Comparing local, state, and global lichen distribution patterns at Jupiter Inlet Lighthouse Outstanding Natural Area (ONA), Florida

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Abstract. **Fifty-five lichen species have been identified from the 120-acre Jupiter Inlet Lighthouse Outstanding Natural Area (ONA), located in southeast Florida. The ONA habitat is comprised of sand pine scrub, oak scrub, and coastal hammock. While our emphasis was on documenting macrolichens, several microlichens were identified. Relative abundance ratings were assigned to each lichen species based on its frequency in the ONA and in Florida. The rating of "rare" for the ONA does not necessarily imply that the species is rare in Florida, but it would be considered rare at the ONA, in most cases because of the area's small size. The sole exception is for the federally endangered *Cladonia perforata*, which is rare throughout its range. For each species, we used the Consortium of North American Lichen Herbaria to determine the number of known sites from Florida compared to their regional and global geographic distribution. Global distribution patterns are generalized, but no attempt at a global abundance ranking was made. Biogeographic patterns are presented for each species, as well as ecological and climate change considerations regarding management actions on this relatively small nature preserve.**

***Key words*. Biogeography, abundance rating, lichen, ecology, *Cladonia perforata*.**

INTRODUCTION: LICHEN BIOGEOGRAPHY

Biogeography is defined as the study of geographical distributions of organisms; the patterns of distribution of taxa; and the processes by which these observed distributions have come about (Galloway 1979 & 2008). Biogeography can help to explain where some species now present in Florida came from, and it tells us something about the different climate influences in this part of the globe. Biogeography might also suggest which species will move north or south with climatic changes.

In this paper, we explore the biogeographic affinities of lichen taxa collected at the Jupiter Inlet Lighthouse Outstanding Natural Area (ONA) in southeast Florida. Long-distance dispersal is known to play an important role in the distribution of lichens (Brodo et al. 2001). So, do lichens have their own biogeographic regions, or do they follow vascular plant biogeographical regions? Lücking (2003) used Akhtajan's floristic regions of the world, based on vascular plant distributions, for his comparative analysis of foliicolous lichen biogeography. In the end, Lücking (2003) combined 19 of those regions into six. Brodo et al. (2001) discuss the major elements of lichen biogeographical distribution based mainly on climate, but include some distributional types found within these major elements. Most lichen species have climatic requirements, yet distributions can be greatly influenced by geologic history. In the case of Florida, most of the peninsula was under the ocean for a long time and surface soils are calcareous sands. Some Florida lichens have migrated south from the Temperate element (Appalachian Mountains/ Southeast US) while others may have migrated north from the Tropical element (Brodo et al. 2001). There are often major differences in lichen species between the Florida panhandle and the peninsula (Lücking et al. 2011). Brodo et al. (2001) encouraged the use of other distributional types within the major elements, and here we follow Brodo et al. to a large extent.

Some lichen genera have geographic areas of diversification. In Florida, the climatic gradient follows the North-South geographic gradient. *Parmotrema* are most diverse in the tropics but also occur up the southeast (SE) coastal Plain in North America (Brodo et al. 2001). One way to explore more in-depth biogeography is by looking at the genetic origins as Leavitt et al. (2018) and Leavitt and Lumbsch (2016) have for the genus *Xanthoparmelia*. Leavitt et al. (2018) examine landscape genetics and gene flow, modeling lichen distributions, and the role photobionts play in determining distributional ranges. These methods may assist in explaining distributional trends for some Florida lichens in the future.

THE STUDY AREA

The Jupiter Inlet Lighthouse Outstanding Natural Area (ONA) encompasses 120 acres of open space in Florida's highly urbanized Treasure Coast, on the Atlantic side of the state in northern Palm Beach County. The ONA is near the southern extent of the deep white sandy soil characteristic of Florida's central ridge scrub habitats, and in the transition area between subtropical and tropical hammocks forests (USDOI BLM 2010). Most of Florida's native plant communities have been impacted by centuries of human occupation, including its many "natural areas" and state parks (Reece and Noss 2014; Tripp and Lendemer 2019). Some of these special management areas are so small that they are regularly impacted by activities conducted on adjacent properties, and by the repeated invasion of non-native plant and animal species. Portions of the ONA have escaped development-related impacts because public access was restricted during 80 years of Coast Guard management (USDOI BLM 2010). Now under jurisdiction of the federal Bureau of Land Management, the site is managed not only for its 150-year old lighthouse, but also for its natural features, biological diversity, federally listed plant and animal species and recreational opportunities. Protection of the ONA's biological resources has been identified as one of the agency's many objectives (USDOI BLM 2010). Our work on the ONA has been an ongoing effort to document the macrolichen flora, while providing managers with guidelines for enhancing this flora—a flora that until recently was poorly known.

The area lies at 60 feet above sea level, one of the highest points in south Florida. The climate has a marked wet season from May through October, and a dry season from November through April. Mean annual rainfall is 157 cm (62 inches) (USDOI BLM 2010). Soils in the scrub habitat portions of the ONA are derived from quartz, slightly to strongly acidic, extremely low in nutrients, and moderately to excessively well-drained, often resulting in arid conditions. These type of white quartz sands are locally referred to as sugar sands due to their texture. Dominant natural vegetation in these sites includes sand pine (*Pinus clausa* (Chapm. ex Engelm.) Vasey ex Sarg.), scrub oak (*Quercus* spp.), saw palmetto (*Serenoa repens* (W. Bartram) Small), and *Cladonia* spp. (*C. evansii* Abbayes, *C. prostrata* A. Evans, *C. subtenuis* (Abbayes) Mattick) common in the understory. Small areas of coastal hardwood hammock are dominated by cabbage palm (*Sabal palmetto* (Walter) Lodd. ex Schult. & Schult.), tupelo (*Nyssa sylvatica* Marshall) and poisonwood (*Metopium toxiferum* (L.) Krug & Urb). Black (*Avicennia germinans* (L.) L.) and red (*Rhizophora mangle* L.) mangrove are present in small colonies.

METHODS

Lichens were collected periodically over the last seven years, as we have surveyed for and monitored *Cladonia perforata* A. Evans populations. *Cladonia perforata* was listed as endangered by the U.S. Fish and Wildlife Service in 1993 (USDOI BLM 2010). Lichen species collected within the Jupiter Inlet Lighthouse ONA are listed with their preferred substrate, relative abundance in the ONA, and their Florida and global distribution, based on the number of herbarium collections listed by the Consortium of North American Lichen Herbaria (CNALH; 2020). The abundance ratings and number of collections are affected by many factors, such as where lichenologists have collected and the ease of access. These are uncontrollable issues in this and other studies. Our abundance

ratings consider the factors of 1) ease of detection; 2) habitat threats, and 3) scale of rarity (McCune et al. 2019). Lichen species were also placed into one of nine geographic and floristic categories, ranging from the narrow regional to the wider cosmopolitan (Table 1). Lichen nomenclature follows Esslinger (2019).

We included literature reports and opensource web material (Harris 1995; Lücking et al. 2011; Lendemer et al. 2013; Rosentreter et al. 2015; Rosentreter et al. 2020). We also included online herbarium records (CNALH 2020) that we have not verified; however, we have indicated where online records that do not fit the general distribution pattern might not be correct. Verification of these records at the state level have been explored to some extent, but not at the global level. Several scattered records (12 records that we know of) were corrected by herbarium curators once we requested a review of the specimens. This included local, national, and international collection records. Lichen specimens we personally collected within the ONA have been placed in either the University of Florida Museum of Natural History Herbarium (FLAS) in Gainesville, Boise State University Snake River Plain (SRP) herbarium in Idaho, or the New York Botanical Garden (NY).

RESULTS

For biogeographic and floristic distributions, we used broad elements as well as finer scale (more regional) patterns that have been used by others (Brodo et al. 2001; Lendemer et al. 2013; Tripp and Lendemer 2019). The biogreographic categories we used were: (1) SE US or coastal Plain, (2) E US and the Ozarks, (3) North America (NA) only, (4) E US Europe (eastern temperate elements), (5) NA Europe (northern temperate), (6) SE US Tropical Americas, (7) E US tropical Americas, (8) Tropical W Hemisphere, and (9) Worldwide or Cosmopolitan (Table 1). Of these, the SE US, the E US and the Ozarks, and the Tropical Americas elements appear to be the greatest influences on the distribution pattern of those lichen species we found at the ONA (Tables 1, 2).

Table 1. Geographic distribution elements of the lichens found at the Jupiter Inlet Lighthouse Outstanding Natural Area (ONA), Jupiter, FL.

Geographic distribution, from regional to cosmopolitan		**Number of species in this category at the ONA**
1.	SE US mostly, or coastal Plain	14
2.	E US Ozarks	8
3.	NA only	1
4.	E US Europe (eastern temperate)	2
5.	NA, Europe (northern temperate)	4
6.	SE US Tropical Americas	6
7.	E US Tropical Americas	7
8.	Tropical W Hemisphere	7
9.	Worldwide (or Cosmopolitan)	6

The geographic distribution and CNALH search results for each lichen species found in the ONA are presented below (Table 2). Substrate preference (the most common), abundance ratings and remarks on each species provide ecological and distributional information at the species level—all based on literature, personal experience, and herbarium label data.

Table 2. Lichens at the Jupiter Inlet Lighthouse Outstanding Natural Area (ONA), Jupiter, Florida. Scientific name, common name, local, state, and global abundance ratings as well as the number of documented voucher specimens of each species at each given scale, with remarks on their ecology and distribution (NA= North America, SA= South America, SE= Southeast US, N= north, S= south, NW= northwest, US= United States, FL= Florida). Abundance ratings are: R = rare; I = infrequent; C = common (Geiser 2004; Miller et al. 2011; McCune et al. 2014).

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Bulbothrix laevigatula Matted eyelash lichen	wood	R	C/73	SE US and Tropical Americas 279	Common on both conifers and hardwoods, in a wide range of habitats. This collection is the farthest south known specimen in Florida; more common northward
Bulbothrix isidiza Isidiate eyelash lichen	wood	R	C/88	SE US and scattered other records northern Hemisphere 263	Rare; more common northward in the SE, on pine and other woody substrates. This collection is the farthest SE known collection in Florida
Calicium leucochlorum Pin lichen	old cabbage palms	R	central and S peninsula Florida I/42	SE US scattered in a few other tropical sites 56	Widespread central and southern peninsula of Florida and a few other tropical sites, only on palm trunks
Caloplaca epiphora Isidiate fire dot lichen	wood	R	I/28	SE US and Tropical Americas 246	On hardwoods, widespread but infrequent (in Florida and elsewhere) in mostly oak habitats
Chrysothrix xanthina Yellow dust lichen	wood	C	C/73	E US 824	Common on various substrates, in a wide range of habitats, records include *C. candelaris* as a syn.
Cladonia beaumontii Beaumont's cup lichen	decaying wood	R	C/207	Mostly in Florida, E US and Ozarks 439	Mostly on organic matter or decayed logs, in a wide range of habitats

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Cladonia chlorophaea Mealy pixie-cup lichen	palm bark	R	I/25	Worldwide 9130	Worldwide, but mostly NA, Europe; on organic matter and soil, in a large range of habitats, various species may be included in this complex
Cladonia dimorphoclada Prostrate thorn cladonia	sand	R	R/18	E NA 706	E NA, more common farther north, always on sandy soil
Cladonia evansii Powder-puff lichen	soil	C	C/888	SE US, mostly 1422	Mostly SE US, nearby tropics. Widespread and common on sandy soil, wood and other substrates, in a range of habitats
Cladonia floerkeana Gritty British soldiers	decaying wood	R	I/10	Mostly NA and Europe 1200	Infrequent in FL on decayed wood, organic matter, and soil in Florida, more common elsewhere in Eastern NA and Europe
Cladonia incrassata Powder-foot British soldiers	decaying wood	C	C/58	E US and N Europe 1010	Widespread and common on stable wood, decayed wood, and organic matter, in various habitats
Cladonia leporina Jester lichen	soil	C	C/1129	SE US and Ozarks 2642	Widespread and common on sandy soil and wood, frequently fertile

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Cladonia pachycladodes Lazy cladonia	white sand	R	I/ 323	SE US 474	Infrequent to rare on white sandy soil; the number of collections give the appearance it is more widespread than it may really be
Cladonia perforata Perforate reindeer lichen	white sand	R (federally Endangered)	R/197	SE US North American endemic 197	Rare on open white sterile sandy soil. Well collected and appears in more collection #'s than appropriate for its true distribution
Cladonia peziziformis Turban lichen	soil	I	C/380	E NA and Tropical Americas 4806	Widespread and common on soil and wood, in many different habitats
Cladonia prostrata Resurrection cladonia	soil	C	3rd farthest south population C/308	SE US 378	Common on open sandy soil, early colonizer; once established, can cover large areas, often in gaps within forested habitats
Cladonia ramulosa Cup lichen	wood	R	C/135	Mostly in E NA and Europe 1976	Infrequent to common on wood and organic matter; often misidentified as *C. peziziformis*
Cladonia rappii Slender ladder lichen	organic matter	I	C/456	Mostly E NA Tropical Americas 1239	Common in openings within the forest, often on organic matter or wood
Cladonia ravenelii Ravenel's cup lichen	decaying wood	I	C/300	Broadly SE US and Ozarks 630	Widespread and common, often on wood or organic matter in various habitats

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Cladonia subradiata Powdery peg lichen	wood	I	C/650	E NA S of Canada and Tropical Americas 1528	Most common sorediate *Cladonia*; on wood or soil in Florida, in many habitats
Cladonia subtenuis Dixie reindeer lichen	soil	C	C/948	E US 6746	Most common shrubby/fruticose *Cladonia* on soil, sand, wood, and other substrates; known locally in Florida as "Deer Moss"
Coccocarpia palmicola Salted shell lichen	wood	I	C/286	Worldwide 2658	E NA, SA and Australia. Widespread and common on bark, wood and moss as an epiphyte but not on soil, in many habitats
Dirinaria applanata Medallion lichen	wood	R	I/41	Tropical W Hemisphere 650	Infrequent as an epiphyte on almost any type of tree, shrub, or rock, in many habitats
Dirinaria picta Powdery medallion lichen	wood	C	C/466	Tropical worldwide 1511	Widespread and common on any substrate but most often on wood or bark, in all types of habitats
Dirinaria purpurascens Purple-eyed medallion lichen	wood	I	C/102	SE US and Tropical Americas 248	Common on the peninsula of Florida but not in the panhandle, on wood or bark, widespread in tropical Americas
Haematomma persoonia Blood spot lichen	wood	C	C/110	SE US Tropical Americas 881	Widespread and common on wood and bark, mostly in forested hammock habitats

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Heterodermia albicans White fringe lichen	wood	I	C/298	Tropical W Hemisphere 1892	The most widespread and common *Heterodermia* in Florida; on wood or rock; in many habitats
Heterodermia speciosa Powdered centipede lichen	wood	R	C/62	Worldwide mostly Tropical but also temperate 3734	Common but not well collected, on wood and bark in Florida, in many habitats, common worldwide
Hypotrachyna livida Wrinkled loop lichen	wood	R	C/252	Mostly E NA and SA 2880	Common on various woody substrates and in many different habitats
Lecanora cf. *helva* Rim lichen	wood	I	R/1	Tropical/ subtropical 200	This group needs work, but is common in the tropics and subtropics, in many habitats.
Leptogium austroamericanum Dixie jellyskin	wood	R	C/197	Broadly SE US 1278	Widespread and common on wood and bark in various habitats
Leptogium cyanescens Blue jellyskin	wood	R	C/287	Widespread W Hemisphere 6194	Widespread and common on rock, moss, and wood in various habitats
Leptogium isidiosellum Salted ruffled blue jellyskin	wood	R	I/109	SE US Appalachia, & Tropical SA 293	Widespread and common, mostly on wood and bark in various habitats
Leptogium millegranum Stretched jellyskin	wood	R	R/12 Florida peninsula	S SE and E coast, 255	Common mostly on wood and bark; S, SE and east coast of NA; doubtful other records, scattered about NA

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Parmotrema gardneri Unwhiskered ruffle lichen (K-, P+ red)	wood	C	C/170	E US Tropical Americas 867	Common on wood, probably undercollected
Parmotrema praesorediosum Unwhiskered ruffle l. (K-, P-)	wood	C	C/478	SE US Tropical Americas 1511	Widespread and common mostly on wood
Parmotrema perforatum complex Perforate ruffle lichen (UV-)	wood	C	C/336	Mostly E US 3334	One of the most widespread **medium-lobed**, non-sorediate/isidiate *Parmotrema's* in Florida and in the entire eastern US; on wood and other substrates
Parmotrema rampoddense Long-whiskered lichen	wood	I	less common in S Florida C/451	SE US mostly, 1258	SE US and S Mexico. On wood; widespread, the most abundant sorediate *Parmotrema* in Florida, SE US & Mexico; doubtful other records, scattered about globally.
Parmotrema subrigidum Ruffle lichen (KC+)	wood	C	C/225	SE US mostly coastal 755	Widespread and common in various habitats in Florida and the SE US, it is mostly coastal
Parmotrema tinctorum Palm ruffle lichen	wood	I	C/640	Worldwide 3586	The most widespread, common, and easy to identify **large-lobed** *Parmotrema* in Florida and worldwide, mostly on wood but also on other firm substrates

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Pertusaria texana Texas wart lichen	wood	C	C/56	SE US Ozarks, Mexico 1235	Common on hardwood bark, UV+
Phaeographis lobata Dark-spored script lichen	wood	I	I/99	SE US Tropical Americas 286	Common on hardwoods in mostly coastal habitats, often on oak twigs
Physcia atrostriata Streaked rosette lichen	bark	R	C/254	SE US Ozarks, Tropical Americas 841	Widespread and common in Florida, most common in tropics on hardwoods
Physcia ciliata Ciliate rosette lichen	wood	R	R/11	SE US Tropical Americas 224	Mostly N hemisphere, on wood
Placynthiella uliginosa Tar spot lichen	wood	C	I/26	NA N of Mexico, Europe 1329	Widespread and common on wood, organic matter, and soil
Protoparmelia isidiata Chocolate rim lichen	wood	R	I/31	SE US 180	Widespread and common in the SE US on wood and twigs
Pyrenula syn= *(Anthracothecium) ochraceoflava* Yellow pox lichen	wood	C	C/93	Peninsular FL, Tropical Americas, well-collected in Galapagos 283	Widespread and common in the peninsula of Florida, on wood UV+ reddish.
Pyrrhospora syn. = *Lecidea varians* Pale crimson dot lichen	wood	R	C/140	NA only 2019	NA only S of Canada. Widespread and common, mostly on hardwoods; in various habitats
Pyxine cocoes Buttoned rosette lichen	wood	C	C/73	Worldwide Tropical 444	Widespread and common on wood and rock in various habitats
Pyxine eschweileri Thin rosette lichen	wood	I	C/206	Tropical Americas 507	Widespread and common; mostly coastal in Florida, in various habitats

Species and Common Name	Substrate	Abundance Local scale	Abundance Statewide scale/No. of herbarium collections from FL	Worldwide Distribution/No. of herbarium collections in the Consortium Database	Remarks
Ramalina complanata Bumpy ramalina	wood	R	C/174	SE US mostly 1254	Mostly coastal SE US and Texas. Widespread and common in coastal and coastal-influenced areas, several inland specimens are probably mis-ID's. on any type of wood in **coastal** and lake habitats
Ramalina stenospora Southern strap lichen	wood	C	C/258	SE US mostly 857	SE US and Texas coast. Widespread and common on all types of wood and trees in various habitats. coastal and inland
Trapeliopsis granulosa Mottled-disk lichen	wood	C	I/12	Worldwide 3804	NA, Europe, and a few other places in the N Hemisphere. Widespread and common on soil and organic matter, and wood, in a wide range of habitats
Trapeliopsis flexuosa Board lichen	wood	R	R/42	Worldwide 1783	Worldwide: NA, SA, Europe, Asia, Australia; always on wood
Usnea pennsylvanica syn. = *(rubicunda)* Red beard lichen	wood	R	I/88	Worldwide 2051	Widespread but infrequent in Florida. Common in NA and Australia, on all types of trees and wood, in a wide range of habitats
Total = 55 species					

DISCUSSION

In small nature reserves, some common lichen species can be infrequent or rare, particularly in southern Florida, where development is prevalent and contiguous natural habitat no longer exists—there is nowhere for the propagules to go or to come from when there have been local extirpations (Endler 1982; Reece and Noss 2014). We have observed several macrolichen distribution trends or patterns we believe hold true, irrespective of Florida's ever-changing landscape.

We have collected macrolichens in nearly 40 of Florida's 175 state parks. Even though the parks vary greatly in size and habitat diversity, some macrolichen distribution patterns seem to hold true. For example, north and central Florida state parks and forests have higher macrolichen diversity than those parks further south (DeBolt et al. 2007; Rosentreter et al. 2018, Rosentreter et al. 2020). We believe there is a general decline in macrolichen diversity as one moves south in Florida. This holds true for species within the genus *Cladonia,* which decline in both diversity and abundance the farther south one travels in the state—except for in the unique open sandy scrub habitat, such as is found on the ONA. In contrast, crustose lichens increase in overall cover and diversity as you proceed south in Florida.

This trend in declining macrolichen diversity in southern Florida is exemplified by *Bulbothrix laevigatula* (matted eyelash lichen). Collected once at the ONA, it is the farthest southerly known specimen for this species in Florida; it is much more common to the north (DeBolt et al. 2007; Harris 1995; Lücking et al. 2011). Despite the presence of apparently suitable habitat (i.e., stable, old sand pine stands) at the ONA, we observed no *Lobaria, Pannaria, Sticta, Collema, Parmelinopsis, Peltigera, Punctelia,* or *Pseudocyphellaria* species at this southern location. Similarly, *Parmotrema rampoddense* (long-whiskered lichen), is also infrequent in southern Florida, whereas it is the most common sorediate *Parmotrema* to the north.

In contrast, and growing more like a crustose species, *Dirinaria purpurascens* (purple-eyed medallion lichen) is common in peninsular Florida, but uncommon in the panhandle. It is, however, widespread in the Tropical Americas.

About 50% of the ONA is comprised of sand pine scrub and oak scrub. Drewa et al. (2008) found that the increased intensity of hurricanes in the panhandle and current fire suppression patterns in the peninsula may shift characteristics of sand pine stands in both regions. Drewa et al. (2008) also found that compared to the panhandle, trees were generally larger, but younger in the peninsula. Trees averaged 18.0 cm diameter at breast height (dbh) across the panhandle sites, but 24.0 cm dbh across the peninsula sites. Sand pines were 34.4 years old on average across peninsula sites, but almost 60 years old in the panhandle. Tree age ranged from 9 to 146 years in the panhandle and 8–76 years in the peninsula. We believe that older age class trees are more likely to retain and disperse macrolichen species that utilize asexual dispersal propagules.

CONCLUSION

Macrolichen diversity at the Jupiter Inlet Lighthouse Outstanding Natural Area is interesting both in how many common, and rare, taxa exist. A surprising number of uncommon lichens occupy the deep white sands of the sand pine scrub and oak scrub habitat, especially within the genus *Cladonia*. By using the Consortium of North American Lichen Herbaria Database to determine the number of collections for each species from the ONA, from Florida, and from around the world, an assessment of each species' geographic distribution and habitat affinities could be made.

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