Dispersal and Establishment of New Populations of the Biological Control Agent Floracarus perrepae (Acariformes: Eriophyidae) on Old World Climbing Fern, Lygodium microphyllum (Polypodiales: Lygodiaceae)

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DISPERAL AND ESTABLISHMENT OF NEW POPULATIONS OF THE BIOLOGICAL CONTROL AGENT FLORACARUS PERREPAE (ACARIFORMES: ERIOPHYIDAE) ON OLD WORLD CLIMBING FERN, LYGODIUM MICROPHYLLUM (POLYPODIALES: LYGODIACEAE)

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Lygodium microphyllum (Cav.) R. Br (Polypodiales: Lygodiaceae), Old World climbing fern, is native to wet tropical and subtropical areas of the Old World. It was initially cultivated as an ornamental plant and was first reported as naturalized in Florida in 1965 (Beckner 1968; Pemberton & Ferriter 1998). Lygodium microphyllum has invaded multiple habitat types and important conservation areas in Florida including Everglades National Park and Arthur R. Marshall Loxahatchee National Wildlife Refuge (Ferriter & Pernas 2006). The fern outcompetes native vegetation by growing over and smothering native plant species primarily in wetland systems (Pemberton et al. 2002). Lygodium microphyllum can alter fire ecology by carrying fire into areas that usually do not burn, including cypress sloughs and tree canopies, and may rapidly colonize areas disturbed by fire (Pemberton & Ferriter 1998; Volin et al. 2004 and references therein). Vigorous vegetative growth from persistent rhizomes and prolific spore production make L. microphyllum difficult to manage using conventional methods (Pemberton & Ferriter 1998).

Floracarus perrepae Knihinicki & Boczek (Acariformes: Eriophyidae) is the most widely distributed herbivore on L. microphyllum in its native range (Goolsby et al. 2003). Females colonize and feed on the subleaflets of L. microphyllum, which causes the leaflet margins to roll. These galls are critical for the survival and reproduction of the mite and are diagnostic of mite presence in the field. Although one gall may contain multiple adults, a single gravid female is capable of inducing gall formation (Freeman et al. 2005). Gallng by the mite reduced aboveground biomass by 49% and belowground biomass by 35% compared to controls during pre-release testing in the native range (Goolsby et al. 2004).

Floracarus perrepaee can form full or partial leaf roll galls on sporelings of several Lygodium species but when mature plants of the same species were tested F. perrepae only completed development on L. microphyllum (Goolsby et al. 2005). Based on these results, the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS) issued a permit for the field release of Floracarus perrepae in 2006 (Boughton & Pemberton 2011). The mite was subsequently released at 6 sites in south Florida during 2008 and at a seventh site in 2010 (Boughton & Pemberton 2011). Low levels of gallng, fewer than 140 galls per site, were observed at 4 of these release sites in the months following releases, but after 14 mo, mite populations persisted at only 2 sites (Boughton & Pemberton 2011; Table 1). Sites were not regularly monitored after June 2011.

The limited establishment and population growth of F. perrepaee led to the assumption that mite populations remained at very low levels or had been extirpated. To test this assumption, release sites were resurveyed between 29 Jan and 13 Feb 2013. Two observers searched L. microphyllum foliage for approximately 25 min at each site. Two of the 7 sites had been treated with herbicide and there was no access to a third (Table 1). Of the 4 remaining sites, there was no mite activity at the site in Loxahatchee National Wildlife Refuge, but the other three, all located within Jonathan Dickinson State Park, had very low levels of gallng, i.e., only a few galls were found (Table 1). This result indicates that F. perrepae has persisted in the release area for more than 5 yr following release and is established within the park.

The recovery of F. perrepaee in Jonathan Dickinson State Park prompted a broader survey of L. microphyllum in the area surrounding the park between 29 Jan and 26 Apr 2013. Roadside patches of L. microphyllum radiating away from the established population at Jonathan Dickinson State Park were searched for galls by 2 observers for approximately 20 min per site. Distances between searches in any given direction were predicated on L. microphyllum presence but intervals were generally 1-5 km. Searches along a given direction were terminated after several
searches yielded negative results. Mite activity was found between 2.8 and 18.5 km from the nearest release; the mean dispersal distance was $10.5 \pm 1.8$ km. Presuming these mite populations originated from the closest release site (JD25) and had recently colonized the sites we surveyed, we conservatively estimate a dispersal rate of $3.5 \pm 0.6$ km/yr. No galls were found in *L. microphyllum* populations located to the south or due west of the park, but multiple patches to the north and northwest contained galls, some of which had abundant mite populations with the majority of subleaflets galled on some plants. Like all Eriophyidae, *F. perrepae* are wind dispersed and their distribution to the north and west of Jonathan Dickinson State Park is consistent with the direction of the prevailing winds for this area, which are from the east and southeast except in March (McCollum & Cruz 1981).

Additional *L. microphyllum* research is underway at several other locations across the fern’s distribution in Florida and *F. perrepae* has not been detected at these sites (E.C.L and M.C.S personal observation). Thus, dispersal was presumed to be limited to the area north and west of Jonathan Dickinson State Park. Recently, however, galls were observed on *L. microphyllum* in the Cape Sable region of Everglades National Park in May 2013. Galls were inspected using a microscope and mites discovered within were confirmed to be *F. perrepae*. Gall densities were abundant, numerous subleaflets galled on many rachises, within the *L. microphyllum* vegetation at several colonized sites, including Cape Sable. Here, damage was observed along a ca. 50 m transect but dense sawgrass, *Cladium jamaicense* Crantz (Poales: Cyperaceae), and time limitations prevented a full survey of the site. The source population for the Cape Sable mites remains unclear. The mites may have dispersed from the only known *F. perrepae* populations in Florida, ca. 220 km northeast or from a rearing site ca. 120 km northeast. It is also possible the source may be a yet undiscovered *F. perrepae* population that exists in southern Florida. These data clearly indicate, however, that *F. perrepae* is more widely distributed than previously thought. Additional research is needed to systematically map the distribution of *F. perrepae*, evaluate its effectiveness as a biological control agent of *L. microphyllum*, and determine the best time to make releases to maximize establishment.

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### Table 1. Location and Status of Floracarus perrepae Releases

| Site                     | Release Date(s) | Status from Boughton & Pemberton (2011) | 2013 Mite Status |
|--------------------------|-----------------|------------------------------------------|------------------|
| Jonathan Dickinson State Park JD1(JD45) | 1-VII to 23-X-2008; 19-VI to 23 X-2008; 15-VII-2009; 17-XI-2010 | galls present after 12-14 mo | Very low density |
| Jonathan Dickinson State Park JD2(JD46) | 8-V-2008 | galls present after 12-14 mo | Very low density |
| Jonathan Dickinson State Park JD25 | 17-XI-2010 | NA | Unknown |
| Grassy Waters Preserve GWP1 | 24-VI to 28-VII-2008; 15-XII-2008 | 13 galls after 1-4 wk | Very low density |
| Grassy Waters Preserve GWP2 | 5-XII-2008; 5-XII-2008 | 0 galls after 1-4 wk | Unknown |
| Loxahatchee National Wildlife Refuge LNWR | 15-VI to 5-XII-2008 | 20 galls after 1-4 mo | Unknown |
SUMMARY

The mite *Floracarus perrepae* Knihinicki & Boczek (Acariformes: Eriophyidae), a biological control agent of *Lygodium microphyllum* (Cav.) R. Br (Polypodiales: Lygodiaceae), Old World climbing fern, was released in south Florida from 2008 to 2010 but did not readily establish in the field. The original release sites were resurveyed in 2013 and the mite has established within Jonathan Dickinson State Park and has dispersed to *L. microphyllum* patches outside the park at a rate of 3.5 ± 0.6 km/yr. The mite has also dispersed to the Cape Sable region of Everglades National Park.

Key Words: eriophyid mite, gall, weed biological control, wind dispersal

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