FIRST U.S. VASCULAR PLANT EXTIRPATION LINKED TO SEA LEVEL RISE? *PILOSOCEREUS MILLSPAUGHII* (CACTACEAE) IN THE FLORIDA KEYS, U.S.A.

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ABSTRACT

The global biodiversity crisis affects species across all continents and taxonomic groups. Direct destruction of species and habitats has been a primary driver of declines, though climate change and associated sea level rise are expected to accelerate loss. The flora of low-lying, relatively isolated islands is especially threatened when high species richness intersects with vulnerability to sea level rise. The Florida Keys represent a hotspot for cactus diversity in the eastern United States, with eight species recognized, three of which are endemic to the islands. Though not endemic to the islands, the Key Largo tree cactus (*Pilosocereus millspaughii*) was known in the United States from only a single population in the Florida Keys. Its decline and ensuing extirpation correspond with rising sea levels in the region. The other cacti in the region, and all rare plants in the Florida Keys, are threatened with a similar fate.

RESUMEN

La crisis global de biodiversidad afecta a especies de todos los continentes y grupos taxonómicos. La destrucción directa de especies y hábitats ha sido el principal impulsor de la disminución, aunque se espera que el cambio climático y el aumento asociado del nivel del mar aceleren la pérdida. La flora de islas bajas y relativamente aisladas se ve especialmente amenazada cuando la gran riqueza de especies se cruza con la vulnerabilidad al aumento del nivel del mar. Los Florida Keys representan un punto crítico para la diversidad de cactus en el este de los Estados Unidos, con ocho especies reconocidas, tres de las cuales son endémicas de las islas. Aunque no es endémico de las islas, el cactus arbóreo de Key Largo (*Pilosocereus millspaughii*) era conocido en los Estados Unidos por una sola población en los Florida Keys. Su declive y su siguiente extinción se corresponden con el aumento del nivel del mar en la región. Los demás cactus de la región, y todas las plantas raras de los Florida Keys, están amenazados con un destino similar.

Key Words: Cacti, at-risk species, climate change, extirpation, ex situ conservation, endemism

The Biodiversity Extinction Crisis

The loss of species at global, national, and local scales is recognized as a crisis requiring urgent action, with a roughly estimated 1 million species of animals and plants at risk of global extinction (IPBES 2019; CBD 2022). In the continental United States and Canada, 65 vascular plant taxa have been reported as globally extinct, with just seven of those taxa extant in conservation collections (Knapp et al. 2021) and at least an additional 22 taxa are considered extirpated (NatureServe 2023a). In southern Florida, the Floristic Inventory of South

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Florida reports 77 vascular plant taxa that may be extirpated from the region, including five global extinctions (*Amaranthus floridanus* (S. Watson) J.D. Sauer, *Eriochloa michauxii* (Poir.) Hitch. var. *simpsonii* Hitch., *Govenia floridana* P.M. Br., *Lechea lakelae* Wilbur, and *Tephrosia angustissima* Shuttlew. ex Chapm.), and 27 taxa that may be extirpated in the continental United States (Gann et al. 2023; Gann, unpublished data).

Causes of extinctions are many, but include habitat destruction and degradation, over-collecting and poaching, and climate change and sea level rise. Plants known from a single site are more likely to become extinct (Knapp et al. 2021). For cacti, the primary drivers of extinction risk historically included over-collecting, ranching, and agriculture (Goettsch et al. 2015), but climate change is predicted to become the primary driver of cactus extinction risk, with 48% of taxa considered at risk in the USA (i.e. global ranking of GH, G1, G2, or G3; (NatureServe 2023b)), and 60% globally (Pillet et al. 2022). In the Florida Keys, sea level rise is a known threat to many rare plant populations (Gann et al. 2002; Goodman et al. 2012; Reece et al. 2013). In cases where in situ recovery is unlikely or impossible, mechanisms to combat extinctions of highly threatened plants or animals include emergency collection (e.g., Wendelberger et al. 2008; Walters et al. 2010), the establishment and curation of ex situ collections, and translocation of populations into suitable habitat within a species' natural range (Guerrant et al. 2004; Seddon et al. 2012; IUCN/SSN 2013; IUCN/SSN 2014; CPC 2019).

Cacti of the Florida Keys

Cacti are primarily a New World plant family, with about 1850 species (Korotkova et al. 2021). In the continental United States, the center of diversity is in the Southwest, including Arizona, New Mexico, and Texas (Kartesz 2015). East of the Mississippi River, cactus diversity and endemism are much lower, with Florida being the most diverse of the eastern states (Kartesz 2015), with 14 native taxa (Wunderlin et al. 2023). Cactus diversity in Florida follows an inverse latitudinal gradient, with southernmost Monroe County, which includes the Florida Keys, being home to at least eight species (Kartesz 2015; Gann et al. 2023, Table 1). This unique assemblage is mostly composed of species of Caribbean/tropical origin, though the Keys endemic *Opuntia abjecta* Small ex Britton & Rose is derived from the temperate/subtropical *O. humifusa* complex (Majure et al. 2017), and the native range of the *O. stricta* complex includes both subtropical and tropical regions (Gann et al. 2023). All eight Keys cacti are listed as rare or threatened by one or more entities (USFWS 1984; USFWS 2013; FAC 1998; Gann et al. 2023).

The first comprehensive examination of cacti in the Florida Keys was conducted by John Kunkel Small, whose Flora of the Florida Keys (Small 1913) recognized six native cactus species in the region, which doubled to 12 cactus species in the Keys in a later treatment (Small 1933). Long and Lakela (1972) included nine native taxa in the Keys. Today, eight native taxa are recognized as extant by Wunderlin et al. (2023). The Florida Keys cacti have been the subject of renewed taxonomic interest and, as a result, taxonomic flux. In the past quarter-century, five taxonomic studies have focused on the region (Austin et al. 1998; Franck 2012; Franck et al. 2019; Majure et al. 2013, 2017). The recognition of a second species of *Pilosocereus* (*P. millspaughii*) in the Florida Keys has only been formally accepted recently (Franck et al. 2019). Previously, the species of *Harrisia* in the Keys was called *H. simpsonii*, but a recent revision determined it was synonymous with *H. fragrans* (Franck 2012). Molecular techniques resulted in the recognition of two taxa (*O. abjecta* and *O. ochrocentra* Small ex Britton & Rose) as endemic to the Lower Keys which had formerly been under synonymy with Cuban taxa (Majure et al. 2013). *Opuntia humifusa* s.str. as currently circumscribed is not known from Florida (Majure et al. 2017). Formerly-recognized species such as *Opuntia keyensis* Britton ex. Small, a narrow endemic with an unmistakably distinct form (Small 1919), may in time be reinstituted by taxonomists. In addition, a significant new population of an endemic cactus (*Consolea corallicola* Small) was discovered (Bradley & Woodmansee 2002). These recent revisions and discoveries of Florida Keys cacti underscore the complexity and uniqueness of this group, which faces an especially dire situation with high vulnerability to sea level rise, tropical cyclones, and other phenomena linked to climate change. Here, we provide an overview of sea level rise in the Florida Keys, examine the case study of the first wild cactus extirpation from the Florida Keys, *Pilosocereus millspaughii* from Key Largo, and discuss what else is at stake regarding the region's cacti.

Table 1. Cacti of the Florida Keys. Taxonomy follows Wunderlin et al. (2023). Range abbreviations include US (United States of America), WI (West Indies), MX (Mexico), CA (Central America) and SA (South America). Rankings of rarity and/or extinction risk are provided by five different organizations. In South Florida, the Institute for Regional Conservation (IRC) follows standards used by natural heritage programs, where a taxon is assigned a number 1–5 and lower numbers represent the greatest risk. The US Fish and Wildlife Service (FWS) lists three of the species as endangered (E) under the Endangered Species Act. The Florida Dept. of Agriculture and Consumer Services (FL) lists seven of the species as threatened (T) or endangered (E). Florida Natural Areas Inventory (FNAI) provides ranks for status of each taxon in the state (S) of Florida and NatureServe (NS) provides each taxon's global (G) ranking. A dash ("–") indicates that the taxon did not meet ranking criteria for a particular agency; "NE" indicates a taxon that has not yet been evaluated.

Taxon	Range	IRC	FWS	FL	FNAI	NS
Acanthocereus tetragonus (L.) Hummelinck	US, WI, MX, CA, SA	SF3	–	T	–	G5
Consolea corallicola Small	FL Keys	SF1	E	E	S1	G1
Harrisia fragrans Small ex Britton & Rose*	Peninsular Florida	SF1	E	E	S1	G1*
Opuntia abjecta Small ex Britton & Rose	Middle and Lower FL Keys	SF1	–	E**	S1**	G3**
Opuntia ochrocentra Small ex Britton & Rose	Lower FL Keys	SF1	–	–	NE	NE
Opuntia stricta (Haw.) Haw.	US, WI, MX, SA	SF5	–	T	–	G4
Pilosocereus millspaughii (Britton) Byles & G.D. Rowley	FL Keys WI	SF1	–	E	S1‡	NE
Pilsosocereus robinii (Lem.) Byles & G.D. Rowley	FL Keys, WI	SF1	E	E	S1	G1❖

*Material in Miami-Dade and Monroe counties was previously referred to as *Harrisia simpsonii* Small ex Britton & Rose. The NS ranking for *Harrisia fragrans* was made in 1994 and included only material from St. Lucie County.
**Ranked by FL, FNAI, and NS as *Opuntia triacantha* (Willd.) Sweet, a Caribbean species misapplied to Florida material.
‡Ranked by FNAI as *Pilosocereus polygonus* (Lam.) Byles & G.D. Rowley, a Hispaniolan species misapplied to Florida material.
❖The NS rank of G1 was made in 2009 and did not include populations in The Bahamas.

Climate Change and the Florida Keys

An acceleration of sea level rise as well as frequency of tropical cyclones is indicated by global (IPCC 2018), national (Sweet et al. 2022), and local (Hoegh-Goldberg 2010) experts, with the coastal, low-lying Florida Keys among regions at the front lines. The Keys are particularly vulnerable to the effects of sea level rise and storm surge due to their low elevation. Much of the land is less than 1.5 meters (5 ft) above sea level, the highest point being on Windley Key at just 5.5 m (18 ft) (Hoffmeister 1974). The sea level monitoring station closest to Key Largo is on Vaca Key, approximately 80 km (50 mi) to the south (NOAA 2023). Data collected at this station between 1971 and 2022 show evidence of rising tides and saltwater intrusion, with an average sea level rise of 4.09 mm/year during that 51-year span, or a total of 0.21 m (0.68 ft). At this rate the sea level would rise 0.41 m (1.34 ft) over the span of 100 years (NOAA 2023). With sea level rise, high tides are becoming higher. The phenomenon known colloquially as "king tides," or exceptionally high tides, has occurred more frequently and impacted more area in recent years (Duquesnel & Wilson, pers. obs.; Mazzei 2019). King tides in the Florida Keys occur in the fall, usually peaking in October (NOAA 2023). As early as 2011, king tide events in the Upper Keys began to negatively impact glycophytes (salt-sensitive plants) in the region (J. Duquesnel, pers. obs.).

Compounding the effects of sea level rise, the Keys' geographic location places them in the paths of many Atlantic hurricanes. Since the year 2000, 19 named hurricanes impacted the Florida Keys (NWS 2023a). Of these, 2017's Hurricane Irma was the most damaging, and was in fact the fourth most intense storm to ever affect the region (NWS 2023b).

Increased saltwater flooding from sea level rise, storm surge, and the combination of these phenomena poses a threat to a multitude of endemic or near-endemic plant and animal species in the Florida Keys (Ross et al. 1994, 2009; Maschinski et al. 2011; Noss 2011; Benedict et al. 2018; Possley & Maschinski 2023). We believe that the first extirpation of a taxon from the wild in the US due to sea level rise occurred with the Key Largo tree cactus (*Pilosocereus millspaughii*) in 2023 when we salvaged the last remnants of what was once a healthy and thriving population.

The Key Largo Tree Cactus

The only population of Key Largo tree cactus documented in North America was discovered in John Pennekamp Coral Reef State Park in 1992 by biologist Joseph J. O'Brien (then with National Audubon Research) and two colleagues. At the time, O'Brien wrote in his field notebook:

> On 12 April 1992, I was exploring a small isolated upland forest surrounded by mangroves with Allan Strong and Rick Sawicki in Key Largo, when I spied a clump of tree cacti emerging from the canopy. We rushed over to the plants to get a closer look and were surprised by the unusual appearance of the cacti. These plants had copious tufts of hairs around the tops of the columns, and around the infructescence. The tree cactus species we were familiar with, *Cereus robinii* did not have anywhere near these amounts of hair. We returned four days later and took numerous picture[s] and collected an aborted fruit lying on the ground. This fruit was deposited at Fairchild Tropical Garden herbarium. A review of the literature of *Cereus robinii* found that J.K. Small had originally described two varieties of tree cactus from the Florida Keys. Initially I thought that we had discovered a variety that may have been thought extinct. The characters did not fit, and I began to examine characters of other taxa of tree cactus found in the Bahamas. The most similar species was found to be *Cephalocereus millspaughii*. A trip to Great Exuma in August 1992 confirmed my suspicions that this was indeed the taxon we had discovered on Key Largo. The clump consisted of approximately 15* columns growing in a small transitional thorn woodland (*sensu* Ross et al. 1992).
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> *This figure seems incongruous with the assessment of Adams and Lima (1994) who reported 75 stems less than two years later, however O'Brien was referring only to the number of columns that extended above the forest canopy.

As O'Brien indicated, the material he found in Key Largo in 1992 was unlike either of the two forms of tree cactus (*Cereus deeringii* Small and *Cereus keyensis* Britton & Rose) recognized by botanist John Kunkel Small (Small 1917, 1933) which were later synonymized with *Pilosocereus robinii*. O'Brien's determination of *Pilosocereus millspaughi* was later confirmed by Franck et al. (2019). *Pilosocereus millspaughii* is a columnar cactus with distribution in the West Indies including the Bahama Archipelago and northern Cuba (Franck et al. 2019). The Key Largo tree cactus may have arisen from a single dispersal event from the Caribbean islands. The habitat where it grew was unique, in that it was a small limestone outcrop surrounded by mature red mangrove forest. Several of these outcrops occur in the mangrove forests of Key Largo and include upland habitat elements of the local rockland hammock (broadleaf dry forest) as well as Keys tidal rock barren. Some of the species present include saffron plum (*Sideroxylon celastrinum* (Kunth) T.D. Penn.), blackbead (*Pithecellobium keyense* Britton ex Britton & Rose), Jamaican capertree (*Quadrella jamaicensis* (Jacq.) J. Presl), limber caper (*Cynophalla flexuosa* (L.) J. Presl), Spanish stopper (*Eugenia foetida* Pers.), hog plum (*Ximenia americana* L.), fragrant prickly-apple (*Harrisia fragrans* Small ex Britton & Rose), and the shell-mound prickly pear (*Opuntia stricta* (Haw.) Haw.). The site also boasts a unique assemblage of epiphytes, specifically Spanish moss (*Tillandsia usneoides* (L.) L.), Southern needleleaf (*Tillandsia setacea* Sw.), tropical resurrection fern (*Pleopeltis polypodioides* (L.) E.G. Andrews & Windham) and dollar orchid (*Prosthechea boothiana* (Lindl.) W.E. Higgins var. *erythronioides* (Small) W.E. Higgins). The transition from this habitat to the mangroves is dominated by halophytes such as turtleweed (*Batis maritima* L.) and perennial glasswort (*Salicornia ambigua* Michx.) that have been encroaching onto the outcrop, and includes sporadic buttonwoods (*Conocarpus erectus* L.), many of which have begun to decline or have died in the past decade. The outcrop contained a rich humic layer atop the limestone that has been rapidly deteriorating as tidal influence increases, and with it much of the upland vegetative elements.

A comprehensive assessment of *Pilosocerus* spp. in the Florida Keys by Adams and Lima in 1994 serves as a baseline for subsequent assessments. They noted that the cacti were "profusely reproductive" with hundreds of flowers on 75 separate stems. No description of stem height was made, but presumably many stems extended above the surrounding hardwood forest canopy as O'Brien described.

The cacti survived through Hurricane Georges in 1998 (Duquesnel, pers. obs.). In 2005, four hurricanes, Dennis, Katrina, Rita, and Wilma all passed over or near the Keys, yet they did not appear to significantly impact the population. Beginning in 2007, a subset of the co-authors monitored the population every 1–2 years, assessing population size and general health (Fig. 1). We defined an individual as a separately-rooted

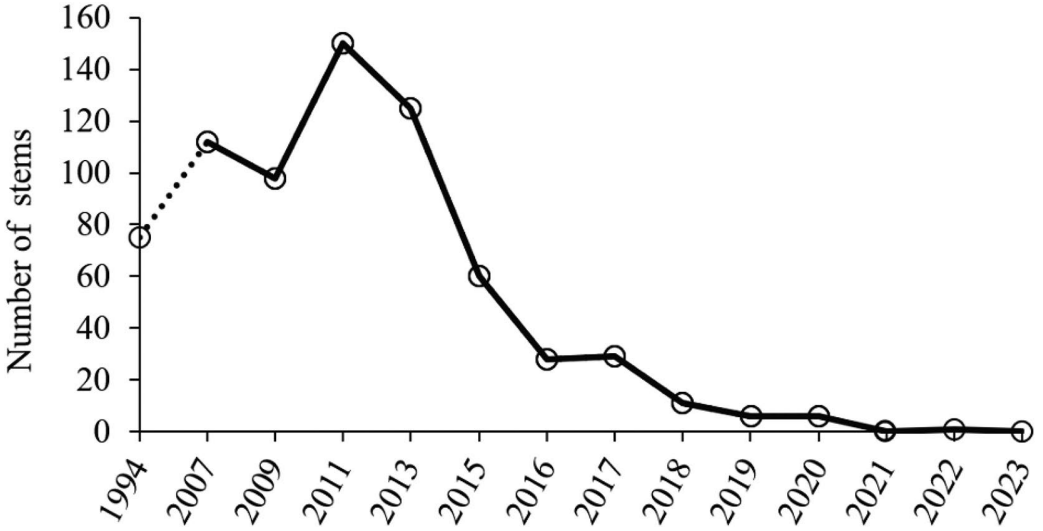

Fig. 1. Number of Key Largo tree cactus (*Pilosocereus millspaughii*) individuals over time. X-axis intervals not to scale. Dotted line represents a 13-year period where no population data were collected.

stem (these were usually, but not always, vertical, and included fallen, prostrate stems that had taken root). This definition was used for all subsequent monitoring events.

The authors first noted that the Key Largo tree cactus began to decline in 2015 (Fig. 2). Only 60 live individuals were recorded during that annual monitoring event, approximately a 50% reduction from the previous monitoring in 2013. In 2015 we observed significant herbivory on roughly half of the stems, where large portions of non-woody stem cortex were gnawed down to vascular tissue, both at ground level, and as high as ~1.25 meters (~4 ft) from the ground (Fig. 3). We deployed a wildlife camera in February 2016 and retrieved it in June of that same year. Of 243 total visits captured on camera, raccoons were the most abundant (58%), followed by birds (31%), marsh rabbits (5%), opossums (4%), cotton mice (<1%) and unknown animals (<1%). Although both introduced black rats and endangered Key Largo wood rats are known to inhabit the area, they were not captured in these images. Camera traps failed to capture any animal directly impacting the cacti, and such significant herbivory was not observed again.

By 2016, it was clear that the population was in peril, having again been reduced by approximately 50% in just one year to 28 rooted stems. Most of the previously-vertical columns had collapsed, and even some of the rooted material was yellowing (Fig. 4). In February of that year, we began to rescue stem fragments (8 in total, each roughly 30 cm long) to cultivate in the nursery at John Pennekamp Coral Reef State Park. In 2017, Hurricane Irma produced approximately 1.5 m (5 ft) of storm surge throughout Key Largo. Stem die-off accelerated. By February of 2019, the once-massive colony had completely collapsed (Fig. 5). In fall 2019, tidal water during "king tides" was first noted by the coauthors as being present within inches of the Key Largo tree cactus. That year, inland flooding was present in the area for up to 3 months (Duquesnel & Wilson, pers. obs.; Mazzei 2019).

As it became increasingly clear that the wild population of Key Largo tree cactus had little hope of recovery in situ, a rescue plan was developed by the authors. The only six remaining individuals, one of which had previously stood more than 3 meters tall and still had 20 branches, were left in place through early summer of 2021 to accommodate a final flowering and fruiting period. Indeed, three fruits formed on the large individual that summer; these were caged to protect them from potential herbivores and harvested when ripe, though only two of them contained viable seeds. After the last fruit was harvested, all green material was salvaged and

Fig. 2. The Key Largo tree cactus, *Pilosocereus millspaughii*, in habitat at John Pennekamp Coral Reef State Park, in 2015. Photograph by James Lange.

Fig. 3. Damage to Key Largo tree cactus, *Pilosocereus millspaughii* from herbivory, photographed in February 2015. **Left:** fresh damage and fragmented cacti. **Center:** teeth marks visible on older damage **Right:** recent damage more than 1 meter from the ground. Left and center photographs by Devon Powell. Right photograph by James Lange.

Fig. 4. The Key Largo tree cactus (*Pilosocereus millspaughii*) at John Pennekamp Coral Reef State Park in 2016, with many stems chlorotic and/or collapsed. Photograph by James Lange.

divided between two nurseries, at Fairchild Tropical Botanic Garden and John Pennekamp Coral Reef State Park. Most material is being grown in containers, but four individuals were planted in the ground behind the Pennekamp nursery; these have grown faster than individuals in containers. Today, ex situ holdings include 36 salvaged fragments, 25 seedlings grown from fruits produced in cultivation, and more than 1000 seeds banked in long-term storage at Fairchild (N=912) and the United States Department of Agriculture's National Laboratory for Genetic Resource Preservation (N=167). Cultivated plants flower in mid-to-late summer each year (Fig. 6). Flowers bloom at night and are hand-pollinated by staff. Most fruits develop well, whether they are selfed or crossed, but fruits rarely develop without hand-pollination. Stored seeds are maintained under low humidity (<25% RH) and freezing temperatures (–20°C), which prolongs their lifespan by orders of magnitude. The genus has been shown to tolerate these conditions (Salazar et al. 2013). We will continue to harvest seeds from fruits produced in cultivation to be used for both storage and further propagation.

After the rescue, we returned to the site in July 2022 and again in July 2023 to search for additional material that we might have missed or that had grown since the rescue. We did not observe any healthy material in 2022, however in July 2023, we found that one small, rooted fragment that had been left in place due to its poor condition had re-grown to approximately 35 cm in height. Although this individual was green and robust, we opted to extract it and bring it into ex situ collections, because it was clear that the area will only continue to succumb to sea level rise. Observations at the site in July 2023 showed continued soil erosion and limerock exposure in higher elevation areas, as well as increasing encroachment of mangroves and salt-tolerant herbaceous vegetation.

Fig. 5. Duquesnel with the recently fallen, last large clump of *Pilosocereus millspaughii* in September of 2020. Standing water is present inches away from the base of the plant. Photograph by Brian Harding.

Fig. 6. *Pilosocereus millspaughii* in cultivation at the nursery at John Pennekamp Coral Reef State Park. **Left:** a plant blooming on 5/26/22. **Center:** the same plant with green fruit on 6/17/22. **Right:** Three fruits harvested on 7/6/22. Photographs by Susan Kolterman.

DISCUSSION

The collapse of the Key Largo tree cactus was likely caused by the confluence of storm surges, sea level rise, and the 2015 herbivory event. The co-occurrence of multiple detrimental factors can have interactive effects that amplify overall impacts to habitat and species viability (Bigler et al. 2005; Tye et al. 2016), confounding any diagnosis. Future conservation plans include continued care for ex situ cacti to encourage flowering and fruiting in order to store seeds in bulk for reintroduction or, at the very least, to ensure that the population will persist in cultivation. Suitable, higher-elevation habitat on or near Key Largo that would be required for reintroduction of *P. millspaughii* is very limited, but one site has already been selected, with plans for translocation in the next few years. The option to introduce *P. millspaughii* to habitat beyond Key Largo (i.e., managed relocation) is currently precluded by a suite of ethical considerations (for a discussion, see Maschinski et al. 2011, pp. 160–161).

The decline and extirpation of the Key Largo tree cactus is not a unique situation. As a group, cacti are particularly imperiled by climate change (Pillet et al. 2022). Decades-long conservation efforts are already underway for other Keys cacti which have exhibited declines, including *P. robinii* (Possley & Maschinski 2023) and *Consolea corallicola* (Stiling et al. 2000; Stiling & Moon 2001; Stiling 2010). Such efforts have included regular monitoring, rescues, establishment of ex situ conservation collections, translocations to wild habitat, and habitat manipulations.

With the tightly restricted ranges of South Florida's endemic cacti, full species extinctions loom on the horizon. Of the three South Florida-endemic taxa, conservation and research efforts have primarily been directed toward the one species with federal status: *Consolea corallicola*. Notably, some *C. corallicola* reintroductions have already experienced mortality associated with sea-level rise (J. Duquesnel, pers. obs.). As a result, more recent plantings have been conducted in slightly higher elevations than those historically occupied by the species.

Relatively recently, no species of *Opuntia* were considered to be endemic to the Florida Keys (Long & Lakela 1971; Wunderlin & Hansen 2011) until studies by Majure et al. (2012, 2013) reinstated *O. abjecta* and *O. ochrocentra* as unique taxa; these were first described by botanist John Kunkel Small (Small in Britton & Rose 1923). While they likely qualify for federal listing, both *Opuntia* species remain unlisted. Fairchild and Key West Tropical Forest and Botanical Garden (KWBG) maintain small ex situ collections of both species; KWBG also monitors a portion of the known wild *O. abjecta* populations and attempted one small-scale reintroduction (Woodmansee et al. 2022). *Opuntia keyensis*, described as endemic to the Keys and the Cape Sable region (Small 1919), remains unrecognized by taxonomists. Erring toward caution, Fairchild maintains a small ex situ collection of this species with material from southern Key Largo.

Beyond cacti, much of the unique flora and fauna of the Florida Keys is imperiled from decades of impacts that include habitat destruction, poaching, and climate change (e.g., Barbour & Humphrey 1982;

Subedi et al. 2002; Bradley & Saha 2009; Daniels 2009; Possley et al. 2022). Evidence that insular areas like the Florida Keys are more vulnerable to species extinction (Bellard et al. 2013) elevates the situation to crisis-level. *Pilosocereus millspaughii* is likely a bellwether for extinctions of Keys-endemic plants and animals and further extirpations of wider-ranging species whose North American distribution is limited to the Florida Keys. Continued cooperation amongst federal, state and local agencies, universities, environmental organizations, botanical gardens, citizen volunteers, and other stakeholders will be needed to conserve and recover these unique species before it is too late.

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