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The Quarterly Journal of the Florida Native Plant Society

Palmetto

Fern Conservation in a Biodiversity Hotspot • Saving the Endangered Florida Key Tree Cactus

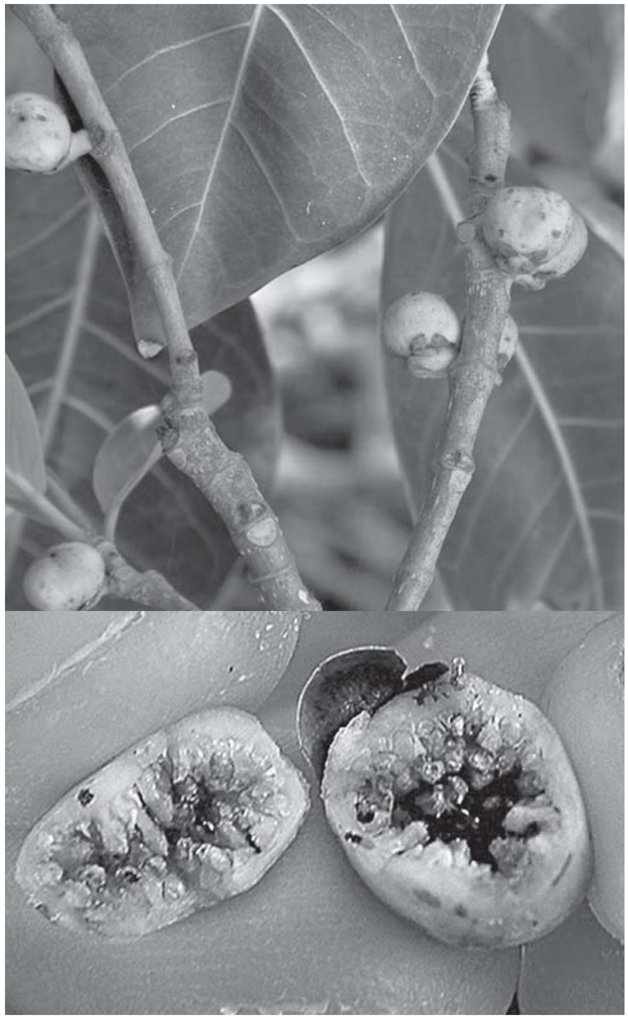
Featured Flora by George Rogers: *Ficus aurea* (Strangler Fig)

Why Do Figs Taste Crunchy?

As a kid vacationing in Florida, I found it scary that a malevolent tree strangles innocent others like the living garrote of the green world. A more mature perspective is less ghastly, and of course the ficus, or fig, does not actually strangle anything; it merely exploits its host tree for a cheap perch in the sun, growing over and around the host, competing for light and eventually root space. I'll bet the host generally lives a long and prosperous life despite its hitchhiker.

The young strangler fig sitting in a tree sometimes looks like a parasitic mistletoe early on, and some observers have attributed the ficus with a propensity for parasitism. However, tree biologist Peter Tomlinson emphasizes the exploitation to be merely epiphytic. But when the host dies does the strangler benefit nutritionally from the host's decay? Probably not.

Forest tree babies struggle for light under taller canopy trees, so each forest tree species needs a coping adaptation to survive its shaded youth. Many evolve large food-filled nuts to sustain the sapling until it rises high enough to compete effectively or until a canopy gap opens. Figs have a different plan: they form lots of tiny seeds (technically achenes) dispersed by birds to lodge in nooks and crannies high and bright on mature trees. Then they grow backwards – from the tree canopy downward to the ground.



Above: *Ficus aurea* plant with figs. Bottom: opened fig showing the tiny orange seeds, which are technically fruits. The entire fig is a hollow open stem, and the hollow seed-lined space is the cave, where you can often find dead wasps. Photos: John Bradford.

Native strangler figs (*Ficus aurea)*, are one of 750 ficus species worldwide. The other Florida native, the bearded fig (*Ficus citrifolia*) is mostly restricted to the southern tip of Florida and the Caribbean. Its whiskerish dangleroots reputedly account for the island name Barbados, translated as "bearded." Florida is home to numerous cultivated figs, some of them escaped nuisances. These garden figs include the banyan, bo tree, counciltree, Cuban laurel fig, edible fig, India rubbertree, and more.

The fruit, also called a fig, is a swollen stem with a hollow cave inside. The cave is lined with tiny male and female flowers followed by seedlike fruits. Pollination is by itsy bitsie teenie weenie wasps who enter through a portal at the end of the fig. The stranger fig has just one species of pollinating wasp (*Pegoscapus mexicanus*), which is perhaps why it does not (or not often) hybridize with bearded fig, which has its own wasp pollinator.

With variation among species, the general pattern is that female wasps enter the fig fruit and lay their eggs into the ovaries of specialized female flowers. Male wasps hatch forth from the eggs inside those flower ovaries and proceed to fertilize the immature female wasps while the girls are still confined within their fig flowers. How do they do that? The motivated guys chew their way through the flower ovary wall to the females, who later use those chew-holes to escape.

Upon exiting its flower-ovary but still inside the fig chamber, the pregnant female wasp packs pollen into a specialized pocket on her body. Then she flies out to visit a different fig to transfer pollen and lay eggs. She must deliver pollen reliably, because no pollen means no flower ovary growth, and no ovary equals no nursery for her babies. Something to try: bust open *Ficus aurea* fruits, poke through the crunchy seeds, and find the little wasps inside.

One or more interloper wasp species use stranger figs as brood chambers without contributing to pollination. One such sneaky pete (*Anidarnes bicolor*) injects its eggs from the outside of the fig, positioning them to mature on the inside, relying upon successful pollination by the proper pollinating wasp.

Starting out as epiphytes and living years on high before rooting in the ground, stranger figs contort around the host, which is why Bonsai enthusiasts like them. Strangler fig and related species have something unusual: bands of living

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ON THE COVER: *Odontosoria clavata* in a Miami-Dade County preserve. Photo: Jennifer Possley.

Features

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Fern Conservation in a Biodiversity Hotspot

Article by Jennifer Possley

Above: *Thelypteris sclerophylla* closeup of sporangia and stellate hairs. Photo: Hank Poor.

Figure 1: Miami's fern grottos are located only on the Miami Rock Ridge, a layer of oolitic limestone. Photo: J. Possley.

Who can blame Ponce de Leon for naming our state "Florida," with our splendid suite of flowering plants from both temperate and tropical climes. But peer between the branches of the trees and beyond the blooms of our flowers, and you may see that our state also boasts an amazing array of ferns. Florida has more native fern species (124) than any other state in the continental U.S., and more than one third of Florida's native fern species are found in Miami-Dade County (Nelson 2000, Wunderlin and Hansen 2008, Gann et al. 2014).

There are several ingredients that make Miami a fern diversity hotspot. If our warm, humid climate forms the base of the recipe, then our hydrology and geology are two of the most important added ingredients. Miami's fern grottos (Fig. 1) are located only on the Miami Rock Ridge, a layer of oolitic limestone that formed 130,000 years ago when higher seas began to recede to present-day levels. Over the ensuing centuries, fresh water from the Everglades percolated through the limestone, carving depressions and holes as it flowed. Areas that were closest to major water through-ways or "sloughs" carved the limestone more extensively, forming grottos.

Another crucial ingredient in the fern grotto recipe is the hardwood hammock plant community. This globally imperiled, closed-canopy, broad-leafed forest is found in Miami-Dade, Monroe and Collier Counties and derives much of its flora from similar forests of the Bahamas and the Greater Antilles (Snyder et al. 1990). Shade from the tropical hammock trees combines with the limestone substrate and fresh water from the Everglades to create the perfect levels of light and temperature, as well as constant high humidity, even through the dry season. In the forest understory, mosses and liverworts completely blanket the limestone with green (Fig. 2). These bryophytes in turn retain even more moisture, further ensuring year-round humidity and providing a perfect nursery where tiny young fern gametophytes (the sexual phase of a fern's life cycle) can live protected until conditions are right for fertilization to occur.

Unfortunately, like flowering plants, ferns are not immune to habitat loss, a phenomenon taken to the extreme in South Florida. In Miami-Dade County alone, habitat loss exceeds 98%. As a result, 14 of our native fern species are no longer found here and an additional 14 are critically imperiled (Gann et al. 2014). An analysis of our flora by The Institute for Regional Conservation found that South Florida's ferns and their allies are more likely than vascular plants to be extirpated or threatened (Gann et al. 2002). Further, they suggested that ferns suffer disproportionately from poaching and from lowering of the freshwater table because they require moisture to complete their life cycle. Thus, while Miami is blessed with high native fern diversity, we are also challenged with preserving a very high proportion of imperiled ferns.

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Figure 2: In the hardwood hammock understory, oolitic limestone and a covering of mosses and liverworts form ideal fern habitat. Photo: J. Possley.

Fairchild Tropical Botanic Garden in Coral Gables is centrally located in Florida's subtropical biodiversity hotspot, and has a history of cooperating to conserve the region's fern diversity (Fig. 3). In 2002, Fairchild entered into what would be a long-term partnership with the County's Environmentally Endangered Lands Program and Natural Areas Management Division. Recognizing the importance of protecting the diversity in the County's network of small preserves, the directors of these programs sought out Fairchild biologists to map, monitor and conserve the dozens of rare plant species in their charge, many of which happened to be ferns. In the ensuing years, Fairchild's native fern conservation program has grown to encompass 18 species. The program has also taken shape into one with a specific goal and underlying objectives (Tables 1 and 2). Because many of our rare native ferns are slow-growing and/or difficult to propagate, this program could only have been possible with the luxury of time.

Twelve years after the inception of Fairchild's current fern program, we have conducted reintroductions or augmentations with some of our rare fern species. We are constrained by each species' unique biology, thus our first outplanting successes have been with species that are relatively easy to propagate and fast-growing once they reach the sporophyte stage. These characteristics are possessed by the creeping star-hair fern *Thelypteris reptans* and the broad halberd fern *Tectaria heracleifolia*, which were our first fledglings. Both species did well in cultivation from spores at Fairchild, and *T. reptans* has the added advantage that it is "radicant" (it can root from the stems), and can be vegetatively propagated. In 2011

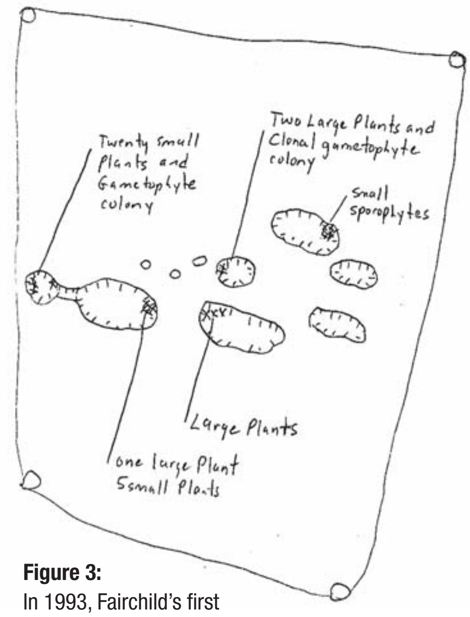

Figure 3:
In 1993, Fairchild's first conservation ecologist, Carol Lippincott, joined forces with geologist Alan Cressler to conduct very thorough rare fern surveys in Miami's devastated hardwood hammocks after Hurricane Andrew. Their hand-drawn maps are still important references today.

Table 1: Fairchild's native fern conservation program

Overall Program Goal: To reduce the risk of extinction of South Florida's rare ferns.	
Objectives:	1. Collect wild propagules
	2. Develop propagation techniques
	3. Establish ex situ populations at Fairchild
	4. Deposit spores into long term storage
	5. Introduce populations to suitable habitat in Miami-Dade County preserves

Table 2: Focus species and objectives met

				Objectives Met (for Miami-Dade Preserves)					
	FL Rank	Global Rarity	Florida Counties	1a. GIS Maps	1b. Population Census	2. Propagation Techniques	3. Ex Situ Collection	4. Spores Stored	5. Reintro
Adiantum melanoleucum	E	Near Endemic	1	●	●	●	●	●	
Anemia wrightii	E	Near Endemic	1	●	❍				
Asplenium verecundum	E	Near Endemic	12	●	●	●	●	●	
Asplenium x biscaynianum	none	FL Endemic	1	●	●				
Ctenitis sloanei	E	Widespread	5	●	❍	●	●	●	
Ctenitis submarginalis	E	Widespread	6	●	●	●	●		
Lomariopsis kunzeana	E	Near Endemic	1	●	●	●	❍		
Microgramma heterophylla	E	Near Endemic	3	●	❍	●	●		
Odontosoria clavata	E	Widespread	2	●	❍				
Tectaria heracleifolia	T	Widespread	8	❍		●	●	●	●
Thelypteris patens	E	Widespread	1	●	●	●	●	●	●
Thelypteris reptans	E	Widespread	8	❍		●	●	●	●
Thelypteris reticulata	E	Widespread	5	●	●	●	●	●	
Thelypteris sancta	E	Widespread	1	●	●				
Thelypteris sclerophylla	E	Near Endemic	1	●	●	●	●	●	
Thelypteris serrata	E	Widespread	12	●	●				
Trichomanes krausii	E	Widespread	1	●	●				
Trichomanes punctatum subsp. *floridanum*	E	FL Endemic	2	●	●				

Objectives met fully (●) or partially (❍). "Near endemic" refers to species found only in Florida and one or more islands of the Greater Antilles.

and 2012, we installed 234 *Tectaria heracleifolia* and 20 *Thelypteris reptans* in a restoration area within Hattie Bauer Hammock – the former site of the old Florida attraction "Orchid Jungle." We consider this reintroduction, which has had nearly 80% survival, to be successfully established (Figs. 4A–D).

This year, we reintroduced *Thelypteris patens*, which was recently extirpated from one of its only two known locations in North America (both of which are in Miami). This species was grown from spores we collected by our cooperators at the Cincinnati Zoo and Botanic Garden's Lindner Center for Research on Endangered Wildlife (CREW), who noted that it was among the quickest of our rare native ferns to form sporophytes. With the help of dozens of staff and

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Figures 4A–D: 4A. Miami-Dade County has a huge task in removing the non-native vegetation used to give Orchid Jungle the "jungly" feeling. Here, Natural Areas Management crews can be seen removing corn plant. 4B. Miami-Dade County biologists Dallas Hazelton and Jane Dozier prepare to plant Fairchild-grown rare ferns *Tectaria heracleifolia* and *Thelypteris reptans* in a restored portion of Hattie Bauer Hammock. 4C. One year after planting, Fairchild-grown rare fern *Thelypteris reptans* is well established in bryophyte-covered limestone in Hattie Bauer Hammock. 4D. Fairchild-grown *Tectaria heracleifolia* one year after planting in Hattie Bauer Hammock. Photos by J. Possley.

volunteers, we installed approximately 200 *Thelypteris patens* in the hammock preserve at The Deering Estate (Figs. 5A–D). These ferns were planted just after the finishing touches were made to a hydrology restoration project at The Deering Estate that is a component of The Central and Southern Florida Project Comprehensive Plan (Comprehensive Everglades Restoration Plan, or "CERP"). We expect that the reintroduced population of *T. patens* will thrive with the increased moisture this restoration is now delivering to the system.

In the next 2-3 years, we will be conducting plantings with other fern species. The climbing vine fern *Microgramma heterophylla* will likely be our next candidate, since it is extremely easy to propagate via cuttings and has done well in our nursery (Fig. 6). Before too long, we hope to reintroduce the fragrant maidenhair *Adiantum melanoleucum* (Figs. 7A–B) to appropriate protected habitat. CREW reports that this taxon is not the easiest to propagate from spores, but once CREW staffers have raised *A. melanoleucum* to the young sporophyte stage, they are hardy growers and can be propagated by rhizome divisions.

A few species are not on our agenda for reintroduction in the near future. These include *Trichomanes punctatum* ssp. *floridanum*, *Trichomanes krausii*, and *Lomariopsis kunzeana* (Figs. 8 and 9). The fact that these three of our rarest taxa are also exceedingly difficult to collect and cultivate is not a coincidence. Each of these ferns has several factors that contribute to natural rarity. First, all possess green spores. Most of the fern species we encounter contain spores that lack chlorophyll and can maintain viability for years. But the green spores of *Trichomanes* and *Lomariopsis* are very short-lived, so they must be sown soon after collection. *Lomariopsis kunzeana* will not sporulate until its fronds are several centimeters long, which may take years to achieve, and mature plants will only form sporangia in the month of June during years when the conditions are favorable (we suspect this is maximum shade and humidity). Our *Trichomanes* spp. sporulate throughout the year with a peak in the summer, but a tiny frond will only form a few sporangia, and these are hidden deeply inside a involucre (tube) on the leaf margin, making them difficult to access.

Despite the strides we have made, our fern conservation work is far from complete. Collection of spores for long-term storage is one of the more daunting tasks ahead of us, as we have only just begun to capture the genetic diversity within the wild populations of our 18 target species (not to mention, there are at least a dozen more species we would like to incorporate into the fold). With many of our rare fern populations being tiny, a random event such as trash dumping, a tree fall,


5B


5C


5A


5D

Figs 5A–D: Many steps are involved in a rare fern reintroduction, from collecting wild spores to propagating, to planting. 5A. A spore print from *Thelypteris patens* is a beautiful way to collect spores for propagation or storage. 5B. Young *Thelypteris patens* grown from spore by the Cincinnati Zoo and Botanic Garden's Lindner Center for Research on Endangered Wildlife. Plants are shipped to Fairchild, unwrapped, and cultured in our nursery. 5C. In Fairchild's nursery, dozens of *Thelypteris patens* await reintroduction day at The Deering Estate. 5D. Dr. Joyce Maschinski and Steve Forman reintroduce the extirpated fern *Thelypteris patens* to the hardwood hammock within The Deering Estate. Photos: J. Possley.

or a hurricane could easily wipe out an entire occurrence. The specter of global climate change suggests that some of Miami's nature preserves may be subject to salt water inundation in several decades. Clearly, the threats to Miami's fern biodiversity are many, and having "back-up" germplasm banked off-site is an important security measure (Fig. 10). Not all fern species possess spores capable of long-term storage (those with green spores do not). For those species especially, cultivating a healthy ex situ collection of live plants is crucial. We hope that this cooperative fern conservation program will be an ongoing, decades-long endeavor. Working in our favor are strong inter-agency partnerships, a long-term commitment, and the tenacious nature of our deceptively delicate-seeming fern flora.

Acknowledgements

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About the Author

Jennifer Possley has been a field biologist at Fairchild since 2001. She maps and monitors the rare flora of Miami-Dade County and researches the effects of vegetation management. She has special interests in ferns and as well as non-native invasive plants. Prior to joining Fairchild's staff, she received a BA in biology from Kalamazoo College and a MS in agronomy from the University of Florida. She is originally from the village of Dexter, Michigan.

Figure 6: *Microgramma heterophylla.* Photo: J. Possley.

Figure 7B: Fragrant maiden hair *Adiantum melanoleucum* grows from a bed of liverworts in the side of a limestone solution hole. Photo: J. Possley.

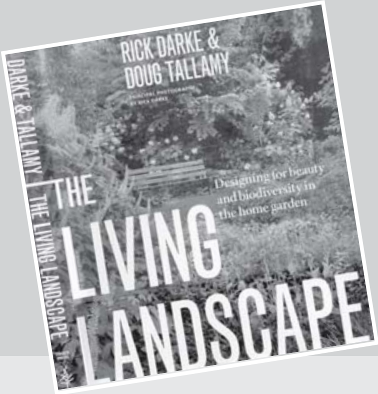
Figure 9: *Trichomanes krausii* (top) and *T. punctatum* ssp. *floridanum* (bottom). The latter species is Florida's only endemic non-hybrid fern and will soon be added to the list of US Endangered Species. Photos: Molly Messer (top) and J. Possley (bottom).

Figure 7A: *Adiantum melanoleucum* arrives in Miami after being packaged and shipped from CREW in Cincinnati. Photo: J. Possley.

Figure 8: A portion of a fertile frond of the endangered holly-vine fern *Lomariopsis kunzeana.* The brown specks in the photos's center are sporangia, or spore cases. The yellow-green patch in the upper right are the chlorophyll-containing spores. Photo: Kristie Wendelberger.

Figure 10: A tiny tube containing thousands of spores of *Thelypteris patens* is ready to be shipped to the USDA's National Center for Genetic Resources Preservation in Ft. Collins, CO. Photo: J. Maschinski.

BOOK REVIEW



The Living Landscape: Designing for Beauty and Biodiversity in the Home Garden

Doug Tallamy and Rick Darke
Published by Timber Press. 392 pages. ISBN-10: 1604694084

Review by Ginny Stibolt

The Living Landscape is a beautiful coffee table book graced with Rick Darke's color photos on every page. Doubtless many people outside the native plant community would be surprised that these plants are natives and that native-based landscapes could look so civilized. You could learn much about how native ecosystems work from this large book – it's 8.5" x 10" and almost 400 pages.

The content

The book's five chapters include: Layers in Wild Landscapes; The Community of Living Organisms: Why Interrelationships Matter More than Numbers; The Ecological Functions of Gardens: What Landscapes Do; The Art of Observation; and Applying Layers to the Home Garden. Chapters include personal essays by each of the authors – Darke's pages are tan, while Tallamy's are blue.

The lessons on layers and ecotones and how to add them to home landscapes are explained clearly and accompanied by appropriate photos. The section on birds and what they require in the landscape is well done, and information on the importance of insects is found throughout the book. The reader will come away with a clear understanding of how ecosystems work and why native plants are important even on a small scale such as the typical urban or suburban yard.

This book provides important lessons on landscape design with examples using native plant material and could be useful in the training of landscape architects and professional landscape installers. Maybe Darke's gorgeous photos will change people's perception of what is beautiful and will encourage the creation of landscapes based on native plants instead of exotics.

With few exceptions, the photos are of the Mid-Atlantic region and focus on relatively large landscapes including Longwood Gardens. While I appreciate the depiction of the progress of landscapes over time and through the seasons, and the aerial and roadside shots of mature woodlands, the book would have been much more useful if it contained pictures of smaller landscapes. Examples of how layering and habitat building can happen on small lots would help readers visualize ways to accomplish this in their own yards. I was disappointed to see only a single photo of a relatively small landscape, which was taken in a botanical garden and not someone's yard. One exception to the Mid-Atlantic focus is the inclusion of an example of the dependence of insects on their host plants featuring coontie (*Zamia pumila*) and the atala butterfly (*Eumaeus atala*), both native to Florida.

Appendices include charts titled "Landscape and Ecological Functions of Plants." These charts use symbols for each ecosystem service, and list details such as whether a particular plant provides cover for wildlife, nest sites for birds, if it flowers extensively, and other useful information. Charts cover several regions, beginning with the Mid-Atlantic (the emphasis of this book), followed by the Southeast, Southwest, Pacific Northwest, Midwest & Mountain states, and New England. There are separate authors for each region.

What is native?

The Florida Native Plant Society defines a native plant as occurring within the state boundaries prior to European contact, according to the best available scientific and historical documentation. Florida native plants include those species understood as indigenous, occurring in natural associations in habitats that existed prior to significant human impacts and alterations of the landscape.

Darke and Tallamy define native as "a plant or animal that has evolved in a given place over a period of time sufficient to develop complex and essential relationships with the physical environment and other organisms in a given ecological community."

Using this description, which does not specify a time scale or take into consideration human effects on ecosystems, couldn't oleander (*Nerium oleander*), be considered native on some level? Oleander is now almost the exclusive larval food source of the oleander moth or polka-dotted wasp moth (*Syntomeida epilais*). This insect is native to Florida and used to feed on a relatively rare member of the dogbane family, Apocynaceae. But over the 500 years since the Spanish first brought oleanders from their home country, the insects have made the switch and now occur wherever oleanders are planted except California. Perhaps the definition of native used in the book should be revised to include the effects of human impact.

Plant lists

For the plant lists in the back of the book, the authors took some understandable shortcuts so each plant would take up one line of text. The Mid-Atlantic list covers two pages, while other regions are allowed one page each.

Disturbingly, the plant list for the Mid-Atlantic includes the exotic *Ginkgo biloba*, native to China, with its one ecological function of carbon sequestration. The comments mention that the roasted seeds are edible, but the ginkgo's putrid-smelling fruit reeks of butyric acid. It is so obnoxious and messy that most of the planted trees are clones of male trees. *Ginkgo biloba* is strangely out of place in a book on native plants. It is also odd to find coontie (*Zamia pumila*) included as a shrub for the Mid-Atlantic region, when it only occurs in Florida and southernmost Georgia.

The list of plants for the Southeast was written by Larry Mellichamp, author of *Native Plans of the Southeast*. The list includes 206 plants, but many of these do not even occur as far south as northern Florida. Some of the plant choices are questionable. For instance, the list includes the endemic Florida yew (*Taxus floridana*), which only occurs in one county and is not commonly sold in the native plant trade. Coontie, a useful native plant, is not on the list for the Southeast. Closer editing would have helped this section, including a crosscheck the latest scientific binomials. Red chokeberry (*Photinia pyrifolia*) is referred to by its old name, *Aronia arbutifolia*, and it is listed as a shade producing plant in its landscape functions for the Southeast, but not in the Mid-Atlantic. I have lived with this lovely plant in both Florida and Maryland and shade production is not one of its characteristics.

The authors

Both Doug Tallamy and Rick Darke are in demand for speaking engagements throughout the country, and FNPS has invited them to be keynote speakers at our annual conference (Doug Tallamy more than once). Their presentations have been well-received and were truly inspirational. Many of us celebrated Tallamy's book *Bringing Nature Home* because it provided clarity and science to the argument for native plants in the landscape.

Conclusion

This attractive book has many positive attributes. Native plant advocates will be able to glean new and interesting information on the concept of habitat services and learn a lot more about how ecosystems work – useful for education and outreach efforts. Landscape designers will be inspired by the lovely photographs that may possibly change the paradigm as to what a beautiful landscape should look like.

Unfortunately, neither Florida or small landscapes are well covered, making the book less useful for Florida gardeners. I looked forward to *The Living Landscape* and eagerly pre-ordered a copy, but I doubt it will have as much impact on Florida native plant enthusiasts as Tallamy and Darke's previous books.

About the Author

Ginny Stibolt is a life-long gardener with an MS in botany from the University of Maryland, and has written about Florida gardening since 2004. She is the author of *Sustainable Gardening for Florida*, 2009; *Organic Methods for Vegetable Gardening in Florida*, 2013; and *The Art of Maintaining a Native Landscape*, to be released in 2015 (all published by University Press of Florida). Ginny is an administrator for the FNPS Facebook page and is one of FNPS' main bloggers. Her own blog about gardening is at www.GreenGardeningMatters.com.

Why Do Figs Taste Crunchy? Continued from page 2

storage tissue (axial wood parenchyma) layered in broad bands in the otherwise dead wood (normal wood is composed of predominantly dead water-pipe and support cells). The oddly abundant living storage tissue is conspicuous as light-colored horizontal bands alternating with the darker bands of proper dead wood. The living bands sequester water and starch, not a normal wood function in other plants. Why do figs do this?

Most epiphytes face a dry life trapped above the ground, using their roots to cling to the host instead of accessing groundwater and storing starch like conventional roots. Epiphytes throughout the plant world consequently develop diverse coping adaptations: succulence, animal symbioses, suspended animation, the expandable pseudobulbs and sponge-covered roots of orchids, the tanks of epiphytes, elaborate scales and hairs, and more. The weird and plentiful storage tissue seems to be the ficus answer to the basic epiphyte lifestyle challenge. There's just a wee bit of "cactus" built in.

This article previously appeared in the blog treasurecoastnatives.wordpress.com/ and has been edited for *Palmetto*.

About the Author

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Call for Research Track Papers and Poster Presentations

The Florida Native Plant Society Annual Conference will be held in Tallahassee, Florida, May 28-31, 2015. The Research Track of the Conference will include presented papers Saturday, May 30, and a poster session on Friday, May 29.

Researchers are invited to submit abstracts on research related to native plants and plant communities of Florida including preservation, conservation, and restoration. Presentations are 20 minutes in total length (15 min. presentation, 5 min. questions).

Abstracts of not more than 200 words should be submitted as a MS Word file by email to Paul A. Schmalzer at: paul.a.schmalzer@nasa.gov by February 1, 2015. Include title, affiliation, and address. Indicate whether you will be presenting a paper or poster.

Correction:

On page 11 of *Palmetto*, #31:1, a photograph of a section of a herbarium cabinet at the Herbarium of Southwestern Florida was printed with the wrong orientation. Herbarium sheets lay flat on shelves inside the cabinet, and the photo mistakenly depicted the sheets standing upright. The correct orientation is shown here. Photo © Naples Botanical Garden.

Saving the Endangered Florida Key Tree Cactus (*Pilosocereus robinii*) Using New Genetic Tools

Tonya D. Fotinos, Dr. Joyce Maschinski & Dr. Eric von Wettberg

Above: *Pilosocereus robinii* stand in the Florida Keys. Photo: Jennifer Possley, Center for Tropical Conservation/Fairchild Tropical Botanic Garden.

Biological systems around the globe are being threatened by human-induced landscape changes, habitat degradation and climate change (Barnosky et al. 2011; Lindenmayer & Fischer 2006; Thomas et al. 2004; Tilman et al. 1994). Although there is a considerable threat across the globe, numerically the threat is highest in the biodiversity hotspots of the world. Of those hotspots, South Florida and the Caribbean are considered in the top five areas for conservation action because of the high level of endemism and threat (Myers et al. 2000). South Florida contains roughly 125 endemic species and is the northernmost limit of the distribution of many tropical species (Abrahamson 1984; Gann et al. 2002). The threat to these species comes predominantly from sea level rise, which could be >1 m by the end of the century (Maschinski et al. 2011).

Above: *Pilosocereus robinii* in bloom at the Center for Tropical Conservation. Photo: Devon Powell, Center for Tropical Conservation/Fairchild Tropical Botanic Garden.

Restoration of imperiled populations is a priority for mitigating the looming species extinctions (Barnosky et al. 2011). Populating new or previously occupied areas or supplementing a local population of existing individuals are strategies that improve the odds that a population or species will survive. Undertaking conservation actions while taking genetics into consideration increases the chance of success and can bolster overall population genetic diversity, thus further improving a species' chance of persistence (Godefroid et al. 2011). The increase in success occurs because genetic factors affect population viability at the same rate or faster than demographic or ecological factors (Frankham & Ralls 1998; Saccheri et al. 1998), making their consideration just as vital as increasing overall population numbers.

Plants, by their nature, are subject to particular genetic trends that can be detrimental to the success of restoration efforts. Plant populations with low numbers of individuals are affected by increased rates of genetic drift and inbreeding. Also, plants are sedentary so they have other genetic considerations such as outbreeding depression and clonality. Supplementing a population with individuals can increase local genetic diversity if done appropriately in conjunction with genetic testing and drastically improve the odds of successful restoration. Conversely, unknowingly introducing individuals without critical, locally adapted genes or other deleterious genetic issues can doom a restoration project.

The Key tree cactus, *Pilosocereus robinii*, is a federally endangered columnar cactus native to the tropical hardwood hammocks in the Florida Keys (Figure 1). *Pilosocereus robinii* is part of a larger *Pilosocereus* complex of species found in the Caribbean but is the only representative of the genus that occurs in North America. The phylogenetic relationships of the various *Pilosocereus* populations in the Keys have been disputed since their discovery in 1838. Botanists John Torrey and Asa Gray first officially documented the cactus in 1838 as *Cereus peruvianus* (Torrey & Gray 1838). The cactus was renamed six more times including genus and species names (see full history USFWS 1999). The Key Largo population has historically been treated as *P. bahamensis* (Britton) Byles & G.D.Rowley (USFWS 2010). Despite this classification, both *P. robinii* and *P. bahamensis* have at times been grouped into the more widespread Caribbean-based species *Pilosocereus polygonus* (Lem.) Byles & G.D.Rowley (Anderson 2001; Zappi 1994), but inclusion into *P. polygonus* has not been upheld elsewhere (ITIS 2013). Therefore, the relationship

Tonya Fotinos removing epidermal tissue of *Pilosocereus robinii* for analysis from the population on Big Pine Key. Photo: T. Fotinos.

between the Key Largo population and the rest of the Keys population has to be resolved for appropriate management and reintroduction action for this species.

As early as 1917, botanist John Small noted in his description that the cactus was rare in the Keys and in danger of extirpation as a consequence of colonization in the area (Small 1917). An extensive survey done in 1984 also noted declines in previously occupied areas (Adams & Lima 1994). Although historically low, the number of remaining individuals has declined by more than 80% in the past decade because of continued habitat loss and environmental change, particularly

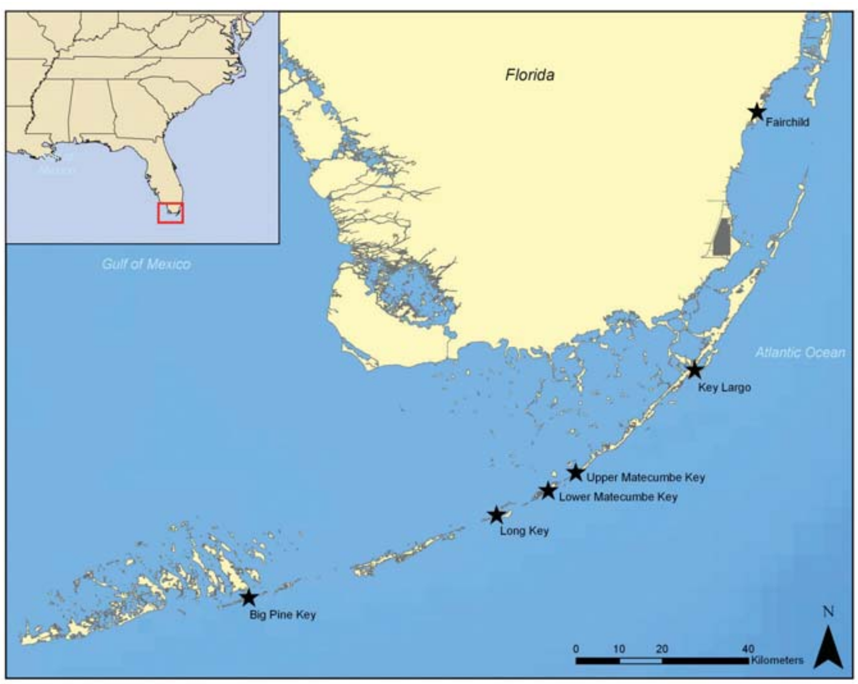
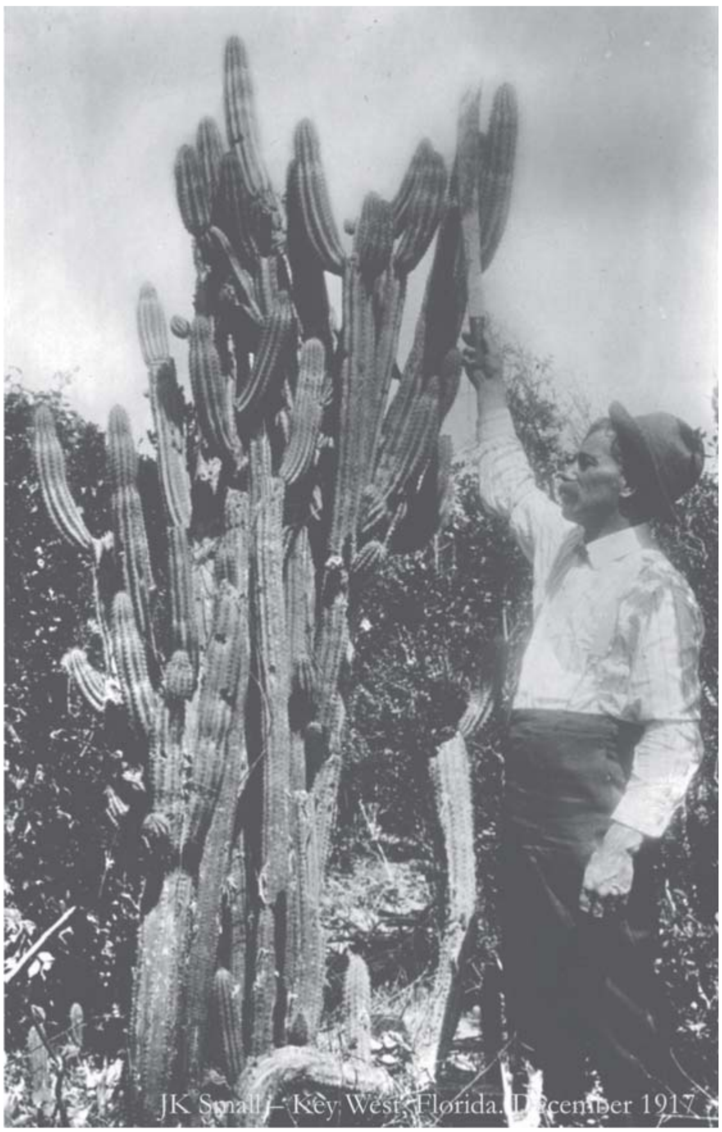


Figure 1: Map showing the populations of *Pilosocereus robinii* in Florida including the ex situ collection held at Fairchild Tropical Botanic Garden in Coral Gables, Florida.

Continued on page 14

soil water salinization (Goodman et al. 2012; USFWS 2010). The tropical hardwood hammocks of the Florida Keys are found on limestone outcroppings that represent the areas of highest elevation on the islands. These forests harbor a large number of endemic populations from the Caribbean region. Tropical hardwood hammocks are threatened currently and historically by urbanization, anthropogenically-induced change in fire frequency, conversion to agriculture, and climate change (Harveson et al. 2007; Ross et al. 2001; Ross et al. 2009; USFWS 1999). Rising sea level is of particular concern and, coupled with a recent increase in storm frequency and intensity, is predicted to have a potentially devastating impact on the small remaining populations in the Florida Keys (Maschinski & Haskins 2012; Maschinski et al. 2011).



Man standing by **Cephalocereus keyensis* 1917 (*later renamed *Pilosocereus robinii*). Photo: JK Small, State Archives of Florida, *Florida Memory*, http://floridamemory.com/items/show/49460

To assess the genetic relatedness of the remaining Key tree cactus populations, root material was collected from twenty individuals from the Fairchild Tropical Botanic Garden ex situ collection which included at least two individuals from each of the five populations, nine of which were from individuals currently extirpated from the wild (Figure 1). A new genetic technique called Restriction site Associated DNA mapping (RAD) was used to identify Single Nucleotide Polymorphisms (SNPs) in the twenty samples. RAD can create hundreds to thousands of genetic markers to compare the relatedness of individuals or populations without the costly development of a DNA primer system. This technique will allow conservation projects to forgo the lengthy genetic marker discovery time for non-model species which could make it a very powerful tool for future conservation efforts (Davey & Blaxter 2010; Rowe et al. 2011). SNPs generated by the RAD technique have less genotyping error and increased statistical power because of the number of markers generated (Allendorf et al. 2010; Hohenlohe et al. 2011). This new technique has the ability to resolve fine scale patterns of variation allowing for resolution of past genetic flow or introgression (Hohenlohe et al. 2013). These methods have the potential to offer new insight into genetic questions that previous marker sets have been unable to address.

The populations of *Pilosocereus robinii* in the Florida Keys display considerable amounts of inbreeding and low levels of genetic diversity. These results are consistent with the species' having a history of population bottlenecks and colonization. There was little genetic difference between the populations of cacti across the Florida Keys. Further analysis indicated that most of the genetic variation is shared among the group as a whole rather than between individual populations. Although populations were genetically similar overall, the greatest amount of differentiation occurred between the Big Pine Key and Lower Matecumbe Key populations. The Big Pine Key population had the most significant deviations in the pairwise comparisons and the greatest breadth of genetic differentiation. However, it was the Lower Matecumbe Key population that was identified as a unique population upon further analysis.

The Key Largo population has long been thought to be a large clonal stand of genetically identical individuals, but DNA sequence data did not support this. These data demonstrate that the population on Key Largo is made up of a number of unique individuals. This cactus population is known to be a prolific reproducer in the wild and has one of the few individuals that has successfully set fruit in the wild since monitoring began. The low amount of differentiation between Key Largo and the other populations suggests that the Key Largo population is closely related to the settlement of *Pilosocereus* in the lower Keys.

The lack of differentiation from the stand of cacti on Key Largo compared to the rest of the populations could indicate that the Key Largo population was established by an initial colonizing event and could be the mother plant to the rest of the *P. robinii* in the Florida Keys. Further testing and comparisons between the *Pilosocereus* genus in the Caribbean can elucidate this issue. The Key Largo stand of cacti appears more similar to all of the rest of the populations than they do to each other. The lack of significant deviations from Key Largo to the rest of the populations lends credibility to the argument that *P. bahamensis* is in fact *P. robinii* since this particular cactus is more similar to the rest of the cacti in the Keys.

The reintroduction of *Pilosocereus robinii* into the Florida Keys is ongoing. The first transplant population was planted August 2012. Most of the transplants are thriving, although some mortality has occurred. The genetic analysis suggests that the reintroduced individuals have not interfered with population structure across the Keys, and that lower Keys material can be transplanted to higher elevation sites in the upper Keys because the Key Largo population is not a unique population or a different species. There is little genetic evidence to suggest that plantings need to remain within the population of origin. Lower Matecumbe and Long Key are priorities for collection since they contain distinct genetic variation and Big Pine Key for its overall greater genetic diversity.

Given the limited knowledge and frequent changes concerning the taxonomic relationship of this genus in the Caribbean, further genetic work must be completed to reveal the relationship of this North American-based species to the rest of *Pilosocereus*. *P. polygonus* samples from the Bahamas and Dominican Republic are being added to this dataset to answer these remaining questions.

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