Determining habitat Requirements of the rare Florida bristle fern (*Trichomanes punctatum* ssp. *floridanum*)

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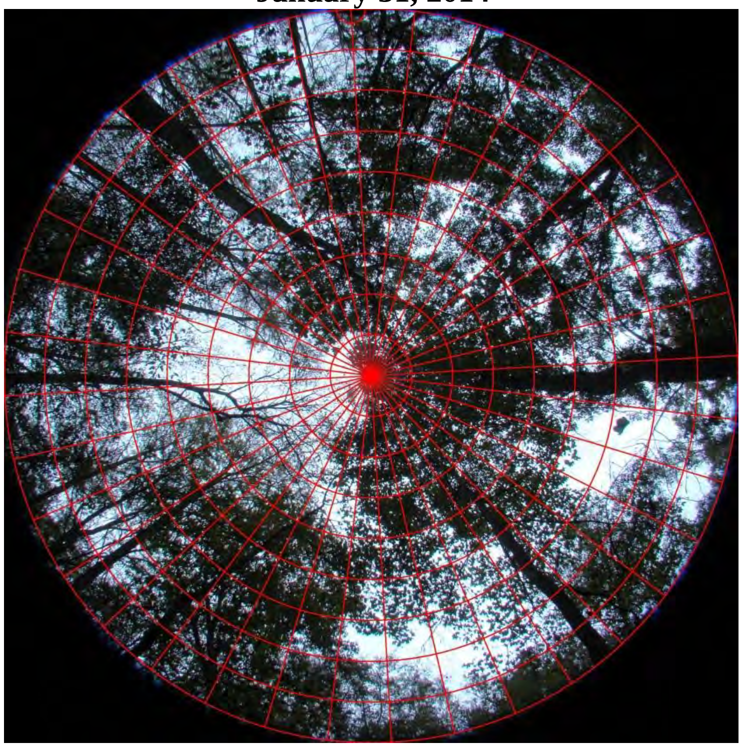

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Introduction

The endemic Florida bristle fern (*Trichomanes punctatum* ssp. *floridanum*) is isolated to two counties within the state of Florida, Sumter and Miami Dade counties (Nauman 1986, Gann et al. 2002). The Florida bristle fern is a small mat-forming fern, which grows epiphytically on tree bark or epipetrically in lime-sinks or on vertical faces of limestone boulders (Correll 1938, Darling 1961, Nauman 1986, Nelson 2000). Aside from basic family descriptions, very little quantitative work has been done to understand its ecological niche in Florida.

The genus *Trichomanes* belongs to the family Hymenophyllaceae, one of the most hygrophilous groups of land plants, which share many anatomical and physiological characteristics commonly associated with aquatic vegetation (Shreve 1911). The family is comprised of more than 600 species, most of which occur in humid tropical forest with the distribution extending to moist shady areas of temperate regions (Iwatsuki 1990, Kromer 2006). Small, thin, delicate leaves, which lack a cuticle, characterize the majority of *Trichomanes spp*. making the ferns susceptible to desiccation without the capability of regulating water loss (Zots and Busche 2000, Kromer 2006, Parra et al 2009). This susceptibility restricts most *Trichomanes spp.* to very humid environments and increases their vulnerability to changes in localized climatic conditions (Schuster 1971, Chen 1999, Zots and Busche 2000).

Logging, wetland drainage, agricultural practices, urban development, and limestone mining have all led to the reduction and near extirpation of the Florida bristle fern. These habitat alterations change microclimate patterns such as moisture, temperature, light, and wind (Chen et al. 1999), which are expected to have a significant negative effect on the survival of this sensitive fern. Anthropogenic stressors have severely decreased the number of population accounts for this species throughout Sumter and Miami-Dade County, possibly enhancing the chances for local extinctions (Mathies et al., 2004).

In Sumter County, there are two documented populations of the Florida bristle fern located within Withlachochee State Forest's Jumper Creek Tract (Figure 1). Both populations are found on elevated mesic hammocks (rarely flooded) containing at least one large oak tree (*Quercus spp.*) with substantial canopies surrounded by hydric hammocks (often flooded) dominated by bald-cypress (*Taxodium distichum*). The hammocks are located in close proximity to privately owned land in which the owner has systematically cleared the land for cattle pasture. It is possible that this could lead to a change in the environmental conditions within the hammocks, increasing the need for continual monitoring.

The objective of this study was to determine the current habitat conditions for the existing populations of the Florida bristle fern found in Sumter County. By determining associated plant species, relative humidity (RH), temperature, and canopy structure we were able to estimate the habitat requirements for these populations of the Florida bristle fern, which can then be utilized as a management tool in order to locate suitable habitats for future reintroductions.

Methods

Study location

The Florida bristle fern populations for this study are found on two hammocks, Tree Frog Hammock (0.28 acres) (Figure 2) and Rocky Hammock (0.44 acres) (Figure 3). Both hammocks are located within public lands in the Jumper Creek Tract of Withlacoochee State Forest, Sumter county FL (Figure 1).

Identifying current populations of the Florida bristle fern

Bristle fern populations were known to occur in two mesic hammocks of the Withlacoochee State Forest, Jumper Creek Tract (van der Heiden et al., 2013). Exposed limestone boulders and tree trunks in both hammocks were visually searched for existing bristle fern patches. Once all individuals were located within each hammock, the ferns were marked with a metal ID tag and its GPS coordinates were recorded (Figure 4).

Bristle fern patch structure, associated plant species, and canopy structure

Photographs, fern orientations, and patch sizes (area that individual patches of the fern covered) were determined for each boulder containing the bristle fern, and all other plant species using the same rock, were documented. Canopy percent cover at each hammock was determined and total tree species, vines, and epiphytes contributing to the hammock canopy were recorded. Canopy structure was calculated by photographing with a fish eye lens at each data logger. The fish eye photographs were analyzed with the use of Gap Light Analyzer software (© 1999, Simon Fraser University, Institute of Ecosystem Studies) to extract canopy structure information, specifically percent canopy closure (Cover photograph).

To define indicator species associated with the Florida bristle fern, we analyzed species richness data collected on all rocks harboring the bristle fern and 14 randomly selected rocks without the bristle fern. Rocks without the bristle fern were randomly selected to represent different areas throughout the hammock. Nonmetric Multidimensional Scaling (NMS) was used to determine any structure in the hammock community. Species data were analyzed using Indicator Species Analysis to determine any association of individual species across rocks that had bristle fern and those that did not. Indicator values are calculated for each species and a Monte Carlo test is used to test for statistical significance. For the Monte Carlo test we use 4,999 randomizations. Rare species that had fewer than 4 occurrences (5% of samples) were dropped from the analysis as recommended by McCune and Grace 2002. For these analyses data were analyzed using PCORD 6.

Determining hammock temperature and humidity gradients

An array of 10 HOBO U23 (Onset) (Figure 5)temperature and RH sensors with data loggers were positioned throughout each hammock for a total of 68 days (9/18/2013-11/24/2013), the sensors were set to record data at two hour intervals. For each mesic hammock, a set of four sensors were positioned in cardinal directions N, S, E, and W along the outside perimeter near the ecotone of the hydric and mesic hammock. An additional four sensors were positioned in each hammock NE, SE, SW, NW whose placement was staggered towards the interior with respect to the four edge sensors (Figure 6). One other sensor was positioned in the center of the hammock apex and another sensor was placed directly adjacent to a bristle fern patch. All 10 sensors within each hammock were placed at a height resembling the average height at which encountered bristle ferns occurred (~25 cm).

Data from HOBO loggers were down loaded on 11/25/2013. Daily average temperature for daylight hours (8, 10, 12, 14, 16, and 18 EDT) and night time hours (20, 22, 24, 2, 4, and 6 EDT) were calculated from the time series data set. Centered moving means were used to smooth the data and compare average temperatures and RH. We used Tukey Honestly Significant Difference to do pairwise comparisons of data loggers within a hammock. To compare both hammocks we took the average temperature of all data loggers from centered moving mean and applied t test comparing means.

Results

Current populations

All Florida bristle ferns in Sumter County were found growing on limestone boulders 0.1-1.5 meters (m) tall. A total of 44 boulders containing the bristle fern in Rocky Hammock and a total of 4 boulders in Tree Frog hammock were tagged and monitored. Often, single boulders would contain multiple separate patches of the fern, which is exaggerated during the winter dry season when the fern begin to desiccate and recede.

Patch size and orientations

Florida bristle fern patches ranged in size from 6.5 cm^2 to 12,967.7 cm^2, average patch size and total area coverage for both hammocks is provided in Table 1. We found a large portion of bristle fern patches on the northern face of limestone boulders and positioned on the northern side of each hammock (Table 2 and Figure 7). We observed the majority of non-north facing bristle fern patches in close proximity to other boulders, trees, or within protected crevices. In addition, bristle fern grows on the north side of both hammocks (Figure 8).

Plant species growing on limestone boulders

We found a total of 26 plant species, including the Florida bristle fern, growing on limestone boulders in Rocky Hammock (Table 3) and a total of 19 species for Tree Frog Hammock (Table 4). The NMS ordination analysis failed to find the best solution for the community data. The indicator species analysis did not show any strong correlations with bristle fern (Table 5). The Monte Carlo test of significance for observed indicator values did not show any difference between groups of rocks that had bristle fern and those that did not (Table 6). Although our analysis did not find any species statistically correlated with boulders containing the Florida bristle fern, we did find two species (*Pecluma dispersa* and *Thelypteris hispidula*) that occurred on greater than 60% of all boulders analyzed (boulders with and without the bristle fern).

Canopy structure

A total of 18 plant species contributed to the canopy of Rocky Hammock (Table 7) and a total of 11 plant species contributed to the canopy for Tree Frog Hammock (Table 8). Rocky Hammock had an average canopy closure of 76.1 ± 4.9% (mean ± SD) and Tree Frog Hammock averaged 75.8 ± 4.2% (mean ± SD) with no statistical difference ($p=0.905$). All % canopy closures and their respected data loggers are shown in Table 9 and 10. The photographs were taken near the end of the study in December and it is likely that the percent cover would be greater in warmer summer months when more foliage is present.

Temperature and Humidity

Total average temperature for the 68 days of this study for Rocky Hammock was 70.1 ± 7.1° F (mean ± standard deviation (SD)) with an average RH of 94.9 ± 8.1% (mean ± SD) (Figure 9). Total average temperature for the duration of the study in the Tree Frog Hammock was 70.1 ± 7.1° F (mean ± SD) with a slightly higher average RH of 95.2 ± 7.8% (mean ± SD). There was no difference in temperature between hammocks. Tree Frog Hammock was more humid over the time of the study $t(124) = 3.33$, $p<0.001$(Figure 10).

For both hammocks, the first half of this study (9/18-10/21) was, on average, slightly greater than 7.0° warmer than the second half of the study (10/22-11/24). Both temperature and humidity were statistically different between the first half of the study compared to the second half for both hammocks ($p>0.001$). Averages and SD for each data logger used in this study are represented in Table 11 (Rocky Hammock) and Table 12 (Tree Frog Hammock).

Using Tukey HSD, average temperatures at the data loggers showed no significant differences between each pairwise comparison within the Rocky Hammock and within

Tree Frog Hammock. There were differences in average RH between data loggers RH in both hammocks (Table 13 and 14).

Discussion

Our results indicate that *T. puncatum* is similar to other members of the Hymenophyllaceae family whose distributions are often linked to the availability of water (Shreve 1911, Parra et al. 2009, Saldana et al. 2013). The hygrophilous nature of this family is due to the lack of stomata and one cell thick lamina and lack of cuticles on the fronds (Parra et al. 2009). The morphology of the fern restricts it to humid and shady places because they cannot regulate water loss, making them similar to some aquatic plants. We found average RH for both hammocks remained high (near 95%) for the duration of this study. Humidity levels dropped slightly during the colder half of the study and a noticeable decline in fern "health" was observed when comparing fern patches from the warm start to the cool ending of the experiment. Bristle ferns had a noticeable qualitative difference from the summer when all colonies, in both subpopulations, were green and densely covered with fertile fronds as opposed to the fall sampling when patches were brown and more bare rock was observed. Tree Frog Hammock had a higher RH and ferns at both sampling times had fertile fronds (no fertile fronds were found in Rocky Hammock during the second sampling effort). Spores were visible as a cone surrounding the bristle that extended beyond the soral involucres (Figure 4). This observation indicates the bristle ferns may do better in a slightly more humid environment.

Canopy cover greatly affects the humidity in hammocks, with higher humidity at ground level, eventually dissipating in higher portions of the canopy (Parra et al. 2009, Saldana et al. 2013). The average canopy closure for each hammock remained above 75% creating a heavily shaded understory and likely shielding the fern from external dynamic environmental pressures such as wind and sunlight. The closed canopy helps to retain higher humidity levels and reduces the chance of desiccation. Low light may also enable bristle fern to out compete or stop competing plants from growing on the same part of the rock. Both hammocks had large oaks that were the largest tree growing in the center of the hammock, which cast heavy shadows on the northern portion of the hammocks.

Our data suggest that the Florida bristle fern are affected by humidity at two spatial scales. The large hammock scales show the bristle fern grows in the north of the hammocks and the majority of the time on the northern aspect of rocks. In the Northern Hemisphere, south facing slopes receive higher solar radiation because of the angle at which the sun hits the earth thus affecting soil temperature, moisture, and soil aggregation which in turn can affect vegetation (Geroy et al. 2011). The south facing portions of the hammocks could become drier and less humid due to this aspect. This is especially true in winter when there are little to no leaves on the trees and the hammock moisture levels could drop beyond the bristle ferns thresh hold. This could explain why bristle ferns are growing in the northern parts of the hammock. At a smaller scale the northern aspect of the limestone boulders, will receive less sunlight and therefore on average will remain cooler and more moist when compared to other portions of exposed rock. Where we found Florida bristle fern supports this theory, which consistently grows on the northern portions of boulders. Boulders, which are shielded by other boulders, trees, or dense canopy cover may contain higher levels of moisture than exposed boulders, allowing the fern to grow on any portion of the shielded rock as long as moisture levels remain high enough to prevent desiccation.

We found the bristle fern on boulders scattered anywhere from the edge of the hammock to near the center, primarily on the northern portion. More work is needed to determine the effect of hammock size, but Tree Frog Hammock was very small and contained only one large oak tree. As long as the microhabitat met the requirements of the bristle fern, and limestone boulders were present, any size hammock could potentially harbor the fern.

In our analysis we did not find any species that were ideal microhabitat indicator species, being exclusively faithful to one group (i.e. growing exclusively with or without bristle fern), which could be used as an indicator for the fern. However, *Melanthera nivea* was more often associated with rocks that did not have bristle fern even though not statistically significant (p=0.07) (Table6). Species that were more often associated with rocks that had bristle fern, though not significant, are *Pecluma dispersa, Pilea microphylla,* and *Thelypteris hispidula*, though they did also occur without the fern. These species, however, are not limited to humid mesic hammocks (Wunderland and Hannson). One of the goals of this initial study was also to characterize the broader habitat of the hammocks in which bristle fern grows. These species, due to their abundance on rocks both with and without bristle fern, could serve as a coarse gauge for suitable hammocks with favorable environmental conditions, similar to the Florida bristle fern, when used in conjunction with RH and canopy cover.

Data loggers did show differences in RH within a hammock. In Rocky Hammock there was a general trend of increasing RH in a south to north gradient with the highest recorded average RH at the center of the hammock. This data logger was in close proximity and slightly north of the large oak. The data logger near the rock that had bristle fern also had a high RH relative to other data loggers. The RH in Tree Frog Hammock had the lowest RH in the south, southwest, and west with the highest recorded in the east. It is interesting that both data loggers placed in the northern part of the hammock had low RH and were not different from the south data loggers. This is opposite to what was expected. However, these data give us a clear picture of variances within the hammocks and we propose that these differences can be caused by slight structural differences of where the data loggers were placed as well as their proximity to water. Data loggers could be used to refine what we now know by being placed around individual boulders that have bristle fern growing on them, and at different heights to determine fine scale differences in humidity.

A high priority management goal would be to locate additional hammocks with similar habitat to those described in this report. It is possible that once an area was logged for timber the RH and temperature were drastically altered, diminishing the ferns habitat, resulting in widespread losses. Areas that were once logged may have recovered, now that logging has ceased, and the proper RH and temperature to support the bristle fern may have returned, depending on vegetation, substrate and hydrology. Additional surveys would be needed to gather information on potential hammocks. Once suitable hammocks have been located transplanting the bristle fern could commence. This is especially important given the small locality of the existing population in Sumter County and their vulnerability to stochastic events. The loss of the single oak tree or other canopy trees could have adverse effects on the population, as the microhabitat within the hammocks would drastically change. To begin the process, additional surveys and setting up data loggers to determine RH and temperature within new hammocks without the fern would be needed in order to determine if the new hammock could host the bristle fern. Concurrently, the bristle fern needs to be grown, by spores or vegetatively, to be ready to transplant onto host rocks within suitable hammocks.

Additional information still needs to be collected on the current population, experimenting with wind barriers and shade cloth could provide additional information on microhabitats and enable us to understand if there is an edge effect. For example having an edge (field or pipe line) too close to a population could drastically affect the bristle ferns microhabitat causing a reduction in the extent of the population. This study is short in duration and did not capture the extent of annual variability associated with environmental factors.

Threats to the population of bristle fern in Sumter County are changes in microhabitat, invasive species, drainage or damming of the Withlacoochee River, and change in land use. Microhabitats have already been explained in detail in this report and any changes to these could adversely affect the fern. Invasive plant species are currently controlled by a yearly visit by Colleen Werner, Withlacoochee State Forest Biologist, Florida Forest Service. She has done an exceptional job at keeping invasive plants away from the Florida bristle fern. Drainage of the surrounding hydric hammocks within the Jumper Creek tract could significantly decrease the RH of mesic hammocks hosting the fern by lowing the surrounding air and soil moisture contents. Damming of the river could result in large changes to the Sumter County hydri/mesic hammock hydrology. Downstream effects could result in a loss of water within the Jumper Creek Tract, both spatially and temporally, possibly adversely affecting the microhabitat needed by the bristle fern. Logging or any activity that deforests the area that will create an edge effect that would unfavorably affect the filmy fern due to changes in wind and moisture content in the hammocks. The Jumper Creek Tract is also home to feral pigs, which could affect the population if they start utilizing the hammocks. We did find one small rock where the bristle fern was scrapped off when a pig used the rock as a rubbing spot after wallowing in the mud.

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Tables

Table 1. Average and total patch size coverage for Sumter County bristle fern populations.

Hammock	Average patch size (m^2)	Total area coverage (m^2)
Tree Frog Hammock	0.033 (± 0.026)	0.132
Rocky Hammock	0.099 (± 0.202)	4.355

Table 2. Bristle fern patch orientation on boulders in Sumter County.

Orientation of the bristle fern	Occurrences
N	23
S	6
E	8
W	8
NE	8
NW	7
SE	1
SW	3

Table 3. Plant species found growing on limestone boulders in Rocky Hammock (* denotes plants which were not identified to the species level).

Scientific name	Common name
Asplenium abscissum	Cutleaf spleenwort
Asplenium cristatum	Hemlock spleenwort
Asplenium verecundum	limestone spleenwort
Callicarpa americana	American beautyberry
Dichanthelium spp.	Rosette grasses
Dryopteris ludoviciana	Southern Wood Fern
Hydrocotyle sp.*	Pennywort
Iresine diffusa	Juba's bush
Melanthera nivea	Snow squarestem
Melothria pendula	Guadeloupe cucumber
Mikania sp.*	Hempvine
Mitchella repens	Partridgeberry
Oplismenus hirtellus	Basketgrass
Pecluma dispersa	Rockcap fern
Peperomia humilis	Polynesian peperomia
Pilea microphylla	Rockweed
Rivina humilis	Rougeplant
Ruellia caroliniensis	Carolina wild petunia
Smilax sp.*	Greenbriers
Thelypteris hispidula	Roughhairy maiden fern
Toxicodendron radicans	Poison Ivy
Tradescantia fluminensis	Small-leaf spiderwort
Trichomanes punctatum ssp. floridanum	Florida bristle fern
Valeriana scandens	Florida valerian
Viola sp.*	Violets
Vitis sp. *	Grape

Table 4. Plant species found growing on limestone boulders in Tree Frog Hammock (* denotes species which were not identified to the species level).

Scientific name	Common name
Asplenium abscissum	Cutleaf spleenwort
Asplenium cristatum	Hemlock spleenwort
Dichanthelium spp.	Rosette grasses
Dryopteris ludoviciana	Southern Wood Fern
Melanthera nivea	Snow squarestem
Melothria pendula	Guadeloupe cucumber
Mikania sp.*	Hempvine
Mitchella repens	Partridgeberry
Oplismenus hirtellus	Basketgrass
Parthenocissus quinquefololia	Virginia creeper
Pecluma dispersa	Rockcap fern
Psychotria nervosa	Shiny-leaved wild coffee
Rivina humilis	Rougeplant
Smilax sp.*	Greenbriers
Thelypteris hispidula	Roughhairy maiden fern
Thelypteris sp.*	Maiden ferns
Toxicodendron radicans	Poison Ivy
Trichomanes punctatum ssp. floridanum	Florida bristle fern
Valeriana scandens	Florida valerian

Table 5. Indicator values of plants associated with boulders with (Group A%) and without (Group B%) the Florida bristle fern. No strong relationships were found.

Species	Avg	Max	MaxGrp	Group A %	Group B %
Asplabsc	11	16	0	5	16
Asplcris	7	13	0	1	13
Asplvere	7	12	0	2	12
Dich spp.	4	5	0	3	5
Dryoludo	11	15	0	6	15
Iresdiff	8	14	1	14	2
Melanive	21	35	0	7	35
Melopend	4	5	0	3	5
Mika spp.	12	13	0	11	13
Mitcrepe	14	23	0	4	23
Oplihirt	10	13	1	13	7
Pecldisp	45	51	1	51	39
Pilemicr	22	40	1	40	4
Rivihumi	23	26	1	26	19
Ruelcaro	4	8	1	8	0
Smil spp.	4	8	1	8	0
Thelhisp	29	37	1	37	22
Valescan	12	13	0	12	13
Viola ssp	3	6	0	1	6

Table 6. Monte Carlo test of significance of observed indicator values based on 4,999 randomizations. P-values indicate the hypothesis that there are no differences between groups.

Species	Maxgrp	Observed indicator Value (IV)	Mean IV from observed randomized groupd Mean	S.Dev	p *
Asplabsc	0	15.9	14.1	5.75	0.4101
Asplcris	0	13.4	7.8	3.65	0.169
Asplvere	0	12.2	8.7	4.67	0.2585
Dich spp.	0	4.8	7.9	3.8	1
Dryoludo	0	15.1	15.3	5.83	0.4503
Iresdiff	1	14.5	15	5.54	0.6695
Melanive	0	34.5	20.9	5.9	0.0752
Melopend	0	4.8	7.8	3.7	1
Mika spp.	0	13.2	18.2	5.99	1
Mitcrepe	0	23.3	15.2	5.74	0.1368
Oplihirt	1	12.9	17.3	5.78	1
Pecldisp	1	51.3	50.1	2.47	0.5791
Pilemicr	1	40.4	30.3	6.18	0.1252
Rivihumi	1	26.5	31	6.14	0.7562
Ruelcaro	1	8.2	7.8	3.79	0.5641
Smil spp.	1	8.2	7.9	3.75	0.5795
Thelhisp	1	37	38	5.62	0.4989
Valescan	0	12.6	18.7	6.23	1
Viola ssp	0	5.6	6.8	2.91	1

* proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
Maxgrp = Group identifier for group with maximum observed IV

Table 7. Rocky Hammock plant species contributing to the canopy (* denotes plant which were not identified to species level)

Scientific name	Common name
Acer negundo	Boxelder
Callicarpa americana	American beautyberry
Carpinus caroliniana	American hornbeam
Carya glabra	Pignut hickory
Celtis laevigata	Sugarberry
Erythrina herbacea	Coralbean
Liquidambar styraciflua	Sweetgum
Magnolia virginiana	Sweet bay
Parthenocissus quinquefolia	Virginia creeper
Quercus laurifolia	Laurel oak
Quercus virginiana	Live oak
Sabal palmetto	Cabbage palm
Sapindus saponaria	Soapberry
*Smilax sp.**	Greenbriars
Taxodium distichum	Bald-cypress
Tillandsia usneoides	Spanish moss
Ulmus americana	American elm
Vitis rotundifolia	Muscadine

Table 8. Tree Frog Hammock plant species contributing to the canopy

Scientific name	Common name
Acer negundo	Boxelder
Carpinus caroliniana	American hornbeam
Celtis laevigata	Sugarberry
Citrus x aurantium	Sour Orange
Liquidambar styraciflua	Sweetgum
Magnolia virginiana	Sweet bay
Quercus virginiana	Live Oak
Sabal palmetto	Cabbage palm
Sapindus saponaria	Soapberry
Taxodium distichum	Bald-cypress
Tillandsia usneoides	Spanish moss
Vitis rotundifolia	Muscadine

Table 9. Tree Frog Hammock % canopy closure

Data logger #	% closure	Data Logger position
928	76.7	E
929	70.4	Fern
835	80.7	N
837	78.0	NW
838	70.3	W
839	77.1	S
840	73.6	NE
842	78.5	SW
846	81.8	Center
848	71.3	SE

Table 10. Rocky Hammock % canopy closure

Data logger #	% closure	Data Logger position
930	78.3	E
931	74.5	N
836	74.2	Center
841	79.3	NE
843	77.6	S
844	72.6	SE
845	77.8	Fern
847	81.5	W
849	64.7	NW
850	80.5	SW

Table 11. Average temperature (Temp) and relative humidity (RH) of each data logger within Rocky Hammock.

Rocky Hammock data logger #	AVG Temp 9/18-10/21 (± stdev)	AVG RH 9/18-10/21 (± stdev)	AVG Temp 10/22-11/24 (± stdev)	AVG RH 10/22-11/24 (± stdev)	AVG Temp 9/18-11/24 (± stdev)	AVG RH 9/18-11/24 (± stdev)
930	74.0 (± 5.1)	94.6 (± 8.6)	66.2 (± 7.0)	93.6 (± 9.0)	70.1 (± 7.2)	94.1 (± 8.8)
931	74.3 (± 5.2)	94.0 (± 9.0)	66.6 (± 7.0)	93.0 (± 9.4)	70.5 (± 7.3)	93.5 (± 9.2)
2843	74.3 (± 5.5)	94.2 (± 9.6)	66.6 (± 7.4)	93.0 (± 10.5)	70.4 (± 7.6)	93.6 (± 10.1)
2844	74.1 (± 4.9)	95.8 (± 7.4)	66.2 (± 6.4)	96.0 (± 6.2)	70.1 (± 7.0)	95.9 (± 6.8)
2845	74.1 (± 4.7)	96.3 (± 6.5)	66.4 (± 6.1)	95.4 (± 6.6)	70.3 (± 6.7)	95.8 (± 6.6)
2836	73.6 (± 4.8)	97.1 (± 6.0)	66.1 (± 6.9)	95.8 (± 7.2)	69.8 (± 7.0)	96.4 (± 6.7)
2841	73.8 (± 4.6)	95.9 (± 6.8)	66.3 (± 6.8)	94.5 (± 8.2)	70.0 (± 6.9)	95.2 (± 7.5)
2849	74.0 (± 5.6)	96.0 (± 7.8)	66.0 (± 7.0)	95.3 (± 7.7)	70.0 (± 7.5)	95.6 (± 7.8)
2850	73.9 (± 5.0)	94.9 (± 8.3)	66.5 (± 7.2)	92.6 (± 10.6)	70.2 (± 7.2)	93.8 (± 9.6)
2847	73.6 (± 4.6)	95.8 (± 7.0)	66.2 (± 6.8)	94.0 (± 8.6)	69.9 (± 6.9)	94.9 (± 7.9)
Total Average	74.0 (± 5.0)	95.4 (± 7.7)	66.3 (± 6.9)	94.3 (± 8.4)	70.1 (± 7.1)	94.9 (± 8.1)

Table 12. Average temperature (Temp) and relative humidity (RH) of each data logger within Tree Frog Hammock.

Tree Frog Hammock Data Logger #	AVG Temp 9/18-10/21 (± stdev)	AVG RH 9/18-10/21 (± stdev)	AVG Temp 10/22-11/24 (± stdev)	AVG RH 10/22-11/24 (± stdev)	AVG Temp 9/18-11/24 (± stdev)	AVG RH 9/18-11/24 (± stdev)
928	73.5 (± 4.0)	98.0 (± 3.8)	66.2 (± 6.3)	95.5 (± 6.5)	69.9 (± 6.4)	96.8 (± 5.5)
929	73.9 (± 4.7)	96.9 (± 5.5)	66.4 (± 6.9)	94.9 (± 7.8)	70.1 (± 7.0)	95.9 (± 6.8)
2835	74.1 (± 5.2)	95.5 (± 7.6)	66.8 (± 7.6)	93.0 (± 10.5)	70.4 (± 7.5)	94.3 (± 9.2)
2837	73.7 (± 4.9)	96.3 (± 6.5)	66.1 (± 7.2)	94.1 (± 8.9)	69.9 (± 7.2)	95.2 (± 7.9)
2838	74.2 (± 5.2)	95.5 (± 7.6)	66.7 (± 7.1)	93.7 (± 9.3)	70.5 (± 7.3)	94.6 (± 8.5)
2839	73.8 (± 5.0)	95.8 (± 7.3)	66.4 (± 7.3)	93.9 (± 9.6)	70.1 (± 7.3)	94.8 (± 8.5)
2840	73.8 (± 4.8)	96.6 (± 5.9)	66.2 (± 7.1)	94.5 (± 8.4)	70.0 (± 7.1)	95.5 (± 7.3)
2842	73.9 (± 4.9)	96.0 (± 7.1)	66.4 (± 7.1)	93.8 (± 9.3)	70.1 (± 7.1)	94.9 (± 8.3)
2846	73.9 (± 4.8)	95.2 (± 7.7)	66.3 (± 7.0)	93.1 (± 9.7)	70.1 (± 7.1)	94.2 (± 8.8)
2848	73.8 (± 4.8)	96.3 (± 6.3)	66.3 (± 7.0)	94.3 (± 8.3)	70.1 (± 7.1)	95.3 (± 7.4)
Total Average	73.9 (± 4.8)	96.2 (± 6.5)	66.4 (± 7.1)	94.1 (± 8.8)	70.1 (± 7.1)	95.2 (± 7.8)

Table 13. Pairwise comparisons of data loggers in Rocky Hammock. * denotes statistical significance.

Comparison	DiffMeans	Q	P	
W v SW	1.1	6.2	0.001	*
W v NW	0.8	4.5	0.0566	
W v NE	0.3	1.8	0.9578	
W v CN	1.6	8.7	<0.0001	*
W v TR	1.1	6.1	0.0013	*
W v SE	1.1	6.3	0.0008	*
W v S	1.3	7.1	0.0001	*
W v N	1.4	7.9	<0.0001	*
W v E	0.8	4.2	0.989	
SW v NW	1.9	10.7	<0.0001	*
SW v NE	1.4	8.1	<0.0001	*
SW v CN	2.7	15.0	<0.0001	*
SW v TR	2.2	12.3	<0.0001	*
SW v SE	2.2	12.5	<0.0001	*
SW v S	0.2	0.9	0.9998	
SW v N	0.3	1.7	0.9707	
SW v E	0.4	2.0	0.9206	
NW v NE	0.5	2.7	0.6628	
NW v CN	0.8	4.2	0.0989	
NW v TR	0.3	1.6	0.9804	
NW v SE	0.3	1.8	0.9578	
NW v S	2.1	11.7	<0.0001	*
NW v N	2.2	12.4	<0.0001	*
NW v E	1.6	8.8	<0.0001	*
NE v CN	1.2	6.9	0.0001	*
NE v TR	0.8	4.2	0.0989	
NE v SE	0.8	4.5	0.0566	
NE v S	1.6	9.0	<0.0001	
NE v N	1.7	9.7	<0.0001	*
NE v E	1.1	6.1	0.0013	*
CN v TR	0.5	2.7	0.6628	
CN v SE	0.4	2.4	0.7949	
CN v S	2.8	15.9	<0.0001	*
CN v N	3.0	16.6	<0.0001	*
CN v E	2.3	13.0	<0.0001	*
TR v SE	0.0	0.2	0.9999	

Comparison	DiffMeans	Q	P	
TR v S	2.4	13.2	<0.0001	*
TR v N	2.5	14.0	<0.0001	*
TR v E	1.8	10.3	<0.0001	*
SE v S	2.4	13.4	<0.0001	*
SE v N	2.5	14.2	<0.0001	*
SE v E	1.9	10.6	<0.0001	*
S v N	0.1	0.8	0.9999	
S v E	0.5	2.9	0.5656	
N v E	0.7	3.6	0.2561	

Table 14. Pairwise comparisons of data loggers in Tree Frog Hammock. * denotes statistical significance.

Comparison	DiffMeans	Q	P	
W v SW	0.3	1.5	0.9875	
W v NW	0.6	3.3	0.376	
W v NE	0.9	4.9	0.0249	*
W v CN	0.4	2.3	0.8326	
W v TR	1.3	6.9	0.0001	*
W v SE	0.7	3.7	0.2222	
W v S	0.3	1.4	0.9923	
W v N	0.3	1.8	0.9578	
W v E	2.2	11.4	<0.0001	*
SW v NW	0.3	1.7	0.9707	
SW v NE	0.6	3.4	0.3332	
SW v CN	0.7	3.8	0.1915	
SW v TR	1.0	5.4	0.008	*
SW v SE	0.4	2.2	0.8662	
SW v S	0.0	0.2	0.9999	
SW v N	0.6	3.4	0.3332	
SW v E	1.9	9.9	<0.0001	*
NW v NE	0.3	1.6	0.9804	
NW v CN	1.1	5.6	0.0049	*
NW v TR	0.7	3.7	0.2222	
NW v SE	0.1	0.5	1	
NW v S	0.4	1.9	0.9412	
NW v N	1.0	5.1	0.016	*
NW v E	1.5	8.1	<0.0001	*
NE v CN	1.4	7.2	<0.0001	*
NE v TR	0.4	2.0	0.9206	
NE v SE	0.2	1.2	0.9976	
NE v S	0.7	3.5	0.2932	
NE v N	1.3	6.7	0.0002	*
NE v E	1.2	6.5	0.0004	*
CN v TR	1.8	9.2	<0.0001	*
CN v SE	1.1	6.0	0.0017	*
CN v S	0.7	3.7	0.2222	
CN v N	0.1	0.5	1	
CN v E	2.6	13.7	<0.0001	*
TR v SE	0.6	3.2	0.4211	
TR v S	1.1	5.6	0.0049	*

Comparison	DiffMeans	Q	P	
TR v N	1.7	8.8	<0.0001	*
TR v E	0.8	4.5	0.0566	*
SE v S	0.4	2.4	0.7949	
SE v N	1.1	5.6	0.0049	*
SE v E	1.5	7.7	<0.0001	*
S v N	0.6	3.2	0.4211	
S v E	1.9	10.0	<0.0001	*
N v E	2.5	13.2	<0.0001	*

Figures

Figure 1. Satellite image of Rocky Hammock (left) ($0.002\ km^2$) and Tree Frog Hammock (right) ($0.001\ km^2$) containing the Florida bristle fern.

Figure 2. Tree Frog Hammock a small mesic hammock surrounded by hydric hammock. Cypress trees can be seen in the background.

Figure 3. Rocky Hammock a mesic hammock with hydric hammock in the North, East and West of the hammock. PVC poles demarcate rocks with Florida bristle fern.

Figure 4. The Florida bristle fern found on the vertical surface of a limestone boulder in Sumter County, FL with inset showing close up of spore production around the bristle that extends from the soral involucres.

Figure 5. Downloading temperature and humidity data from data logger

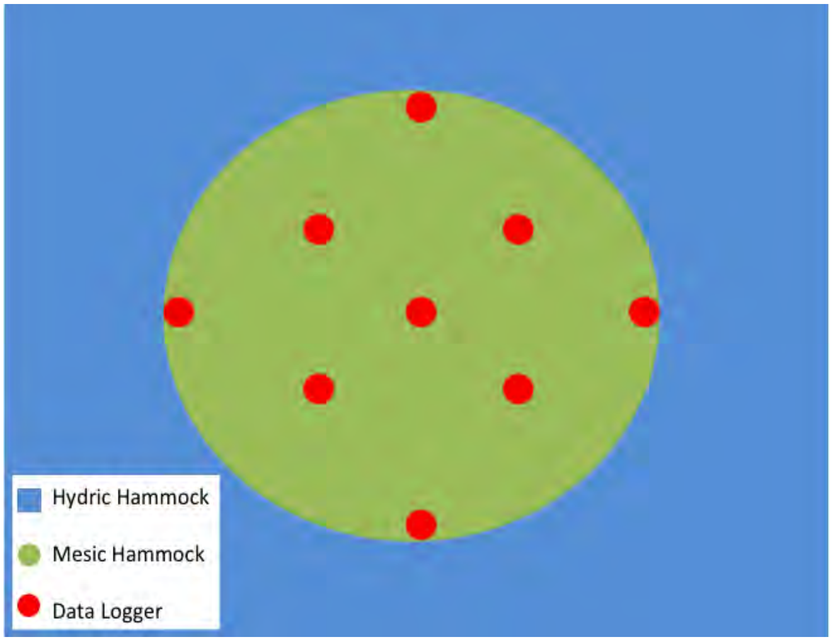

Figure 6. Conceptual diagram of the data logger array for each mesic hammock containing the Florida bristle fern. Both mesic hammocks are surrounded by a large hydric hammock.

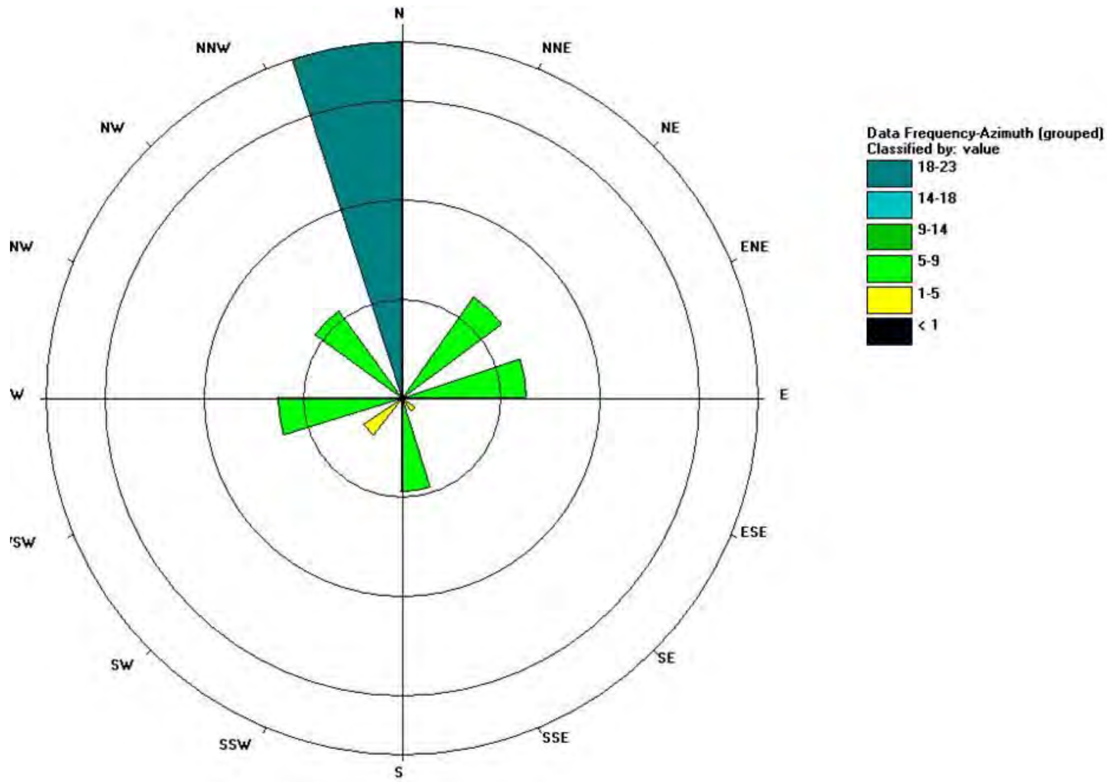

Figure 7. Rose diagram depicting the placement where the Florida bristle is found growing on boulders in Sumter County.

Figure 8. Rocky Hammock outlined in green with the shaded green area showing the extent of the Florida bristle fern occurrences isolated to the northern portion of the hammock.

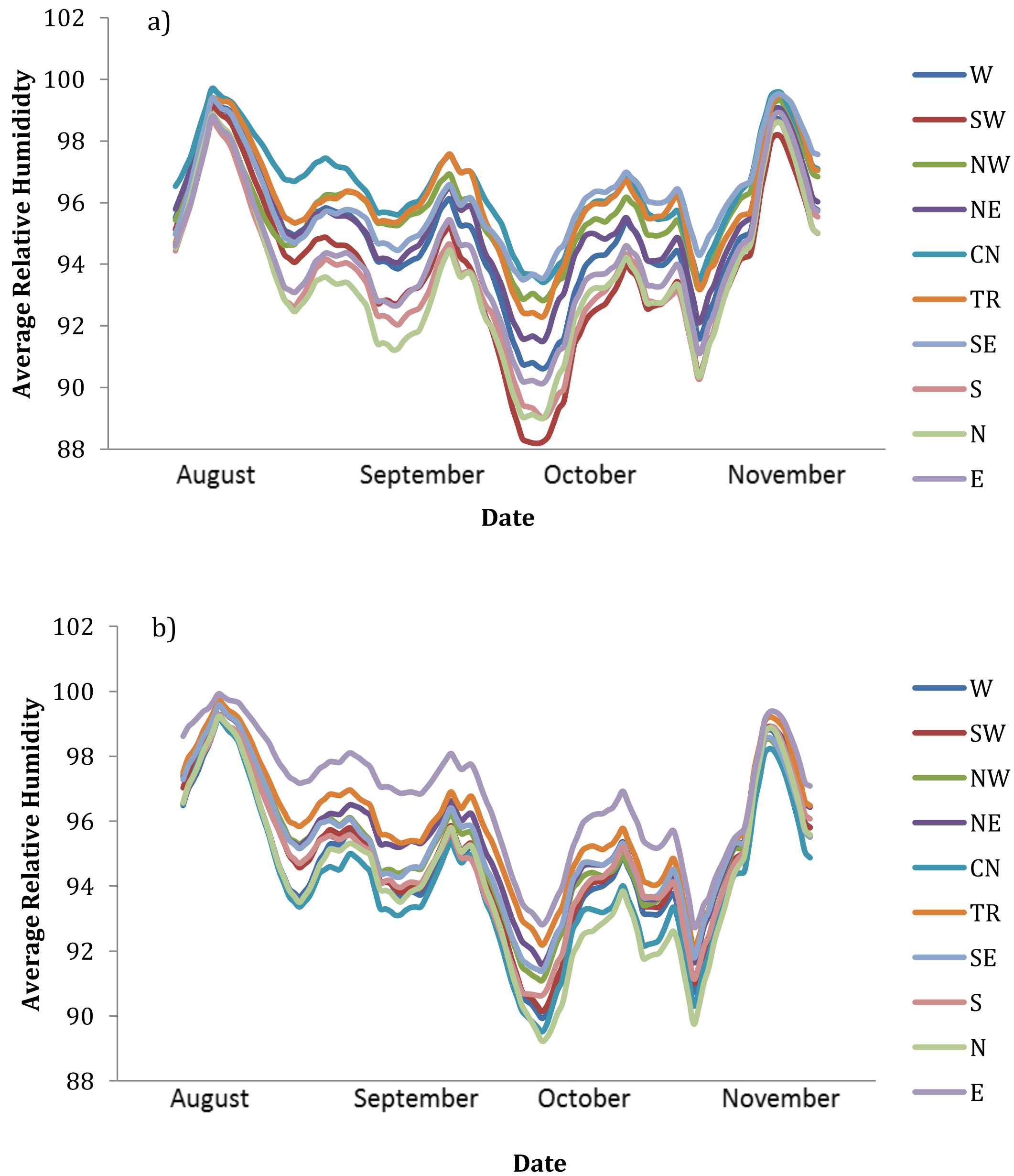

Figure 9. Relative humidity in (a) Rocky Hammock and (b) Tree Frog Hammock, calculated from moving averages from data loggers**.** Data are collected from cardinal directions within each hammock (W-west, SW-south west, NW-north west, CN-center, TR-*Trichomanes punctatum*, S-south, N-north, E-east).

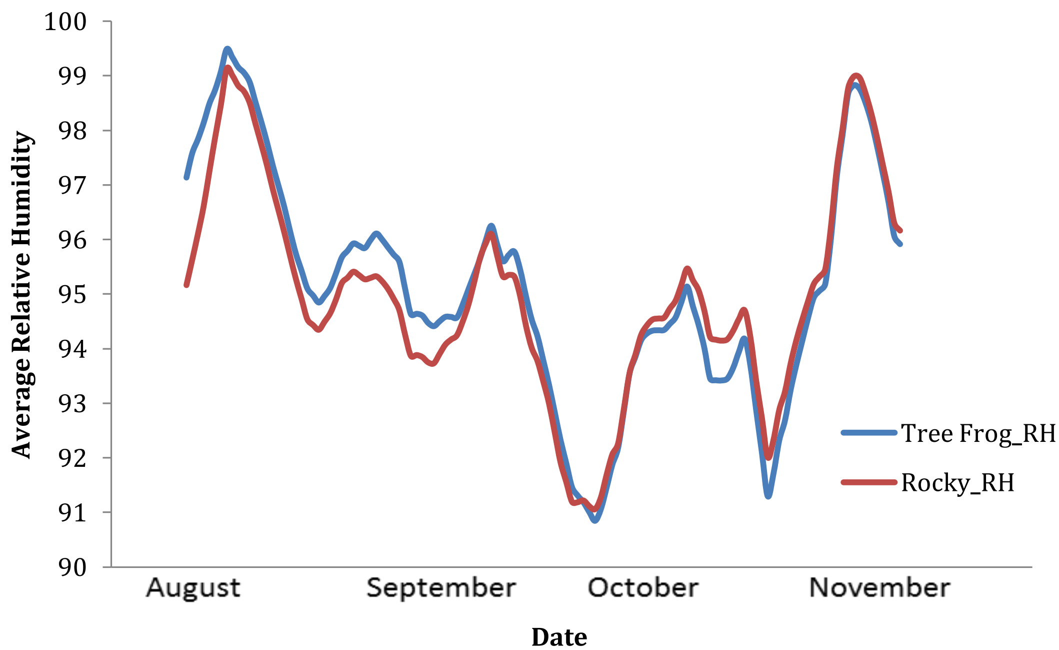

Figure 10. Relative humidity of Rocky Hammock and Tree Frog Hammock. Tree Frog Hammock was on average more humid than Rocky Hammock.**)**