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RESEARCH NOTE

Distribution of *Croton linearis* in Miami-Dade County Preserves with Potential for Supporting the Federally Endangered Butterflies *Strymon acis bartrami* and *Anaea troglodyta floridalis*

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ABSTRACT: Extreme south Florida has suffered recent losses of butterfly populations and even species extinctions. Information about the life histories of rare butterflies and their host plants is needed to recover their populations. We assessed urban fragments of pine rockland for their potential to support the federally endangered butterflies *Strymon acis bartrami* and *Anaea troglodyta floridalis*. We sampled and mapped the distribution of the larval host plant *Croton linearis* and used GIS data and fire records to rank each of the ten preserves for suitability to support the rare butterflies. Our findings revealed that host plants are patchily, but widely, distributed and are generally abundant. *Croton linearis* populations were largest in fragments that had experienced fire within the past decade. In total we estimated that 49,813 *C. linearis* individuals occurred in nine of the ten preserves we surveyed in 2013. While it is possible that nine of the ten preserves containing *C. linearis* could support populations of either rare butterfly, our suitability matrix showed that not all preserves are equal, enabling us to make recommendations about where to focus butterfly recovery efforts and how to improve rare habitat at preserves with lower scores.

Index terms: butterfly, fire, fragmentation, host plant, pine rockland

INTRODUCTION

Biodiversity loss is a global phenomenon that shows little sign of reversing, or even slowing (Butchart et al. 2010). Decline of pollinators in particular has been a major concern for well over a decade (Kearns et al. 1998; Potts et al. 2010), with Lepidoptera being no exception. The IUCN Red List includes 27 extinct butterfly and moth species, and another 50 that are endangered or critically endangered (IUCN 2014). European butterflies have decreased by 11% in recent decades (van Swaay et al. 2006). In North America, the decline in migrations of the once ubiquitous monarch butterfly (*Danaus plexippus* L.) has been well-documented (Brower et al. 2012), while rare species have gone extinct or appear to be hanging by a thread (USFWS 2003; Minno 2010; Schultz et al. 2011).

With the most sensitive species already gone, scientists and land managers have a mandate to act quickly to prevent further extinctions of Lepidoptera, which likely serve as early warning indicators that extinctions of other, longer-lived animal and plant species are looming (Krauss et al. 2010). Recovery of the most imperiled species will require thorough understanding of each species' unique biology and interspecies mutualisms, most notably with larval host plants. Scientists will need to work with land managers to ensure there is adequate habitat to sustain each species, often balancing one rare species' management needs against another (Schultz et al. 2011). Some of the most important data that are needed include information on larval host plant distribution and ecology.

We present a case study from the globally critically imperiled, highly fragmented pine rockland (or, pineland) forests of Miami-Dade County, Florida. This plant community is home to the Florida leafwing (*Anaea troglodyta floridalis* F. Johnson and W. Comstock) and Bartram's scrub-hairstreak (*Strymon acis bartrami* W. Comstock and Huntington) butterflies, both of which are subspecies of West Indian butterflies found only in extreme south Florida (Smith et al. 1994), and both are recent additions to the list of species protected under the federal Endangered Species Act (USFWS 2014). The Florida leafwing is currently found only in the Long Pine Key region of Everglades National Park, while Bartram's scrub-hairstreak is located in Long Pine Key as well as Big Pine Key in the Florida Keys and in a handful of forest fragments within urban Miami-Dade County (USFWS 2014). The only known larval host plant for both taxa is pineland croton (*Croton linearis* Jacq.), a shrubby member of the Euphorbiaceae. In order to aid conservation planning for these newly endangered butterflies, we describe the distribution and abundance of *C. linearis* within the heavily fragmented portion of the butterflies' ranges in Miami-Dade County, and we use these data, along with GIS and fire history information, to rank county preserves for suitability to support the butterflies.

METHODS

Study Species: *Croton linearis*

Croton linearis is an evergreen shrub that grows to two m tall, often maintaining a shorter stature in frequently burned habitats (Figure 1). Leaves are alternate, entire, and linear to elliptic to about seven cm long. Individuals are dioecious with racemes of small white male or female flowers occurring on separate plants (Correll and Correll 1982). *Croton linearis* is found in the West Indies and in southeast Florida, USA (Correll and Correll 1982). In Florida, it is found only in five counties: Martin, Palm Beach, Broward, Miami-Dade, and Monroe (Gann et al. 2014). In Miami-Dade County, *C. linearis* is found primarily in pine rocklands. Pine rocklands are a globally critically imperiled plant community found only in South Florida, The Bahamas, and in the Turks and Caicos Islands (FNAI 2010). Within the footprint of Miami, less than 2% of this habitat remains as isolated islands of nature surrounded by dense urban and agricultural development (Figure 2).

Survey Methods

We concentrated survey efforts in two core areas representing the two largest areas of pine rockland outside of the much larger, intact Long Pine Key area in Everglades National Park (Figure 2). The Richmond area is 28 km southwest of downtown Miami, and Navy Wells is 48 km southwest of downtown Miami. Both areas have well-established populations of Bartram's scrub-hairstreak (USFWS 2014). The Florida leafwing was once established in both regions, but has not been documented as maintaining a population at either location in the past 25 years (USFWS 2014). For each of the two core areas, we selected preserves to survey if they contained pine rockland and were within four km of the core. We further narrowed our criteria to include only preserves owned and managed by Miami-Dade County, thus excluding approximately 250 ha of pine rockland in the Richmond area that are in federal or private ownership. With these restrictions in mind, we selected ten preserves total-

Figure 1. *Croton linearis* in Miami-Dade County's Larry and Penny Thompson Park. This male plant is being visited by the federally endangered butterfly, Bartram's scrub-hairstreak. Photo: J. Possley.

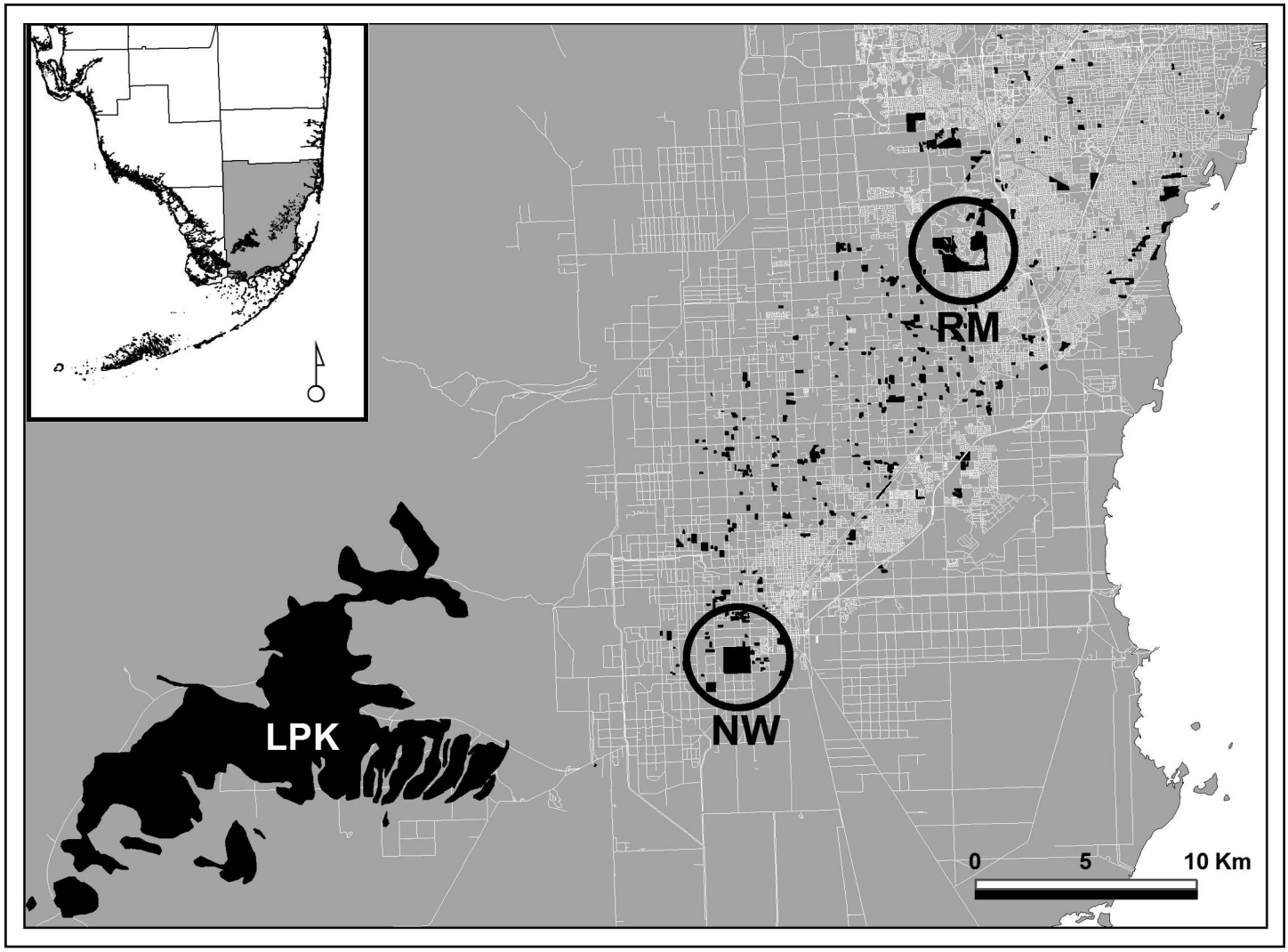

Figure 2. Location of Miami-Dade County within southern Florida (inset) and detail showing intact forest (black) in the Long Pine Key (LPK) region of Everglades National Park and in scattered fragments in urban Miami-Dade. The two core survey areas, Navy Wells (NW) and Richmond (RM), are indicated on the map as black circles.

ing approximately 414 ha to survey for *C. linearis* (Table 1).

We surveyed for *C. linearis* from January through July 2013, with limited follow-up surveys in 2014. Surveyors used handheld GPS units to collect location information. When we encountered *C. linearis,* we scanned within a 2.5-m radius for other individuals and recorded the total number of plants observed within the radius.

We implemented two different survey methods depending on the size of the preserve. For sites <20 ha (Florida City, Navy Wells 39, Palm Drive, Sunny Palms, Eachus, and Tamiami Pineland Complex Addition), surveyors walked all pine rockland edges, including fire breaks and trails. For parcel interiors, we made several passes back and forth through each unit, attempting to cover as much ground as possible in the time allotted (1–2 days) (Figure 3).

For sites >20 ha (Navy Wells, Larry & Penny Thompson, Martinez, and Zoo Miami), surveyors walked all edges, fire breaks, and trails and made passes back and forth through a portion of the interior so that we sampled at least 10% of the total pine rockland area.

For all preserves regardless of size, we used our *C. linearis* counts to extrapolate the number of individuals in the entire preserve based on the area surveyed, according to a simple proportional formula: $N_T = (A_T \times N_S) \div (A_S \times 5)$, where N_T is the total extrapolated *C. linearis* population size, N_S is the number of individuals counted during surveys, A_T is the total area of pine rockland, and A_S is the area covered during surveys. We multiplied the total track length by 5 m, the width of our survey area (2.5 m on each side). Prior to analysis, we excluded irrelevant portions of survey tracks. In calculating the square meters of pine rockland for each preserve, we excluded developed areas (e.g., pavement, buildings, orchards) and, on rare occasion, areas that were heavily infested with exotic plants.

Table 1. The 10 Miami-Dade County pine rockland (PR) preserves surveyed for *Croton linearis*. The total areas surveyed were estimated by adding up the length of GPS tracks and multiplying by 5 m, the width of our visual search area. Total pineland area for Navy Wells includes 30 ha owned by the Florida Keys Aqueduct Authority. Total pineland area for Martinez Pineland includes 4 ha owned by the National Oceanic and Atmospheric Administration.

		Distance from core (km)	Number of distinct PR management units	Number of *C. linearis* individuals mapped	Estimate of total area surveyed (m^2)	Estimate of total area of pineland (ha)	Estimate of total *C. linearis* individuals at site
Richmond	Eachus	1	2	0	18,630	6.5	0
	Larry & Penny	0	10	780	139,445	93.5	5230
	Martinez	0	3	963	34,485	53	14,800
	Tamiami Pineland Complex Addition	2	1	434	28,645	7	1061
	Zoo Miami	0	14	1695	176,220	102	9811
Navy Wells	Florida City	1.5	1	658	25,520	8	2063
	Navy Wells	0	11	2296	212,765	118	12,734
	Navy Wells 39	1.75	1	506	16,780	5.7	1749
	Palm Drive	2.5	1	76	17,305	6.8	299
	Sunny Palms	0.75	3	234	15,845	14	2068

Suitability Ranking

In order to rank the ten preserves for suitability to support Bartram's scrub-hairstreak and/or Florida leafwing, we compiled information from *Croton linearis* ground surveys, Fairchild Tropical Botanic Garden's GIS, and Miami-Dade County's burn records. Following information available in the USFWS rule (USFWS 2014) and Krauss et al. (2010), we chose seven criteria and treated each as categorical data: (1) presence of *C. linearis*, (2) density of *C. linearis* (using extrapolated totals), (3) preserve size, (4) preserve isolation, which we quantified as distance to the nearest neighboring pine rockland, (5) matrix quality, with natural area being the most desirable surroundings for any preserve, followed by nurseries or agriculture, followed by buildings, (6) fire history, which we quantified as number of years since the last fire, and (7) mosaic potential, which indicates how many permanent fire breaks exist within a preserve that would promote patchy burning instead of fires that affect the entire preserve. With the exception of presence/absence of *C. linearis*, all criteria had possible scores of 1, 2, or 3, with higher scores reflecting greater suitability. Each preserve's score was then tallied for comparison, divided by 18 (the maximum score) and multiplied by 100 to reflect the percentage of total possible score (S_T): $S_T = (\sum S \div 18) \times 100$.

RESULTS

We surveyed approximately 71 of 414 ha (17%) in ten preserves for the presence of *Croton linearis*. One site, Eachus Pineland, lacked any *C. linearis.* In the other nine preserves we mapped a total of 7642 individual *C. linearis* (Tables 1, 2). When we extrapolate the *C. linearis* populations, we estimate that the total number of *C. linearis* at all sites is 49,815 individuals. Martinez Preserve had the highest extrapolated population at 14,800, and Navy Wells was the second highest at 12,734. Of the preserves where *C. linearis* was present, Palm Drive Pineland had the fewest individuals, with 76 counted (299 extrapolated).

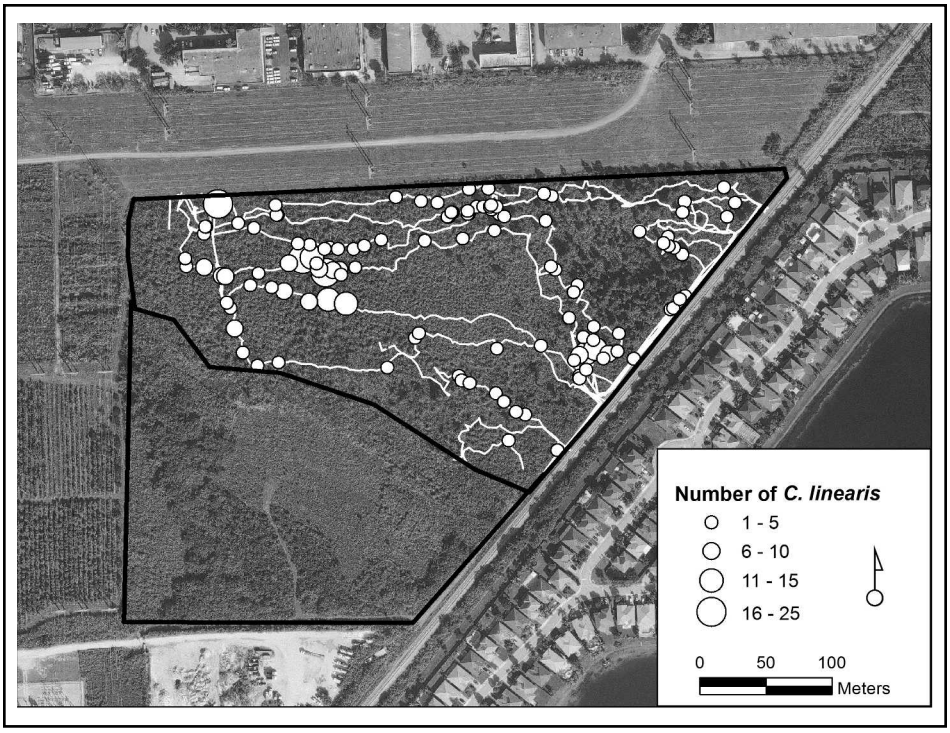

Figure 3. Example of spatial data collected during *Croton linearis* surveys at Tamiami Pineland Complex Addition. Surveys (white line) were only conducted in pine rockland habitat, which in this case is the northern 7 of the preserve's total 12 ha. Aerial photo, taken in 2012, from www.labins.org.

Our ranking matrix awarded the highest preserve score for supporting rare butterfly populations to the pinelands at Zoo Miami (Table 2). The Zoo was the only site that received a maximum score of 3 in the "matrix quality" category, because it is surrounded on almost all sides by pine rockland forest. The next most suitable sites were Navy Wells and Larry and Penny Thompson Park. No preserve received the lowest possible score (28). The lowest-scoring pineland was Palm Drive (39).

DISCUSSION

Results from these surveys can be used to inform conservation planning for the Florida leafwing and/or Bartram's scrub-hairstreak butterflies in urban Miami's protected pine rockland forest fragments. We strongly recommend that introductions focus on Zoo Miami, Larry and Penny Thompson Park, and Martinez Preserve in the Richmond area, and Navy Wells and Sunny Palms in the Navy Wells area. Bartram's scrub-hairstreak reintroduction efforts might also include Navy Wells 39, since there is a documented population of that taxon there (Possley, pers. obs.). Additional efforts toward the recovery of these butterflies in Miami's urban fragments should include restoring habitat in these preserves, conducting prescribed fires in a mosaic pattern and at frequencies between two and ten years (USFWS 2014), and perhaps introducing *Croton linearis* to Eachus pineland or augmenting the population at Palm Drive Pineland. Additional mapping and survey efforts might also focus on the presence of nectar plants adjacent to concentrations of *C. linearis.* In addition, research into the life history of both butterfly species is needed, as some aspects—especially regarding adult insect biology—are poorly understood, yet could be crucial to conservation planning.

In Miami-Dade County, the presence of pine rockland habitat is clearly a limiting factor for both rare butterflies. However, within the core areas of Richmond and Navy Wells, abundance of the host plant *Croton linearis* is relatively high and may not limit butterfly abundance. The exception is Eachus Pineland, which lacked *C. linearis.* Our surveys suggest another limiting factor for the rare butterflies is fire: sites with more frequent fire had more abundant *C. linearis*. A marked exception to this trend was Martinez Preserve, which had the largest (extrapolated) population of *C. linearis* despite not having had a recent fire. Martinez Preserve contains remnant marl prairie, which may make it less vulnerable to invasion by native hardwoods that reduce suitability for *C. linearis* and the butterflies that depend on it. It is also noteworthy that the Long Pine Key area of Everglades National Park supports populations of both rare butterflies, despite having a fire-return interval up to ten years (USFWS 2014). However, the pine rockland fragments in urban Miami likely require a shorter fire-return interval, as they experience edge effects and propagule pressure from urban tree plantings (native and not) to a much higher degree than forested areas of the national park.

Finally, in considering whether the techniques we employed might work for other plant–pollinator relationships, it is probably most suited for cases like ours in which a rare butterfly has co-evolved with a larval host plant that is relatively common. As with our efforts, any similar surveys need to consider the trade-off between precision in host plant counts versus the available time and funding. In cases where both the insect and the plant are exceedingly rare, efforts might be better spent mapping individual plants and exploring how to increase their abundance.

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Table 2. Matrix of 10 Miami-Dade County pine rockland preserves, ranking suitability to support populations of the federally endangered butterflies Bartram's scrub-hairstreak and Florida leafwing. Excepting "*C. linearis* presence," criteria had possible scores of 1, 2, or 3, with higher scores reflecting greater suitability. "*C. linearis* density" (figures not shown) was calculated by dividing the extrapolated number of *C. linearis* by the hectares of pine rockland. We used increments of 0.5 in the "Matrix" and "Fire history" categories; in the "Matrix" category, this indicated a preserve was surrounded by more than one category of matrix, and in the "Fire History" category, this indicated that only a portion of the preserve burned during the period.

	Criteria	*C. linearis* presence	*C. linearis* density (#/ha)	Pine rockland area (ha)	Fragment isolation (km)	Matrix	Fire history (yrs)	Mosaic potential (# units)	
	Data source	Field surveys	Field surveys	GIS	GIS	GIS	NAM	GIS	
	Data categories	Present/ Absent	1) <50	1) 1–37	1) >1	1) Urban	1) >10	1) 1	
			2) 51–100	2) 38–74	2) 0.1–1	2) Agric.	2) 3–10	2) 2–3	Total score
			3) >100	3) 75–118	3) 0	3) Natural	3) 0–2	3) ≥4	(max: 100)
Richmond	Eachus	Absent	0	1	2	1.5	1	2	42
	Larry & Penny	Present	2	3	3	2	2	3	83
	Martinez	Present	3	2	3	2.5	1	2	75
	Tamiami Pineland	Present	3	1	2	2	2	1	61
	Zoo Miami	Present	2	3	3	3	2	3	89
Navy Wells	Florida City	Present	3	1	2	1	1	1	50
	Navy Wells	Present	3	3	2	2	2	3	83
	Navy Wells 39	Present	3	1	1	2	3	1	61
	Palm Drive	Present	1	1	1	2	1	1	39
	Sunny Palms	Present	3	1	2	2	3	2	72

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