Wetlands have experienced dramatic losses in extent around the world, disrupting ecosystem function, habitat, and biodiversity. In Florida’s Greater Everglades, a massive restoration effort costing billions of dollars and spanning multiple decades is underway. As Everglades restoration is implemented in incremental projects, scientists and planners monitor the outcomes of projects. In this study, we evaluated the progress of a restoration project in the southwestern Everglades. We aimed to determine whether the presence and density of small mammals differed between areas with the hydrologic restoration of the ecosystem and areas without restoration. Our three focal species were: marsh rice rat (*Oryzomys palustris*), hispid cotton rat (*Sigmodon hispidus*), and cotton mouse (*Peromyscus gossypinus*). Using spatially explicit capture-recapture models, we found greater densities of cotton mouse in restored habitat and lower densities of hispid cotton rat in sites with higher water levels. In addition, we found an increase in the presence of the marsh rice rat in restored areas compared to unrestored, but captures were too low to reliably assess significance. Our study provides evidence that ongoing restoration in the southwestern Everglades is already impacting the small mammal community.

**Key words:** hydrologic restoration, indicator, Picayune Strand State Forest, rodent

### Implications for Practice

- Results indicate that restoring water flow across the landscape in the southwestern Everglades is improving habitat conditions and resulting habitat use by wetland-dependent small mammals.
- Small mammals, particularly the presence of the semi-aquatic marsh rice rat, may be a useful indicator of wetland restoration progress.
- Results highlight the importance of monitoring to detect ecological responses to the multibillion-dollar investment of restoration and provide evidence that continued restoration may be able to reverse biodiversity and ecosystem loss in the Greater Everglades.

### Introduction

Globally, wetland ecosystems have experienced degradation and significant loss in extent (Davidson 2014; Hu et al. 2017), despite their known benefits to both humans and the ecosystems they are part of. Wetlands are critical for providing clean water to people, and coastal wetlands provide flood and storm surge protection (Kirwan & Megonigal 2013). However, since 1900, global wetland area has been reduced by 54%, and in the last 300 years 87% of the world’s wetlands have been lost (IPBES 2018), largely due to their conversion for human use, such as agricultural and residential development. To help combat the degradation and loss of wetland habitats as well as the biodiversity they host and the ecosystems services they provide, measures have been developed to reduce impacts of human population expansion into these natural landscapes such as environmental mitigation, strategic conservation planning, ecological engineering, and ecosystem restoration.

In the 1800s, the Greater Everglades was an expansive wetland (28,000 km²) of southward flowing freshwater moving slowly across the landscape before it reached Florida’s coasts (Davis & Ogden 1994). Drainage of the Everglades for residential and other development began in the 1880s and ultimately led to a highly compartmentalized wetland as a result of the multitude of drainage canals and levees dividing the landscape (Light & Dineen 1994). Currently, the Everglades provides drinking water to most of South Florida’s residents and is a substantial source of income to the State of Florida and the nation due its diversity in habitats and wildlife, which attract outdoor enthusiasts and eco-tourists from around the world (Mather Economics 2010). However, draining the Everglades has damaged ecosystem function and biodiversity, limiting its ability to provide ecosystem services to people.

Author contributions: SSR was responsible for the conceptualization and study design; JPC, MRH were responsible for the data collection; LED conducted analysis; SSR, LED wrote the manuscript.

1 U.S. Geological Survey, Wetland and Aquatic Research Center, 3321 College Ave., Fort Lauderdale, FL 33314, U.S.A.

2 Address correspondence to *S. S. Romañach, email sromanach@usgs.gov*

Published 2020. This article is a U.S. Government work and is in the public domain in the USA. Restoration Ecology published by Wiley Periodicals LLC on behalf of Society for Ecological Restoration. This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
doi: 10.1111/rec.13332
Supporting information at: http://onlinelibrary.wiley.com/doi/10.1111/rec.13332/suppinfo
services. In 2000, Congress authorized the Comprehensive Everglades Restoration Project (CERP), the largest hydrologic restoration project in the United States and one of many examples of large-scale restoration programs worldwide aimed at restoring damaged ecological function and processes. Restoration efforts associated with CERP have been estimated at a cost of $16.4 billion (Central & Southern Florida Project 2015) and will take decades to complete (National Research Council 2008).

In general, the benefits of ecosystem restoration are estimated to be 10 times the cost, not only as benefits for biodiversity but also for improved livelihoods (IPBES 2018). South Florida, with a population of almost 7 million people, is predicted to receive 4 times the benefit from every dollar spent by restoring the Greater Everglades ecosystem (Mather Economics 2010). Projected benefits include carbon storage (Jerath et al. 2016), as well as improved water quality, restored hydrologic patterns that can assist with reducing saltwater intrusion, enhanced wildlife populations, increased recreational opportunities, increased freshwater drinking supply, and job creation (Mather Economics 2010).

Given the large investment required for Greater Everglades ecosystem restoration, monitoring the progression of projects to assess their effectiveness and inform the implementation of future projects is critical. Indicators of ecosystem health can be designed to help monitor environmental conditions and restoration progress (Heink & Kowarik 2010). In the mid-2000s, Everglades restoration planners together with the scientific community developed a suite of ecosystem-wide indicators as a means for determining and communicating restoration progress (Doren et al. 2009). The presence and population status of species that depend on more natural hydrologic patterns can serve as indicators of hydrologic change and successful ecosystem restoration. Wading bird population metrics, for example, were selected for their obvious connection to water, and therefore, hydrologic restoration, and because they can indicate the health of ecological functions necessary for many wetland organisms (Doren et al. 2009; Frederick et al. 2009). Some former wetland areas are so degraded that appropriate hydrologic conditions no longer exist for the persistence of wetlands or the species that inhabit them (e.g. Swartz et al. 2020), so the return of wetland-dependent species could be an indicator of restoration progress and success. Amphibians, for instance, have been shown to rapidly colonize and establish breeding populations in restored wetlands (Lehtinen & Galatowitsch 2001).

In the southwestern Everglades, a major aim of restoration is to fill or plug drainage canals to restore hydrologic pattern and function to the Picayune Strand State Forest (PSSF). Monitoring some Everglades indicators is particularly challenging in an area like PSSF with short-hydroperiod wetlands, and because of the logistical challenges of monitoring traditional wetland fauna (e.g. fish, crayfish) in remote habitats that are only inundated for a short period of the year. Small mammal populations are not often used as indicators of wetland restoration success but should be given greater consideration given their use of wetland, bottomland, and swamp habitats (Conner et al. 2000). Rodents in particular are known to adapt quickly to new opportunities as ecosystem conditions change; they also play an important role in species composition through seed dispersal, as well as serve as a food source for many carnivores (Ryszkowski 1975).

We hypothesized that small mammals could serve as indicators of wetland restoration success within the Everglades ecosystem. We examined whether the presence and density of small mammals differed between areas of implemented restoration projects at PSSF in the southwestern Everglades versus areas where restoration has yet to be completed. Our focal species were the three most common rodents in (and are all native to) the Everglades: marsh rice rat (Oryzomys palustris), hispid cotton rat (Sigmodon hispidus), and cotton mouse (Peromyscus leucopus). These three species differ in their responses to hydrologic conditions in the Everglades. Marsh rice rats are semi-aquatic so although they utilize the drier hammocks (particularly for reproduction) during the wet season, they easily move through the surrounding wet prairies, and then take advantage of available mesic areas in the dry season; cotton rats tend to seek drier hammocks during the wet season and venture into the surrounding prairie in the dry season; and cotton mice primarily utilize the drier hammocks (Smith & Vrieze 1979). As PSSF experiences longer hydroperiods with restoration, wildlife populations should begin to recover. We predicted that marsh rice rat densities should recover as wetland hydrology is restored. Conversely, cotton mice and hispid cotton rat densities should decrease as wetland hydrology is restored, as neither species is semi-aquatic.

**Methods**

**Study Site**

Picayune Strand State Forest is a 31,565-ha forest in southwestern Florida surrounded by several protected areas: Fakahatchee Strand Preserve State Park, Ten Thousand Islands National Wildlife Refuge, Collier-Seminole State Park, and Florida Panther National Wildlife Refuge (Fig. 1). In the 1950s, land in this region was purchased to develop “the largest subdivision in the world” (Carter et al. 1973). Although subdivision development failed and the area was left largely undeveloped, roads and canals were built to divert water flow and drain the area in preparation for residential development (USACE & SFWMD 2004). By the 1970s, it became evident that the widespread landscape change was having an adverse effect on hydrologic patterns and natural communities (Carter et al. 1973). The State of Florida began buying back parcels of land in the 1990s, and with the help of the federal government, lands that were set to be acquired was complete by 2006 (Worley et al. 2007). To reverse ecological damage, the Picayune Strand Restoration Project was the first CERP project to begin construction. Seven miles of the easterly Prairie Canal were plugged, and 104 km of roads were removed by late 2007. Restoration of PSSF will continue into the early 2020s and will result in a total of 77 km of plugged or filled drainage canals and the removal of 418 km of roads to allow restored water flow (USACE 2018).

**Live Trapping**

We used Sherman live traps to capture and mark rodents in the PSSF between October 2014 and April 2016 (IACUC permit
We selected areas to trap small mammals within the major vegetative types within PSRP: cypress, pine, hardwood hammock, and wet prairie. Disturbance from development within PSSF has altered natural vegetation communities to include species adapted to drier conditions and shorter hydroperiods (SFWMD and NRCS 2003); however, we selected trapping sites as that were predominantly comprised of each of the major vegetation types (e.g. cypress).

We trapped in paired “restored” and “unrestored” areas of each habitat type. Drainage canals in PSSF have been recorded to reduce the water table up to 4.8 km away (Chuirazzi & Duever 2008). Areas considered “restored” were within 1.4 km of Prairie Canal, which was plugged in 2007. Areas considered “unrestored” were at least 8.5 km from Prairie Canal in areas that are heavily drained by existing canals (Fig. 1). Plugging Merritt Canal to the west of Prairie Canal was completed in 2015, between sampling years; however, Merritt is 5.4 km from the nearest unrestored trapping grid so hydrologic restoration to the region surrounding Merritt would not impact the unrestored trapping grids. Water levels (stages) are consistently higher in the restored areas (Fig. 2).

We set Sherman traps in a $6 \times 6$ grid with traps spaced 10 m apart for a total of 36 traps per grid (0.25-ha grids). We set three replicates of each $6 \times 6$ trapping grid in each of the four restored habitat types, as well as the four unrestored habitats. Each trapping grid was located at least 300 m away from any other trapping grid on the landscape to ensure the independence of grids. Traps were active for four consecutive nights. The study totaled 168 four-day trapping sessions for 24,192 trap nights.

We set traps in the evenings and checked them in the early morning before temperatures rose to protect the health of the animals. When an individual was captured, we took body measurements and then released it in the location it was captured. We identified species, age, sex, reproductive status, weight, and length of body, hind foot, and tail. A unique, numbered tag was secured to each individual’s ear to obtain recapture data in subsequent trapping sessions.

**Spatially Explicit Capture-Recapture Modeling**

We estimated the density of small mammals using trapping data formatted into spatial capture histories for analysis in program R using the “secr” package (Core Team 2019; Efford 2020). We generated models for species with ≥20 captures which included the cotton mouse, the hispid cotton rat, and the marsh rice rat.

Spatially explicit capture-recapture models (SECR models, Borchers & Efford 2008) estimate density by combining a point process model (locations of an individual’s capture) and a detection model which are fitted jointly. Using a detection function modeled as a function of the baseline capture probability at the animal’s activity center ($g_0$) and a scale parameter ($\sigma$), which describes how capture probability decreases between an animal’s activity (or home-range) center and trap locations. We ran multisession models that stratified density estimates by

---

*Figure 1. Map of Picayune Strand State Forest, Naples, Florida, USA. The four main canals are shown in blue. Restored trapping sites are shown with a square and unrestored with a triangle.*
trapping grid separately for each species. After examining plots of effective sampling area for each species (Efford 2020), we determined that a buffer distance of 60 m was adequate for all three species. We first determined the best models for the activity center, \( g_0 \), for each species by comparing models that varied by temporal or behavioral effects while keeping density and the scale parameter, \( \sigma \), constant. We ran candidate models for the activity center, \( g_0 \), that varied by the sampling occasion (\( t \)), learned response after capture (\( b \)), and learned response specific to detector location (\( bk \)). Using Akaike’s information criterion corrected for small sample sizes (AICc), we determined the best model for the animal’s activity center, \( g_0 \), for each species and subsequently used them in our species-specific models of density.

We expected the density of animal activity centers to vary across habitat, restoration status, and water levels within the landscape. Thus, our model of density for each species varied by the categorical covariates of habitat type and restoration status along with the continuous covariate of average water stage during the trapping week at the trapping grid (Table 1). Daily water stage measurements were obtained from the South Florida Water Management District’s DBHydro database (https://www.sfwmd.gov/science-data/dbhydro) at water gage stations surrounding the trapping grids, and stage was interpolated across the landscape using kriging via the “autoKrige” function in the R package automap (Hiemstra et al. 2009).

Figure 2. Average water level (stage, in meters) for wells surrounding the mammal trapping sites in the restored and unrestored hydrology locations. Dotted black lines indicate dates when mammal trapping occurred.

Table 1. Definition of site and detection covariates used in models of small mammal density in Picayune Strand State Forest, Naples, Florida, USA.

| Covariate | Description |
|-----------|-------------|
| Habitat   | Categorical habitat type present at the sampling grid; values can be cypress, hardwood hammock, pine, or prairie. |
| Restored  | Whether the trapping grid was in the restored hydrology area; values can be restored or unrestored. |
| Stage     | Water stage (meters) averaged over the 4-day trapping session. |

Results

We captured seven species of small mammals, with the most common species being the cotton mouse and the hispid cotton rat (Table 2). We obtained 1,557 captures (466 individuals) of cotton mouse, 320 captures (165 individuals) of hispid cotton rat, and 21 captures (17 individuals) of marsh rice rat. All capture data are available online (Romañach 2020). Trap saturation for any one occasion within a session averaged at 8% and the maximum observed was 64% (Table S1), well below the threshold at which the literature suggests estimates from SECR analysis would be biased (Efford et al. 2009; Romairone et al. 2018). We captured animals in all four habitat types and in both restored and unrestored sites. The number of individual cotton
mice was higher at restored sites within cypress and prairie habitat, but lower at restored sites within hardwood hammock and pine sites (Fig. 3). Hispid cotton rat apparent abundance was higher with restoration only in pine habitat. Marsh rice rats were only captured during the second year of trapping and were more abundant in restored prairie and pine habitats. The second year of trapping yielded higher water levels across all habitats (Fig. 2). There were enough captures of the cotton mouse, hispid cotton rat, and marsh rice rat to build species-specific models of density. Cotton mouse densities averaged 7.13 (± 0.51) animals per ha across sites. Compared to cypress habitat, cotton mouse densities were significantly lower in pine and prairie habitats, and densities were significantly higher in restored versus unrestored sites (Table S2, Fig. 4). Hispid cotton rat densities averaged 2.22 (±0.21) animals per ha across sites. Compared to cypress habitat, hispid cotton rat densities were significantly lower in hardwood hammock habitats (Table S2). In addition, we found a significant negative relationship between water stage around trapping grids and hispid cotton rat densities (Table S2, Fig. 5). Marsh rice rat densities averaged 0.42 (±0.15) animals per ha across sites but captures were too low to estimate effects of any covariates on marsh rice rat density.

**Discussion**

Modeling in the northeastern United States has shown that even small amounts of wetland loss can result in a high risk of extinction for many taxa including birds, small mammals, and turtles (Gibbs 1993). Ecosystem restoration has been shown to increase species richness, abundance, reproductive success, and biomass for taxa such as butterflies (Waltz & Covington 2004), amphibians (Shulse et al. 2012), and fish (Bond & Lake 2005). In the Everglades, scientists have anticipated increases in populations of many additional taxa with restoration such as the endangered Cape Sable Seaside Sparrow (Pearlstine et al. 2016), wading birds (Gawlik 2002), crocodilians (Mazzotti et al. 2009), fish and other aquatic fauna (Trexler & Goss 2009; Romañach et al. 2019), and seagrasses at the coastal outflow (Herbert et al. 2011). In our study, we were able to detect a positive effect from restoration on the density of cotton mice, but not for any other species analyzed. Our results provide evidence that hydrologic restoration in the southwestern Everglades via removing barriers to water flow across the landscape has had a positive impact on the density of at least one species of mammmal within the system. Our results for cotton mice dovetail with Gonzalez (2019) who found a decrease in captures of cotton mice at a site
in the northern Everglades after a pump became non-functional and caused drying of the landscape.

While we did not detect a significant effect of restoration on densities of the hispid cotton rat, we did detect a significant effect of water level on the density of this species. Consistent with previous studies of cotton rat habitat preference (Cameron & Kruchek 2005), we found higher densities of cotton rats in drier sites compared to wetter sites (i.e. sites with higher water stages). A recent study in the Everglades found cotton rat densities to be double in the dry season compared to the wet season (Chapman & Noonburg 2019). However, we note that one trapping study in Everglades National Park found that cotton rats were more abundant in the wetter lowlands while cotton mice were more abundant on the dry hammocks (Worth 1950). This discrepancy may be due to an association of vegetation with hydrology instead of analyzing water stage explicitly, as we have done here. Our ability to detect an effect of restoration for cotton rats may have been obscured by the higher water levels for both restored and unrestored sites during the second year of sampling, causing cotton rats to move out of both restored and unrestored sites as water levels rose.

The semi-aquatic marsh rice rat was captured only in the second, wetter year of our study, with the majority in the restored wet prairie habitat. Marsh rice rats are known to dive and swim rapidly underwater for more than 10 m, and their water-repellant fur allows them to float on water (Esher et al. 1978). Marsh rice rats have been found to be highly mobile in the Everglades ecosystem and move through wetlands in search of food resources (Gaines et al. 2002); one individual was recorded to have moved at least 1 km on one occasion (Smith & Vrieze 1979). Marsh rice rats in our study were potentially able to move into suitable, wetter habitats as ecosystem restoration progressed. Smith and Vrieze (1979) and Smith (1980) found that marsh rice rats move into mesic areas (e.g. alligator holes) during the dry season. Fernandes (2011) found that marsh rice rats in the Everglades had higher survivorship during the wet season. Although we caught fewer marsh rice rats compared to cotton mice and hispid cotton rats and could not statistically test for an effect of restoration, these captures are significant in that their presence may be a useful indicator of wetland restoration progress.

Our results show that restoring ecosystem hydrology can improve habitat conditions and habitat use by wetland-dependent small mammals. We detected significant effects of habitat on both cotton mouse and hispid cotton rat densities. Our results agree with Worth (1950) in that cotton mice appear to prefer hardwood hammock and cypress habitats, as their densities were higher in these habitats. In addition, we found that hispid cotton rat densities were lower in hardwood hammock habitats compared to cypress. This finding is consistent with previous literature that found both hispid cotton rats and cotton mice prefer more upland habitats (Smith & Vrieze 1979). The PSSF has experienced changes to its historical vegetation community composition as a result of hydrologic and soil disturbance from canal and road construction as well as from changes in fire frequency. As a result, areas that were previously cypress forest, adapted to water-logged soils, now experience reduced hydroperiod and vegetation adapted to drier conditions such as the (native) saw palmetto (Serenoa repens) have spread into these areas. A native but aggressive species, the cabbage or sabal palm (Sabal palmetto), has spread thorough PSSF after canals were dug to drain the forest and it is now the dominant vegetation type in some areas (SFWMD & NRCS 2003). Exotic species such as Brazilian pepper (Schinus terebinthifolius) have become dominant near canals as well (SFWMD and NRCS 2003). Although Everglades rodents are known to occupy areas dominated by invasive vegetation, it is unknown how reproduction compares to areas with native vegetation (Mazzotti et al. 1981). Data already show hydrologic improvements as a result of restoration at PSSF. As additional restoration projects are implemented, the appropriate hydrology to support the native vegetative communities occupied by wildlife, including small mammal communities, should continue to shift toward communities more typical of wetlands.

The relatively short hydroperiod habitats at PSSF limit the number of sampling efforts (Ceilley et al. 2020); therefore, adopting indicator species, such as small mammals that are not restricted in their capture by the short duration of inundation, could provide more feasible and reliable monitoring data. In addition, our three focal species tend to reproduce year-round (Ceilley et al. 2020). For the past 3 years, fish, treefrogs, and aquatic macroinvertebrates have been monitored at PSSF as they are known to respond quickly to changes in hydrology (Ceilley et al. 2020). However, even anurans have been slow to respond to restoration in the PSSF and most effects are seen in the graminoid marshes (Ceilley et al. 2020). In our assessment of small mammal
response to restoration, we were able to detect a response to restoration or water levels from two common rodent species in the Everglades (cotton mouse and hispid cotton rat). In addition, although not statistically significant, the return of the marsh rice rat to wet prairie habitats is biologically significant in the context of restoration. These findings point to a shifting mammal community that is moving from a cotton rat-dominated landscape to a more diverse landscape including wetland-dependent species. Some criteria used to evaluate potential indicators in the Everglades are their applicability on an ecosystem-wide scale and whether the indicator can provide early warning signs of ecological change (Doren et al. 2009). Small mammals, as seen through our results, are sensitive to changes in habitat including changing water levels through the ecosystem and could be used as a biological indicator.

One of the aims of Everglades restoration is to return hydrologic conditions toward a more natural, pre-drainage state to restore ecosystem function and resulting biodiversity (USACE 1999). Returning PSSF to a more natural hydrologic regime should not only increase habitat availability for important Everglades species but is also expected to restore connectivity among natural areas adjacent to PSSF such as Fakahatchee Strand State Preserve, Ten Thousand Islands National Wildlife Refuge, and Florida Panther National Wildlife Refuge (Romañach et al. 2019). However, continued land use changes could affect the connectivity. Urbanization throughout Florida is projected to negatively impact the spatial extent of remaining natural resource communities, particularly if current strategies continue to be implemented that do not aim to reduce urban sprawl (Romañach et al. 2020). Reducing sprawl could at least allow for continued connectivity among habitats across the landscape.

Everglades restoration has been ongoing for decades, will likely take decades more to complete, and is expected to cost billions of dollars, but we are already beginning to see returns on investment. The State of Florida anticipates great returns in ecosystem services, far outweighing the cost of restoration (Mather Economics 2010). The Comprehensive Everglades Restoration Plan (CERP) Adaptive Management Program is designed to adjust restoration project implementation if restoration objectives are not being met (LoSchiavo et al. 2013). Monitoring is critical to determine the outcomes of restoration as well as support CERP’s Adaptive Management Program (National Academies of Sciences, Engineering, and Medicine 2018). Our results highlight the importance of monitoring to detect ecological

Figure 5. Estimated density (animals per ha) and 95% confidence bands of hispid cotton rat (*Sigmodon hispidus*) under varying water stage levels and habitat types as estimated from a spatially explicit capture-recapture model.
responses to the multibillion-dollar investment of restoration and suggest that continued restoration project implementation can yield rapid responses to reverse biodiversity and ecosystem function loss in the Greater Everglades.

Acknowledgments

We dedicate this manuscript to our friend, colleague, and co-author, Matt Hanson, whose love and passion for the outdoors was evident in every aspect of his life, a life that was cut too short. He is greatly missed by all whose lives he touched. Funding for this work was provided by the U.S. Geological Survey, Greater Everglades Priority Ecosystems Science. Thanks to Michael Gaines for the gift of live traps for this study. We thank the Florida Forest Service for allowing us to conduct this study at the Picayune Strand State Forest. We are grateful for our field volunteers: H. Crowell, D. Walker, L. Carnohan, C. Samaras, M. Urquiol, and A. Romañach. Many thanks to S. Clem, K. Kovacs, and three anonymous reviewers for helpful comments on earlier drafts. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

LITERATURE CITED

Bond NR, Lake PS (2005) Ecological restoration and large-scale ecological disturbance: the effects of drought on the response by fish to a habitat restoration experiment. Restoration Ecology 13:39–48

Borchers DL, Ellord MG (2008) Spatially explicit maximum likelihood methods for capture-recapture studies. Biometrics 64:377–385

Cameron GN, Kruchek BL (2005) Use of coastal wetlands by hispid cotton rats (Sigmodon hispidus). The Southwestern Naturalist 50:397–402

Carter MR, Burns LA, Cavinder TR, Dugger KR, Fore PL, Hicks DB, Revells HL, Schmidt TW (1973). In: Ecosystems analysis of the Big Cypress Swamp and estuaries. Report EPA9049–74–002. Atlanta, Georgia: U.S. Environmental Protection Agency.

Ceilley DW, Clem SE, Martin LE, Everham EM III, Diaz G, Clark PE (2005) Use of coastal wetlands by hispid cotton rats (Sigmodon hispidus). The Southwestern Naturalist 50:397–402

Davis S, Ogden JC (1994) Everglades: the ecosystem and its restoration. St. Lucie Press, Boca Raton, Florida

Doren RF, Trexler JC, Gottlieb AD, Harwell MC (2009) Ecological indicators for system-wide assessment of the Greater Everglades ecosystem restoration program. Ecological Indicators 9:S2–S16

Efford MG (2020) secr: Spatially explicit capture-recapture models. R package version 4.2.2. https://CRAN.R-project.org/package=secr.

Efford MG, Borchers DL, Byrom AE (2009) Density estimation by spatially explicit capture-recapture: likelihood-based methods. Pages 255–269 in: Thomson DL, Cooch EG, and Conroy MJ (eds) Modeling demographic processes in marked populations. Springer US, Boston, Massachusetts.

Eisher RJ, Wolfe JL, Layne JN (1978) Swimming behavior of rice rats (Oryzomys palustris) and cotton rats (Sigmodon hispidus). Journal of Mammalogy 59: 551–558

Fernandes MV (2011) Effects of Changes in the Everglades on Two Indicator Species: Sigmodon hispidus and Oryzomys palustris. Open Access Dissertations. Paper 606. Ph.D. Dissertation. University of Miami, Florida

Frederick P, Gawlik DE, Ogden JC, Cook MI, Lusk M (2009) The white ibis and wood stork as indicators for restoration of the Everglades ecosystem. Ecological Indicators 9:S83–S95

Gaines MS, Sasso CR, Diffendorfer JE, Beck H (2002) Effects of tree island size and water on the population dynamics of small mammals in the Everglades. Pages 429–444. In: Tree Islands of the Everglades. Springer, Dordrecht

Gawlik DE (2002) The effects of prey availability on the numerical response of wading birds. Ecological Monographs 72:329–346

Gibbs JP (1993) Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13:25–31

Gonzalez SC (2019) Documenting changes in mammal communities in the northern Everglades. Southeastern Naturalist 18:619–629

Heink U, Kowarik I (2010) What are indicators? On the definition of indicators in ecology and environmental planning. Ecological Indicators 10:584–593

Herbert DA, Perry WB, Cosby BJ, Fourqurean JW (2011) Projected reorganization of Florida bay seagrass communities in response to the increased freshwater inflow of Everglades restoration. Estuaries and Coasts 34:973–992

Hiemstra P, Pebesma EJ, Twenhofel CJ, Heuvelink GBM (2009) Real-time automatic interpolation of ambient gamma dose rates from the Dutch radioactivity monitoring network. Computers & Geosciences 35:1711–1721

Hu S, Niu Z, Chen Y, Li L, Zhang H (2017) Global wetlands: potential distribution, wetland loss, and status. Science of the Total Environment 586: 319–327

IPBES (2018) The IPBES assessment report on land degradation and restoration. In: Montanarella L, Scholes R, Braimah A (eds) Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES, Bonn, Germany

Jarath M, Bhat M, Rivera-Monroy VH, Castañeda-Moya E, Simard M, Twilley RR (2016) The role of economic, policy, and ecological factors in estimating the value of carbon stocks in Everglades mangrove forests, South Florida, USA. Environmental Science & Policy 66:160–169

Kirwan ML, Megonigal JP (2013) Tidal wetland stability in the face of human impacts and sea-level rise. Nature 504:53–60

Lehtinen RM, Galatowitsch SM (2001) Colonization of restored wetlands by amphibians in Minnesota. The American Midland Naturalist 145:388–397

Light SS, Dineen JW (1994) Water control in the Everglades: a historical perspective. In: Davis SM, Ogden JC (eds) Everglades: the ecosystem and its restoration. St. Lucie Press, Delray Beach, Florida

LoSchiaivo AJ, Best RG, Burns RE, Gray S, Harwell MC, Hines EB, McLean AR, St Clair T, Traxler S, Vearil JW (2013) Lessons learned from the first decade of adaptive management in comprehensive Everglades restoration. Ecology and Society 18:70–81

Mather Economics (2010) Measuring the economic benefits of America’s Everglades restoration. Study Prepared for The Everglades Foundation, Palmetto Bay, Florida

Mazzotti FJ, Best GR, Brandt LA, Cherkiss MS, Jeffery BM, Rice KG (2009) Alligators and crocodiles as indicators for restoration of Everglades ecosystems. Ecological Indicators 9:S137–S149
Mazzotti FJ, Ostrenko W, Smith AT (1981) Effects of the exotic plants \textit{Melaleuca quinquenervia} and \textit{Casuarina equisetifolia} on small mammal populations in the eastern Florida Everglades. Florida Scientist, 44:65–71

National Academies of Sciences, Engineering, and Medicine (2018) Progress toward restoring the Everglades: the seventh biennial review [Congressional Briefing]. National Academies Press, Washington, D. C.

National Research Council (2008) Progress toward restoring the everglades: the second biennial review. In: Committee on Independent Scientific Review of Everglades Restoration Progress (CISRERP). National Academies Press., Washington, DC 71e107 (Chapter 3)

Pearlstine L, Galbo AL, Reynolds G, Parsons JH, Dean T, Alvarado M, Suir K (2016) Recurrence intervals of spatially simulated hydrologic metrics for restoration of cape sable seaside sparrow (\textit{Ammodramus maritimus mirabilis}) habitat. Ecological Indicators 60:1252–1262

R Core Team (2019) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria https://www.R-project.org/

Romairone J, Jiménez J, Luque-Larena JJ, Mougeot F (2018) Spatial capture-recapture design and modelling for the study of small mammals. PLoS One 16:e0198766

Romañach SS (2020) Small mammal captures at the picayune Strand state Forest, October 2014—April 2016: U.S. In: Geological survey data release. https://doi.org/10.5066/P9BWA7RD. Reston, Virginia: U.S. Geological Survey

Romañach SS, Benscoter AM, Haider SM (2020) Potential impacts of future urbanization and sea level rise on Florida’s natural resources. Journal of Fish & Wildlife Management 11:174–184

Ryszkowski L (1975) The ecosystem role of small mammals. Ecological Bulletins, 19:139–145

Shulse CD, Semlitsch RD, Trauth KM, Gardner JE (2012) Testing wetland features to increase amphibian reproductive success and species richness for mitigation and restoration. Ecological Applications 22:1675–1688

Smith AT (1980) Lack of interspecific interactions of Everglades rodents on two spatial scales. Acta Theriologica 25:61–70

Smith AT, Vrieze JM (1979) Population structure of Everglades rodents: responses to a patchy environment. Journal of Mammalogy 60:778–794

Swartz LK, Lowe WH, Muths EL, Hossack BR (2020) Species-specific responses to wetland mitigation among amphibians in the greater Yellowstone ecosystem. Restoration Ecology 28:206–214

Trexler JC, Goss CW (2009) Aquatic fauna as indicators for Everglades restoration: applying dynamic targets in assessments. Ecological Indicators 9: S108–S119

USACE (1999) Central and southern Florida project comprehensive review study: final integrated feasibility report and programmatic environmental impact statement. https://www.nrc.gov/docs/ML1219/ML12193A285.pdf Accessed 29 January 2020.

USACE (2018) Integrated Delivery Schedule. https://www.saj.usace.army.mil/Missions/Environmental/Ecosystem-Restoration/Integrated-Delivery-Schedule/

USACE and SFWMD (2004) Comprehensive Everglades Restoration Plan Pica-yune Strand Restoration (Formerly Southern Golden Gates Estates Ecosystem Restoration) Final Integrated Project Implementation Report and Environmental Impact Statement.

Waltz AE, Covington WW (2004) Ecological restoration treatments increase butterfly richness and abundance: mechanisms of response. Restoration Ecology 12:85–96

Worley KB, Schmid JR, Schuman MI, Booher VG, Johnson LA, Addison D, Bartoszek IA (2007) First year post-restoration aquatic Fauna monitoring in the picayune Strand restoration project area (2016–2017). Final report for South Florida water Management District. Conservancy of Southwest Florida, Naples, Florida

Worth CB (1950) Observations on ectoparasites of some small mammals in Everglades National Park and Hillsborough County, Florida. The Journal of Parasitology 36:326–335

Supporting Information
The following information may be found in the online version of this article:

Table S1: Proportion of traps occupied (trap saturation) by an animal in each session and trapping occasion.

Table S2: Effects of habitat, restoration status, and water stage estimated using spatially explicit capture-recapture estimates of cotton mouse (\textit{Peromyscus gossypinus})

Received: 19 August, 2020; First decision: 2 November, 2020; Revised: 18 November, 2020; Accepted: 19 November, 2020