plan of the Lower Keys marsh rabbit (*Sylvilagus palustris hefneri)* on the lower half of the Florida Keys island chain


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## Acknowledgements

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## Executive Summary

Lower Keys marsh rabbits (*Sylvilagus palustris hefneri*, subsequently referred to as LKMR) are endemic to the lower portion of the Florida Key Island chain. They have been extirpated from much of their historic range and now are only found on Big Pine, Bocca Chica, Saddlebunch, and Sugarloaf Keys with some individuals present on smaller surrounding islands. They rely on coastal marshes for their diet of sedges, grasses and young mangroves as well as for cover from their vast array of predators. Populations have been on a steady decline for several decades, resulting in their listing as an endangered species in Florida and across the nation in 1990. Their status has not changed since then due to the general lack of data, especially regarding population dynamics and recovery. The cause of this decline is attributed to reduced habitat availability and increased fragmentation due to human development and sea-level rise. Additionally, increasing populations of feral cats and Burmese pythons significantly increase predation of all ages of LKMR. The goal of this management plan is to allow for recovery across the Florida Keys island chain by raising the population of LKMR to a stable point where they can reproduce and disperse adequately. Efforts include increasing the number of individuals in the population, reducing predation by invasive species, and increasing the availability and connectivity of the habitat. A secondary goal of the plan includes increasing the economic revenue resulting from the existence of LKMR in the Florida Keys to fund conservation efforts and benefit local economies. This will be accomplished with educational program and development of low-impact tourism and revenue from non-consumptive wildlife use. Quick action in this plan is of critical importance if there to be a chance for recovery in the species. With ever changing conditions in the environment and potential for more disastrous events in the future, it is unlikely that this species will recover, but not for the lack of trying.

## Introduction

Lower Keys marsh rabbits are an endangered species, endemic to four main islands in the Florida Keys island chain. They have been in decline due to habitat loss and fragmentation, increased predation by Burmese pythons and feral cats, two invasive species in Florida as well as from low reproductive rates in a small population of 100-300 individuals. This management plan is designed to mitigate habitat loss through restoration, decrease predation by removing invasive predators, augment current populations through a captive-breed and release program, and increase public awareness and involvement with this species and its conservation efforts. It is important to consider that this area experiences unpredictable levels of alteration and all efforts can be wiped out in a single weather event.

## Natural History

### Description

Lower Keys marsh rabbits (*Sylvilagus palustris hefneri*) are the smallest marsh rabbits, weighing 1000-1400 and ranging in length 361-404mm as adults. They have a darker dorsal fur compared to a lighter brown-red color found in other marsh rabbits. The ventral side of LKMRs is a greyish-brown color while the undersides of cottontails and swamp rabbits are white. The tail and hind feet of LKMRs are smaller than the other rabbits, measuring 20-43mm and 77-82mm respectively. The subspecies also has the shortest ears of marsh rabbits, 44-49mm in length compared to 55mm average in eastern cottontails (*Sylvilagus floridanus*) and marsh rabbits (*Sylvilagus palustris sp*.) found on the mainland of Florida (Lazell 1984). These ears are rounded and are often notched at the top. The eyes of the rabbits are black and round, positioned on the side of their heads with normal size relative to the head. The specific differences between LKMRs and mainland marsh rabbits are cranial; a narrower and taller facial profile, shorter front teeth and wider skull towards the dorsal side are observed in LKMRs (Lazell 1984).

*Figure 1. Lower Keys marsh rabbit with a biologist from the United States Fish and Wildlife Service. This specific rabbit has been used in an educational outreach program involving geocaching in the Florida Keys (https://www.geocaching.com/track/details.aspx?id=3290430)*

## Survival and Reproduction

Lower Keys marsh rabbits have a maximum lifespan of 2-3 years and become sexually mature at 6-9 months (Forys 1995, Holler and Conway 1979). Gestation lasts 30-37 days allowing the rabbits to produce multiple litters per year with breeding beginning as early as February and continuing as late as December. Fecundity ranges throughout the year, females produce 1.82-2.42 young per litter from February to June and 0.54-0.72 young from September to December. The LKMR subspecies averages fewer litters per year averaging 3.7 compared to 5.7 of the higher marsh rabbit species (Holler and Conway 1979). This results in a range of 2.3-11.21 young per female, per year (Holler and Conway 1979). Mortality is common in rabbits thus survival rates are low, making recruitment difficult. The probability of mortality is 0.80 in young, 0.97 in juveniles, 0.94 in first year adults and 0.98 in adults in their second year. This mortality is a combination of disease, predation, drowning, and roadkill (Lord 1961). Using their fecundity levels and mortality, the outcome of the population over the next 10 years was estimated.

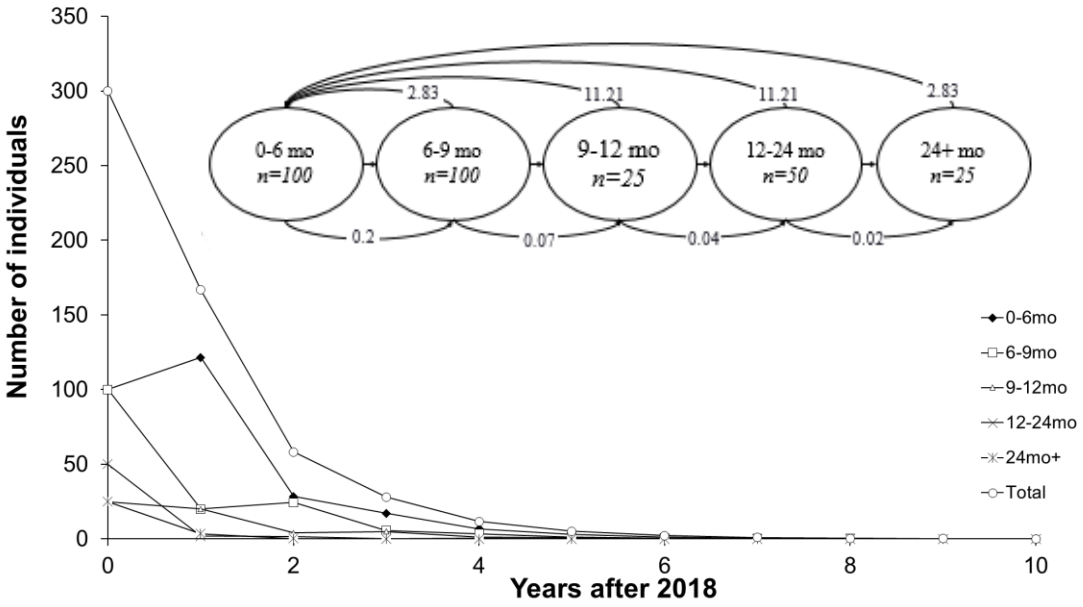



*Figure 2. Population projection for next ten years at current survivability and fecundity rates for each stage. The model displays the age classes and the estimated population at each stage with fecundity on top of the model and survivability on the bottom. At these rates, LKMR will be extinct within the next decade. The model does not factor in carrying capacity nor does it account for mortality aside from natural causes, roadkill, and invasive species predation.*

## Habitat and Cover

LKMR are habitat specific unlike their habitat generalist relatives the marsh rabbit and Eastern cottontail (Chapman et.al. 1982, USFWS 1990). Feeding, nesting, and shelter needs are reliant on the transition zone of sedges and grasses on the higher regions of the saltmarsh. These dense coastal saltmarshes host a variety of plant species including cord grasses, rushes, seashore dropseed, sea daises, glassworts, mangroves, and other occasional hardwood species (Schmidt et.al. 2011). LKMR also uses freshwater marshes, tidal swamps, beach berms, and wooded upland areas (Schmidt et.al. 2011). The use of these habitat types varies across the current range of the LKMR based on the specific key they live on. In general, brackish wetlands are used most, despite the low availability. Upland habitat is plentiful but used minimally by the LKMR. Freshwater wetlands are uncommon across the entire range and are not used except for on Big Pine Key where it is the primary habitat type (Faulhaber et.al. 2006).

| Vegetation type | Big Pine Key $n = 2$ | | Boca Chica Key I & II $n = 8$ | | Boca Chica Key III $n = 5$ | | Sugarloaf Key $n = 4$ | | Saddlebunch Keys $n = 1$ | | Little Pine Key I $n = 5$ | | Little Pine Key II $n = 4$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avail | Use | Avail | Use | Avail | Use | Avail | Use | Avail | Use | Avail | Use | Avail | Use |
| Brackish wetlands | | | | | | | | | | | | | | |
| Buttonwoods | 9 | 0 | 3 | 26 | 3 | 0 | 6 | 16 | 6 | 88 | 7 | 1 | 7 | 36 |
| Mangroves | 24 | 0 | 19 | 21 | 9 | 2 | 28 | 7 | 28 | 3 | 24 | 0 | 24 | 54 |
| Saltmarsh | 2 | 0 | 3 | 49 | 3 | 98 | 11 | 61 | 11 | 9 | 8 | 97 | 8 | 2 |
| Total | 35 | 0 | 25 | 96 | 15 | 100 | 45 | 84 | 45 | 100 | 39 | 98 | 39 | 92 |
| Freshwater wetlands | 9 | 95 | 2 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Upland[a] | 56 | 5 | 73 | 4 | 73 | 0 | 53 | 16 | 55 | 0 | 60 | 2 | 60 | 8 |

[a] All upland sites used by LKMRs were in hammocks except on Big Pine Key where pinelands were used.

*Figure 3. Habitat use-availability by the Lower Keys marsh rabbit. The number of rabbits tracked per patch is represented with n. Seven patches were monitored across the five islands of which four (Big Pine, Boca Chica, Sugarloaf, Saddlebunch) are natural populations and one (Little Pine) contains translocated rabbits from a reintroduction program (Faulhaber et.al. 2006).*

## Food Needs*

Rabbit species are completely reliant on plants for the makeup of their diet, either from direct consumption of plant material or consumption of plant rich pellets that were not digested and have been excreted (Chapman et.al. 1982). Lower Keys marsh rabbits browse 19 different plant species found in its habitat. Pellet samples determined that 50% of the diet consists of 2 grasses: seashore dropseed (*Sporobolus virginicus*) and gulf cordgrass (*Spartina spartinae*). Another 25% of the diet consists of the leaves of white mangrove (*Laguncularia racemose*), red mangrove (*Rhizophora mangle*) and the bushy seaside tansy (*Borrichia frutescens*). The remaining 25% consists of various other grasses, sedges, trees, and shrubs (Forys 1999).

*The food needs of the LKMR were taken from a single study to avoid the need for extrapolation from other rabbit species. The study was conducted by Elizabeth Forys on Saddlebunch and Boca Chica Keys in 1999.

| Plant species | Mean relative density of plant species in fecal pellets | Mean ground cover |
|---|---|---|
| *Sporobolus virginicus*—Poaceae | 35.74 (5.21) | 14.60 (4.31) |
| *Spartina spartinae*—Poaceae | 17.33 (3.87) | 17.40 (8.49) |
| *Laguncularia racemosa*—Combretaceae | 10.25 (2.49) | 1.20 (0.20) |
| *Borrichia frutescens*—Asteraceae | 8.40 (1.51) | 8.40 (3.80) |
| *Rhizophora mangle*—Rhizophoraceae | 6.81 (1.97) | 1.00 (0.32) |
| *Andropogon glomeratus*—Poaceae | 6.14 (2.04) | 4.20 (2.01) |
| *Eleocharis cellulosa*—Cyperaceae | 3.75 (1.63) | 0.80 (0.49) |
| *Typha latifolia*—Typhaceae | 2.10 (0.77) | 1.00 (1.00) |
| Unidentified material | 1.64 (0.50) | 0.00 |
| *Muhlenbergia filipes*—Poaceae | 2.27 (1.32) | 2.60 (1.19) |
| *Coccoloba uvifera*—Polygonacea | 1.35 (0.81) | 1.00 (0.63) |
| *Sesuvium maritimum*—Aizoaceae | 0.63 (0.10) | 0.80 (0.80) |
| *Jacquinia keyensis*—Theophrastueae | 0.75 (0.30) | 0.05 (0.01) |
| *Fimbristylis castanea*—Cyperaceae | 0.76 (0.38) | 4.20 (1.91) |
| *Salicornia virginica*—Cheropodiaceae | 0.63 (0.31) | 1.40 (0.93) |
| *Avicennia germinans*—Avicennianceae | 0.38 (0.23) | 1.00 (0.32) |
| *Baccharis halimifolia*—Asteraceae | 0.31 (0.18) | 0.10 (0.04) |
| *Erithalis fruticosa*—Rubiaceae | 0.24 (0.17) | 0.20 (0.12) |
| *Fimbristylis spathacea*—Cyperaceae | 0.23 (0.23) | 1.60 (1.17) |
| *Maytenus phyllanthoides*—Celastraceae | 0.17 (0.17) | 0.15 (0.10) |
| *Conocarpus erecta*—Combretaceae | 0.00 | 2.80 (0.74) |
| *Monanthochloe littoralis*—Poaceae | 0.00 | 4.40 (1.94) |
| *Pithecellobium guadelupense*—Fabaceae | 0.00 | 2.00 (2.00) |

*Figure 4. Food use (+/- SE) by fecal samples and availability (+/- SE) by ground cover percentage on Saddlebunch and Boca Chica Keys in 1999 (Forys 1999).*

### Parasites and Diseases

Ticks are the most prevalent parasite found not only in LKMRs but in all rabbit species. These ticks are vectors for two big diseases; tularemia and Rocky Mountain spotted fever. Tularemia is present mostly in the spring and fall and causes sluggish behavior that eventually leads to 100% mortality in diseased rabbits. The disease is communicable to humans; 90% of cases in humans are caused by some rabbit species, primarily eastern cottontails. There is potential for transmission from LKMRs should a human poach and consume a LKMR, though that is unlikely to occur. The occurrence of tularemia is unknown but correlates to high tick densities (Brown et al 2015, Chapman et al 1982). Other known diseases in LKMRs include infections by the bacteria *Staphylococcus aureus* (McCoy and Steenbergen 1969) and rabbit hemorrhagic disease (Dalton et al 2012). The prevalence of these diseases is also unknown in LKMRs but are assumed to occur based on related species.

## Needs of Lower Keys Marsh Rabbits

### History

Lower Keys marsh rabbit are an endangered subspecies of marsh rabbit, endemic to a small number of islands in the Florida Keys chain. During the Würm glacial age (40,000-12,000 years ago), the lower Florida Keys formed a plateau extending to the continental shelf, allowing the ancestral parent species of marsh rabbit to establish across the landscape. When the ice melted, sea levels rose resulting in the formation of the island chain and the isolation of the marsh rabbit populations on those islands. Through modern genetic analysis, these isolated populations were determined to be different enough to be classified as a subspecies of marsh rabbit (Lazell 1984). Without connection to the mainland population, the numbers of the rabbit found on the island began to fall resulting in their listing as a federally endangered species on 21 June 1990 (USFWS 1990). The primary reason for listing the Lower Keys marsh rabbit (LKMR) was the growth of human development leading to habitat loss and fragmentation, hardwood succession, rising sea levels and hurricane damage (LaFever et al. 2007, Schmidt et al. 2010, Schmidt et al. 2011). The United States Fish and Wildlife Service (USFWS) developed a management plan in 1990 to combat the decline of the subspecies, but little progress has been reported and the continuing

habitat degradation by additional development, climate changes and large weather events has surely impacted the effectiveness of the outdated plan.

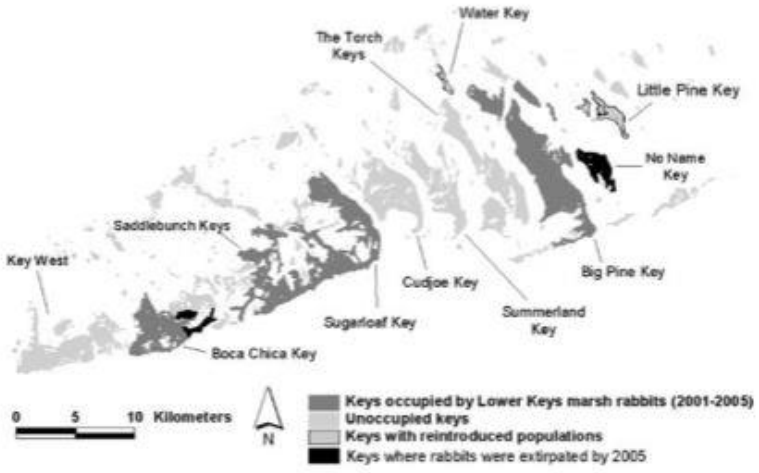



*Figure 5. Distribution of LKMR as determined by Faulhaber et al, 2007 across its known range in the lower portion of the Florida Keys, USA. (2001-2005).*

## Ecological Issues

In the Florida Keys ecosystem, LKMR are important primary consumers and serve as a food source for native raptors and snakes (Chapman and Willner 1981). Additionally, 50% of adult LKMR mortality is caused by feral cats and raccoons limit establishment in potential habitats due to the increased chance of predation (Schmidt et al. 2010). Introduction of the Burmese python to the Southern portion of the Florida mainland also poses a threat to the LKMR. Stomach content analysis of the python has shown rabbits as part of their diet, expansion of their range into the Lower Keys could add another limiting factor to recovery (Mauldin and Savarie 2010). Another issue to recovery is the low reproduction rates of LKMR compared to other marsh rabbits. 3.7 litters on average are raised every year by LKMR while marsh rabbits in southern Florida raise an average of 5.7 litters (Holler and Conway 1979, USFWS 1990). Models created in the original management plan gave the LKMR 50 years to extinction with that reproduction rate (USFWS 1990). The last ecological problem facing the recovery of LKMR is the difficulty with reintroduction and translocation due to genetic difference within the subspecies itself. Reintroductions have been a successful tool for the LKMR recovery plan, with one project showing between 80-100% survivals of released rabbits (Faulhaber et al. 2006).

Current genetic studies have suggested that there two distinct genetic clades in the few isolated islands with little gene flow between the two. This could pose a problem with using translocations as a recovery tool in the future (Crouse et al. 2010).

## Economic Issues

As an endangered species, there is no legal take of the LKMR so there would be no direct economic value from harvest of this species (ESA §3[18] via Randel et al. 2012). Furthermore, the habitat that the rabbit occupies is far from human development resulting in minimal viewing by wildlife enthusiasts, thus little economic value. This habitat preference also keeps the rabbit from having any impact on agricultural practices (Jones 1997).

## Sociocultural Issues

Rabbit species across the United States are sources of several different zoonotic diseases and the LKMR is no exception. Tularemia cases have been reported after consumption of marsh rabbit meat in Florida. An uninformed hunter taking and consuming a LKMR risks contracting the disease (Hoff et al. 1975). Additionally, LKMR are known to host ticks that carry Rocky Mountain Fever (Chapman and Willner 1981). Aside from zoonotic diseases, humans pose a large threat to LKMR with continued development due to increased tourism to the area. Annual tourist populations in the Florida Keys have grown intensely in the last two decades. Following a report on tourism numbers published in 2013, an increase of over a million visitors was observed over the course of seven years (Monroe County Tourism 2014). These increases in visitors will require more development for housing and recreation, reducing the amount of available space for LKMR and further fragmenting their already narrow geographic range.

## Legal Issues

The Endangered Species Act (ESA) protects the LKMR, which has been listed both on the federal level and in the state of Florida. The only legal issue that has developed with the conservation of the LKMR is storm relief organizations such as FEMA not adhering to the ESA's regulations. FEMA failed to factor in impact on the endangered species in their storm relief work following hurricanes, violating section 7 of the ESA (Randel et al. 2012, USFWS 1990). Enforcing all government agencies to adhere to these rules is critical to balance the needs of human and the needs of the endangered species.

## Goals and Objectives

**Goal 1.0:** Increase the population of Lower Keys marsh rabbits to a stable level to allow for recovery across the Florida Keys island chain.

**Objective 1.1:** Increase current population of the LKMR throughout the Florida Keys by 50% within the next 10 years.

**Action 1.1.1:** Estimate current population using pellets surveys and capture-recapture methods to cover both patch and range wide population estimates.

Pellet surveys is a method population estimation that involves collecting pellets in a randomized grid system of potential habitat patches. These pellet counts are then supplemented with a capture-recapture study using a random sample of the patches used in the pellet sample. These two results are used to determine the range-wide population estimate by correlating average pellet density with density estimates from the capture-recapture study using a linear regression. This method is preferable because it considers the variability of an endangered species (Schmidt et al 2011). Pellet surveys are a strong tool for rabbit population estimations, but they have limitations. Time and exposure to weather breaks down the pellets which lowers overall pellet abundance, lowering the estimated population size of rabbits. Additionally, habitat patches that can be used in a pellet survey often contain >5 pellets/$m^2$ which skews the regression to produce lower rabbit population estimations. Using pellet surveys alone will produce an underestimation for the rabbit population which is not acceptable for an endangered species (Schmidt et al. 2011). Capture-recapture methods can employ a variety of tools including Tomahawk Traps and drift fences. The drift fence funnels the rabbits to the open passageway made by the live trap device. This satisfies the guidelines set by the American Society of Mammalogists for proper trapping and handling techniques (Crouse et al. 2009).

**Action 1.1.2:** Captive breed and release Lower Keys marsh rabbits to occupied and connected habitat patches starting in 2018 and continuing through 2028.

Captive breeding programs have increased in popularity in wildlife management due to their high short-term success rate. Drawbacks to a captive breeding program include increased disease, altered behavior, expense, and need for continuous management. Reintroduction of rabbits can have difficulties as well regarding establishment, competition and predation. All factors considered, captive breeding remains an effective tool for short-term recovery. Rabbits are released after breeding and rearing to habitat patches that were well connected, composed of suitable habitat and hosted a network of established local populations. This increases the survival rate of introduced rabbits to the same level of survivability for established rabbits (Faulhaber et al. 2006, Snyder et al. 1996). A final consideration of reintroduction is the presence of different subpopulations across the range. Lower Keys marsh rabbits are divided into a larger western clade (n=257, Faulhaber et al. 2007, Schmidt et al. 2011) and a smaller eastern clade (n=25, Faulhaber et al. 2007, Schmidt et al. 2011). Introducing rabbits from diverged populations into eachother may lead to lower breeding success and failed breeding programs (Crouse et al. 2009).

**Action 1.1.3:** Live capture LKMRs in the wild and apply 5% carbaryl insecticide to control ticks.

Ticks are the source of two of the most well-known diseases in rabbits. By applying an insecticide to the rabbits already in the population, there is a reduced chance that those rabbits will carry ticks. Lower tick populations correlates to less prevalence of rabbit disease, a step towards reduced mortality which would allow more individuals to survive and reproduce (Chapman et al 1982). 5% carbaryl insecticide, known commercially as "% Sevin Dust," is a commonly used tool in domestic rabbit husbandry to control ticks and fleas. Application is simple and the dust does not harm the rabbit even if ingested (House Rabbit Society 2016).

**Action 1.1.4:** No Action: If no action is selected, there will not be a current estimation of the Lower Keys marsh rabbit population to assess the chance of recovery.

***Final Course of Action:*** **1.1.1, 1.1.2, 1.1.3.**

I decided to select these actions because they are the documented methods used specifically for Lower Keys marsh rabbits. Choosing these methods allows the management of the species start without the need for extrapolation from methods used on other related rabbit species. LKMRs have proven difficult to work with due to their solitary behavior so using known methods of assessment was logical. For supporting information that was not directly from work with LKMRs, similarity within genus *Sylvilagus* as well as domesticated rabbits was assumed.

**Assessment Protocols for Objective 1.1:** A population estimation will be conducted before the management efforts take place and will be repeated annually to monitor progress year to year. If populations begin to trend upward, management actions will be deemed successful. If populations continue to decline, management efforts must be altered to find conditions suitable with population growth. This could involve pulling all remaining individuals of LKMR out of the wild and bringing them into captivity for breeding and protection from predators. Once the population is high enough in the captive setting and the landscape's predators are not accustomed to rabbits anymore, release efforts can begin again.

**Objective 1.2:** Increase the acreage of potential habitat by 25% within five years.

**Action 1.2.1:** Using remote sensing and geographic information system technology, assess current habitat conditions and land cover classes.

The technology age has provided wildlife researchers with a tool that allows them to conduct hours of field work in a matter of minutes. The habitat assessments that can be completed using GIS and remote sensing, especially when backed up by check points between the technology and the field, are critical to solving habitat issues when time is sensitive. Regarding habitat assessments of marsh land for LKMRs, GIS allows for the analysis of habitat distribution, vegetation health, patch connectivity, causes of habitat degradation, and land use over time (Rebelo

et al 2009). These attributes are important to consider because LKMRs exist in a metapopulation structure where dispersal can occur through lower mangrove forested corridors, but individuals often remain in a single patch (Forys and Humphrey 1996). This means that if management efforts are focused on increasing dispersal of LKMRs, knowing where forested corridors occur or could easily be created is important (Forys and Humphrey 1999) and can be provided with GIS technology.

**Action 1.2.2:** Convert unused, frequently flooded and/or degraded land along the coastal marshes of the Florida Keys into suitable marsh habitat for LKMRs.

When natural coastal marshes are degraded or developed, a common method to recover that land for wildlife use and other ecological functions is to create and restore that habitat (Craft et al 2002). Special plant nurseries across the United States continuously grow native plants for such recovery efforts. These plants are grown in comparable conditions to provide for easy acclimation, avoiding the shock of being planted. Supplemental planting of seashore dropseed (*Sporobolus virginicus*), gulf cordgrass (*Spartina spartinae*), white mangrove (*Laguncularia racemose*), red mangrove (*Rhizophora mangle*) and the bushy seaside tansy (*Borrichia frutescens*) would increase abundance of 75% of diet and cover material and could allow for rapid population expansion (Faulhaber et al 2008, Forys and Humphrey 1996).

**Action 1.2.3:** Define any marshland containing seashore dropseed, gulf cordgrass, white mangrove, red mangrove and the bushy seaside tansy as critical habitat to place it under protection of endangered species act.

The species listed make up 75% of the LKMRs diet and cover and can be deemed necessary to management and recovery operations for the endangered species (Faulhaber et al 2006). Be designating this habitat as critical habitat, incidental take permits would be required to damage that habitat, reducing the chance that development on habitat will continue (Yagerman 1990).

**Action 1.2.4:** No Action: If no action is selected there will be no assessment of current habitat conditions following recent weather events and human development. Additionally, no action does not provide any way for habitat conditions to improve either through creation or protection.

***Final Course of Action:*** **1.2.1, 1.2.2, and 1.2.3.**

These actions were chosen because they satisfy the three big habitat management processes; assessment, creation, and preservation. The assessment using GIS is a quick and simple method that does not focus too many resources into lengthy field habitat surveys in a landscape that is not easy to traverse. Habitat creation satisfies a couple of management considerations aside from purely creating habitat for a species in need It also allows for the public to have direct involvement in the recovery of the species which will likely produce a population that supports conservation more. (This idea is presented in a habitat restoration day flyer, Appendix II.)

**Assessment Protocols for Objective 1.2:** A change analysis will be conducted to determine the success of this objective. This will require developing a land cover map prior to the protection, creation and restoration efforts. This will be compared using the GIS software to a map of the same area after the management efforts. If there is an increase in available habitat, it will be considered successful. If there is no change or less available habitat, actions must be altered to provide adequate habitat availability. This could include the purchasing of lots that would be developed and remove habitat. It could also include purchasing property destroyed by hurricanes from landowners and converting that land into marsh as well.

**Objective 1.3:** Reduce invasive predator populations by 50% over the next five years.

**Action 1.3.1:** Establish continuous lethal management protocols for Burmese pythons in South Florida within the next year.

Burmese pythons (*Python molurus bivittatus*) are a growing concern in the Florida Keys as their range has been expanding since their release in Florida

during the 1980s (Mauldin and Savarie 2010). These carnivorous reptiles are known to prey upon anything they can catch including Key deer, opossums, wading birds, crocodiles, and cottontail rabbits. LKMRs would be another easy prey source for these predators should their range expand to the lower portion of the Florida Keys (Mauldin and Savarie 2010). A system of control must be established for the Burmese python to prevent it from expanding and threatening LKMRs. Acetaminophen is an effective toxin that can be used to lethally remove pythons from the population (20 mg dose 14% mortality, 40 mg dose 87% mortality, 80 mg dose 100% mortality) by inserting into a prey animal. Suspending the toxin filed bait above the ground or placing it inside a python-sized pipe would reduce the amount of non-target species that could access the toxin-filled bait. This allows for successful take of Burmese pythons while reducing threats to other predators and scavengers (Mauldin and Savarie 2010).

**Action 1.3.2:** Develop programs to reduce feral cat populations in the Keys within the next two years.

Feral cats depredate a wide variety of birds and small mammals and can cause large scale population fluctuations depending on the abundance and diversity of prey species (Courchamp et al 1999). Predation severity by feral cats on islands is even higher, often leading to extinctions of the island dwelling prey (Nogales et al 2004). As the only known invasive mammalian predator of LKMR (Chapman et al 1981), reducing feral cat populations would reduce threats to the endangered rabbit. Successful eradication programs on islands include poisoned baits, viral disease introduction and most successfully, hunting with dogs (91% success on 43 islands) (Nogales et al 2004).

**Action 1.3.3:** No Action: Failure to remove these invasive predators would allow for a greater predation rate on the endangered rabbit and would severely impact the chances of recovery. These invasive predators are very successful and if combined with the natural predators, diseases, and habitat loss could eliminate recovery options.

***Final Course of Action:*** **1.3.1 and 1.3.2**

These actions were selected because they reduce risks to Lower Keys marsh rabbits while removing invasive species at the same time. This will allow for multiple organizations to become involved with LKMR recovery as there is support for invasive species removal. Extensive research in invasive species removal has been done and the benefits for native flora and fauna are high.

**Assessment Protocols for Objective 1.3:** Conducting trapping nights for these invasive predators would be an effective assessment tool to gauge population reduction. This is accomplished by comparing the number of individuals of each invasive observed at the beginning of management to the number of individuals observed after management practices are in place. If populations of predators are lower after management than before, the management practice will be deemed successful. If predator populations increase or remain the same, alternative options must be considered. Some options could include increased lethal take of predators and increased application of trapping efforts.

**Goal 2.0:** Increase both public awareness for LKMR and involvement in conservation efforts in lower Florida Keys region.

**Objective 2.1:** Develop a continuous public education program on the importance of the species for wide variety of age groups over the next year

**Action 2.1.1:** Host public education events on a seasonal basis in the Florida Keys to raise awareness for LKMR and their needs starting in 2020.

Educational programs are an excellent outreach opportunity and can have a huge influence on community support for conservation projects (Morgan and Gramann 1989). These programs, offered at no cost bring interested citizens into the conservation process as many people that attend educational programs are those that donate funds and services to the conservation projects related to the education they received (Morgan and Gramann 1989). By establishing programs about the Lower Keys marsh rabbit, both monetary and physical support can be gained for the recovery process.

**Action 2.1.2:** Create a mascot for the Lower Keys marsh rabbit that could be adopted by a school or organization in the next year.

Mascots are a popular site at sporting events, educational functions and community parades. The friendly characters connect to all generations and can produce support for their represented entity (Baltz and Ratnaswamy 2000). If these mascots were applied to conservation efforts, awareness of the issues the species faces would increase, funding could be sourced from the public and partnerships can be developed with the mascot and other supporting organizations (Baltz and Ratnaswamy 2000). Developing a mascot for the Lower Keys marsh rabbit could increase the effectiveness of educational programs and could become an important symbol of the Florida Keys.

**Action 2.1.3:** Hire an educational intern to provide daily tours of LKMR habitat and surrounding landscape following platform construction in next 5 years.

Education via tour groups is growing rapidly in the tourism spectrum, providing opportunities for people to observe wildlife in their natural habitat (Roger et al 2007). These tours host a wide variety of benefits including explanation of biology, conservation concerns, and what the public can do to aide in conservation efforts (Zeppel 2008). Establishing these types of programs for LKMR would further increase public support and knowledge for conservation.

**Action 2.1.4:** No Action: No education on LKMRs leaves the public to learn everything on their own if they are interested. Fot those individuals that are interested, effort will be made. For those who would be interested but do not know there is an issue, those individuals will continue living without the Lower Keys marsh rabbits in mind. Public support will be low and variable at best.

***Final Course of Action:*** **2.1.1, 2.1.2, and 2.1.3**

These actions were chosen because they maximize the amount of educational opportunities present for the LKMR and that is the best chance at gaining public support for conservation efforts and will provide some funding for those efforts.

**Assessment Protocols for Objective 2.1:** A public survey will be distributed across the Florida Keys to both tourists and residents to gauge how much the people know about the rabbit without the educational programs. After the educational programs have been established, another survey can be sent in the final year of the management plan's timeline to assess the effectiveness of the educational programs and whether participants found them useful and enjoyable. Appendix III contains an example of this follow-up survey. If surveys are returned with a majority of citizens answering that they still know very little about LKMR, the educational systems, their advertisement, and all other outreach programs must be reassessed and altered to increase their effectiveness in the community. This could involve expanding the range of outreach programs, increasing the volume of outreach programs, or offering incentives for attendance and participation.

**Objective 2.2:** Increase low impact ecotourism to the region over the next ten years

**Action 2.2.1:** Continue current ecotourist activity using the geocache "Annie the Marsh Rabbit."

Geocaching is a niche sport, often compared to a large-scale game of hide-and-seek. It involves using a GPS and satellite coordinates to find a small container full of trinkets that can be traded and moved all around the world. Geo-bugs are trackable items, using a unique code that can be entered online. This not only shows where that geo-bug has been, but also provides the finder with a short summary of that item and why it is there (Schlatter and Hurd 2005). USFWS released a geo-bug in the summer of 2011 named "Annie the Marsh Rabbit." This stuffed rabbit has traveled over 1400 miles since her release, bringing with her critical information about her species, what the public can do to help and other fun facts (Geocaching 2018). This pubic outreach, though it reaches a small community can be effective at spreading information as far as the public can take it (Schlatter and Hurd 2005).

**Action 2.2.2:** Construct 5 viewing platforms on the edge of marshes to provide potential viewing opportunities of LKMR and their ecosystem in the next 5 years.

Wildlife tourism is a growing trend in the United States and viewing platforms are associated with areas with large ecotourism programs (Higham 2008). These platforms are in an area that provides tourists with a chance to observe wildlife and its habitat without directly disturbing them (Higham 2008). Viewing platforms satisfy the need for experience-based recreation, which has been a goal of recreational areas since the expansion of these areas in the 1980s (Manfredo et al 2002). Viewing wildlife and their associated habitat garners support for the species and entrance fees or donations to these recreational areas provide a source of revenue for more conservation work (Higham 2008).

**Action 2.2.3:** Establish volunteer programs for habitat restoration in the next year. A growing amount of conservation work is carried out by volunteers due to increased public interest and smaller conservation budgets of the organizations carrying out the work (Halpenny and Caissie 2003). Though untrained, volunteer's passion for what they are doing makes them valuable to conservation project managers. Small incentives or rewards for volunteer service are often cheaper to provide than hiring trained biologists to do the same work (Halpenny and Caissie 2003). Volunteer programs to restore LKMR habitat would be an excellent public outreach program and the rewards provided could inspire more people to join in the efforts. A sample of a habitat restoration volunteer program can be found in Appendix II.

**Action 2.2.4:** No Action: Without increasing the amount of ecotourism opportunities in the Florida Keys, development of more damaging tourist practices will continue. Additionally, there will be few tangible tourist opportunities that would garner support for the Lower Keys marsh rabbit, something that is vital to conserve the species.

***Final Course of Action:*** **2.2.1, 2.2.2, and 2.2.3**

These actions were selected because they provide for the greatest amount of ecotourism opportunities for LKMR, are easy to establish and can easily be maintained at little expense for the foreseeable future of the rabbit.

**Assessment Protocols for Objective 2.2:** A current list of low-impact tourism practices focused around LKMRs or their habitat can be drawn up. Then to assess whether there was an increase in these tourism practices, the number of additional opportunities that arise after the management plan is enacted can be counted. Partnering with Monroe County Tourism provides the numbers of tourists visiting the area and allows for the calculation of the percentage of those tourists that participate in the low-impact tourism practices compared to others. If numbers remain low, the next step would be the creation of a partnership with local businesses and Monroe County Tourism to expand the amount of tourist activities

## Conclusion

Combined efforts from the public and conservation organizations will provide the Lower Keys marsh rabbits with the chance to recover and establish a population that can sustain itself. Through habitat restoration, invasive predator removal and large amounts of education, LKMRs will be able to combat the effects of habitat loss and invasive predator introduction. Further considerations into management can include ways to protect the marshes from rising seas and hurricane damages. Additionally, sources of funding and specific organizations to be involved with each component must be established. Lastly, continuation of research into LKMR is important to update current management techniques throughout the timeline of this management plan. Conditions are constantly changing in the Florida Keys and unaccounted fluctuations can render the plan useless. Consistent population numbers will be needed in order to determine whether or not the recovery of the species is likely or not and whether or not funds and time should be spent to recover it.

## Literature Cited:


Baltz, M.E., M.J. Ratnaswamy. 2000. Mascot conservation programs: using college mascots to support species conservation efforts. Wildlife Society Bulletin. 28:159-163.

Brown, V.R., D.R. Adney, H. Bielefeldt-Ohmann, P.W. Gordy, T.A. Felix, F.J. Olea-Popelka, R.A. Bowen. 2015. Pathogenesis and immune responses of *Francisella tularensis* strains in wild-caught cottontail rabbits (*Sylvilagus spp*). Journal of Wildlife Diseases 51:564-575.

Chapman, J.A., G.R. Willner. 1981 *Sylvilagus palustris*. Mammalian Species. 153:1-3.

Chapman, J., J.G. Hockman, W.R. Edwards. 1982. Cottontails. Wild Mammals of North America. 5:83-115

Courchamp, F., M. Langlais, G. Sugihara. 1999. Control of rabbits to protect island birds from cat predation. Biological Conservation. 89:219-225

Craft, C, S. Broome, C. Campbell. 2002. Fifteen years of vegetation and soil development after brackish-water marsh creation. Restoration Ecology. 10:248-258

Crouse, A.L., R.L. Honeycutt, R.A. McCleery, C.A. Faulhaber, N.D. Perry, R.R. Lopez. 2010. Population structure of the Lower Keys marsh rabbit as determined by mitochondrial DNA analysis. Journal of Wildlife Management. 73:362-367.

Dalton K.P., I. Nicieza, A. Balseiro, M.A. Muguerza, J.M. Rosell, R. Casais, A.L. Alverez, F. Parra. 2012. Variant rabbit hemorrhagic disease virus in young rabbits, Spain. Emerging Infectious Diseases 18:2009-2012

Faulhaber, C., N. Perry, N. Silvy, R. Lopez, P. Frank, M. Peterson. 2006. Reintroduction of Lower Keys marsh rabbits. Wildlife Society Bulletin. 34:1198-1202

Faulhaber, C., N. Perry, N. Silvy, R. Lopez, P. Frank, P. T. Hughes, M. Peterson. 2007. Updated distribution of Lower Keys marsh rabbit. Journal of Wildlife Management. 71:208-212.

Faulhaber, C., N. Silvy, R. Lopez, D.H. LaFever, P. Frank, M. Peterson. 2008. Diurnal habitat use by Lower Keys marsh rabbits. Journal of Wildlife Management. 72:1161-1167.

Forys, E.A. 1995. Metapopulations of marsh rabbits: A population viability analysis of the lower keys marsh rabbit (*Sylvilagus palustris hefneri*) University of Florida, Dissertation <https://archive.org/details/metapopulationso00fory> Accessed 19 February 2018

Forys, E.A., S.R. Humphrey. 1996. Home range and movements of the Lower Keys marsh rabbit in a highly fragmented habitat. Journal of Mammalogy. 77:1042-1048.

Forys, E.A., S.R. Humphrey. 1999. The importance of patch attributes and context to the management and recovery of an endangered lagomorph. Landscape Ecology.14:177-185.

Forys, E.A. 1999. Food habits of the Lower Florida Keys marsh rabbit (*Sylvilagus palustris hefneri).* Florida Scientist. 62:106-110.

Geocaching.com. 2018. Annie the marsh rabbit. <https://www.geocaching.com/track/details.aspx?id=3290430> Accessed 4 April 2018

Halpenny, E.A. and L.T. Caissie. 2003. Volunteering on nature conservation projects: volunteer experience, attitudes, and values. Tourism Recreation Research. 28:25-33.

Higham, J.E.S. 2008. Wildlife viewing: the significance of viewing platforms. Journal of Ecotourism. 7:137-146.

Hoff G.L., WM.J. Bigler, W.H. Lawrence. 1975. Tularemia in Florida: *Sylvilagus palustris* as a source of human infection. Journal of Wildlife Diseases. 11:560-561.

Holler, N.R., C.H. Conway. 1979. Reproduction of the marsh rabbit (*Sylvilagus palustris*) in South Florida. Journal of Mammalogy. 60:769-777.

House Rabbit Society. 2016. Fleas on Rabbits. < http://www.allearssac.org/fleas.html > Accessed 15 March 2018.

Jones, M., B. Sherrill 1997. Wildlife profiles: marsh rabbit, *Sylvilagus palustris*. North Carolina Wildlife Profiles. <http://www.ncwildlife.org/Learning/Species/Mammals/Marsh-Rabbit> Accessed 13 February 2018.

LaFever, D.H., R.R Lopez, R.A. Feagin, N.J. Silvy. 2007. Predicting the impacts of future sea-level rise on an endangered lagomorph. Environmental Management. 40:430-437.

Lazell Jr., J.D. 1984. A new marsh rabbit (*Sylvilagus palustris*) from Florida's Lower Keys. Journal of Mammology. 65:26-33.

Lord Jr., R.D., 1961. Mortality rates of cottontail rabbits. Journal of Wildlife Management. 25:33-40

Manfredo, M.J., C. Pierce, J.J. Vaske, D. Whittaker. 2002. An Experience-based approach to planning and management for wildlife-viewing recreation. Wildlife Viewing. 5:70-92.

Mauldin, R.E., P.J. Savarie. 2010. Acetaminophen as an oral toxicant for Nile monitor lizards (*Varanus niloticus*) and Burmese pythons (*Python molurus bivittatus*). Wildlife Research. 37:215-222.

McCoy, R.H. and F. Steenbergen. 1969. Staphylococcus epizootic in western Oregon cottontails. Bulletin of Wildlife Disease Association. 5:11

Monroe County Tourism. 2014. Key West and Monroe County demographics and economy. <https://www.keywestchamber.org/demographics--economy.html> Accessed 12 February 2018

Morgan J.M., J.H. Gramann. 1989. Predicting effectiveness of wildlife education programs: a study of students' attitudes and knowledge toward snakes. Wildlife Society Bulletin. 17:501-509.

Nogales, M., A. Martin, B.R. Tershy, C.J. Donlan, D. Veitch, N. Puerta, B. Wood, J. Alonso, 2004. A review of feral cat eradication on islands. Conservation Biology 18:310-319.

Randel III, C.J., H.O. Clark Jr., D.P. Newman, T.P. Dixon. 2012. Habitat Conservation Planning. The Wildlife Techniques Manual. 2: 307-318.

Rebelo L.M., C.M. Finlayson, N. Nagabhatla. 2009. Remote sensing and GIS for wetland inventory mapping and change analysis. Journal of Environmental Management 90:2144-2153

Rodger, K., S.A. Moore, D. Newsome. 2007. Wildlife Tours is Australia: Characteristics, the place of science and sustainable futures. Journal of Sustainable Tourism. 15:160-179.

Schlatter, B.E. and A.R. Hurd. 2005. Geocaching: 21st century hide-and-seek. Journal of Physical Education, Recreation, and Dance. 76:28-32

Schmidt P, R.A. McCleery, R.R. Lopez, N.J. Silvy, J.A. Schmidt. 2010. Habitat succession, hardwood encroachment and raccoons as limiting factors for Lower Keys marsh rabbits. Biological Conservation. 143:2703-2710.

Schmidt P, R.A. McCleery, R.R. Lopez, N.J. Silvy, J.A. Schmidt, N.D., Perry. 2011. Influence of patch, habitat and landscape characteristics on patterns of Lower Keys marsh rabbit occurrence following Hurricane Wilma. Landscape Ecology. 26:1419-1431.

Snyder, N.F.R., S.R. Derrickson, S.R. Beissinger, J.W. Wiley, T.B. Smith, W.D. Toone, B. Miller. 1996. Limitations of captive breeding in endangered species recovery. Conservation Biology 10:338-348.

USFWS. 1990. Lower Keys rabbit (*Sylvilagus palustris hefneri*). South Florida Listed Species. < https://www.fws.gov/verobeach/ListedSpeciesMammals.html>. Accessed 13 February 2018.

Yagerman, K.S. 1990. Protecting critical habitat under the federal endangered species act. Environmental Law. 80:834-845.

Zeppel, H. 2008. Education and conservation benefits of marine wildlife tours: developing free-choice learning experiences. The Journal of Environmental Education. 39:3-18.

# Appendices

## Appendix I: Letter to Legislator

The Honorable Holly Raschein
Florida House of Representatives
Tallahassee, FL 32399

Dear Representative Raschein:

The legislation addressing oil and gas drilling on the coast of Florida (H.R. 5014) is of high importance to me because I am a wildlife student working on designing a management plan for Lower Keys marsh rabbits, a species listed as endangered both in Florida and the United States as a whole. This issue directly impacts this endemic species as their coastal habitat is subject to damage from oil spills like the Deepwater Horizon disaster. Additionally, I am a passionate diver and fear that the underwater ecosystems I enjoy could be impacted by another oil spill in the future.

I am primarily concerned about the likelihood of a bill that prevents oil exploration being passed do to our nations high demand for oil and gas as well as recent legislation passed by Congress to explore oil and gas sources in places that have been protected and maintained as National Parks for decades. I believe that this bill, H.R. 5014, is a necessary step both Florida and the United States must take to protect our wildlife, their habitat and the economic status of both the state of Florida and its residents. For the Lower Keys marsh rabbit, recovery efforts that are in place by the United States Fish and Wildlife Service and those that I am designing in my management plan would be severely impacted by an oil spill and the species would likely fail to recover and become another species that human development has driven to extinction.

I have read the proposed bill and followed articles released about it by the Wildlife Society but have not heard if there is support for the bill. I look forward to hearing from you regarding this issue and would like to thank you for taking the time to hear my opinions about oil and gas drilling. I firmly believe it is an issue of high importance and I would be pleased to see H.R. 5014 pass to garuntee the protection of Florida's coastline, wildlife and associated habitats and the economy of your state.

Sincerely,

Cody J. Sears
Paul Smith's College
607-778-0397
csears2@s.paulsmiths.edu

**Appendix II: Habitat Restoration Flyer**

# Habitat Restoration for Lower Keys Marsh Rabbit on Big Pine Key, Summer 2020

## Lower Keys marsh rabbits need your help!

Starting on June 1, 2020, the United States Fish and Wildlife Service will be hosting marsh restoration days where you and your group will play a crucial role in protecting and creating critical habitat for the Lower Keys marsh rabbit. To register please fill out the form below and send it to biologist Cody Sears at 30587 Overseas Hwy, Big Pine Key, FL 33043. Your efforts will be part of ongoing work to help this species recover from habitat loss and fragmentation due to human development, rising seas, and extensive hurricane damage. All volunteers will receive a t-shirt showing that you are part of the team that is helping save the Lower Keys marsh rabbit.

For more information, please contact:

Cody Sears

Wildlife Biologist

(607) 778-0397

csears2@s.paulsmiths.edu

# Habitat Restoration for Lower Keys Marsh Rabbit on Big Pine Key, Summer 2020

Group Name _____

Number of Members _____ Age Range _____

T-Shirts Sizes: Small ___ Medium ___ Large ____ XL ____

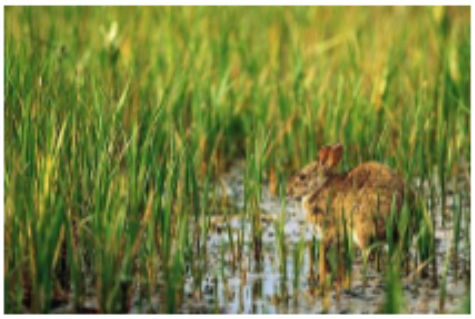
Contact Information _____

Date(s) to Volunteer _____

_____


*All tools will be provided, work area will be wet so proper footwear is a must. Long pants are also required as the area is prone to ticks. Be sure to check for ticks at the end of the work day. Light snacks and water will be available. Thank you for your support!*

## Appendix III: Lower Keys Marsh Rabbit Survey



# Current Status of Lower Keys Marsh Rabbits

*(Sylvilagus palustris hefneri)*

**The United States Fish and Wildlife Service has hosted several community outreach programs in the past ten years and we want to know what our community thinks?**

Have you attended any of our educational programs for Lower Keys marsh rabbits and the tidal marshes they rely on in the past 10 years?

☐ Never ☐ 1 program ☐ 2 or more programs

How would you rate your experience at the LKMR program?

☐ Outstanding ☐ Good ☐ Adequate
☐ Needs improvement ☐ Poor

How often have you visited any National Wildlife refuges in the Florida Keys within the past 10 years?

☐ One Visit ☐ 2-5 Visits ☐ More than 6 Visits

Did you observe any Lower Keys marsh rabbits or sign while on one of these visits? (Select all that apply)

☐ Observed Individuals ☐ Observed Sign (browse, droppings) ☐ No observations/sign

How confident would you be with identifying Lower Keys marsh rabbit individuals or indirect sign?

Not Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ Completely Confident

How confident would you be with identifying the habitat of Lower Keys marsh rabbits?

Not Confident ☐ ☐ ☐ ☐ ☐ ☐ ☐ Completely Confident

Do you have any additional comments or suggestions for us?

_____
_____
_____
_____

Page 1 of 2

## Demographics

Do you consider yourself an outdoorsperson?

☐ Yes ☐ No

Are you a Florida Keys Resident, Mainland Florida Resident or Visitor?

☐ Florida Keys Resident ☐ Mainland Florida resident ☐ Visitor to Florida

Gender

☐ Male ☐ Female ☐ Neutral ☐ Prefer not to answer

Age Group

☐ <18 ☐ 18-25 ☐ 26-30 ☐ 31-40 ☐ 41-55 ☐ 56-70 ☐ >71

Ethnicity

☐ White ☐ Black ☐ Hispanic ☐ Asian ☐ Middle Eastern ☐ Native American ☐ Other_____

Education

☐ High School ☐ Some College ☐ Associates ☐ Bachelors ☐ Masters/PhD ☐ None

**Return to:**

**Wildlife Biologist Cody Sears**

**csears2@s.paulsmiths.edu**