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EXPANSION AND IMPACT OF LAUREL WILT IN THE FLORIDA EVERGLADES

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Tree islands are a prominent feature of the Florida Everglades landscape. These ovoid patches of forest vegetation are scattered throughout a matrix of herbaceous marsh and are important contributors to Everglades biodiversity and fundamental ecosystem processes. Tree islands have high species diversity, provide wading bird nesting habitat, and provide critical upland habitat for wildlife during the wet season. Everglades tree islands also play a key role in biogeochemical cycling and serve as nutrient sinks, particularly in the case of phosphorus (Wetzel et al. 2005). As such, tree island protection and restoration are increasingly viewed as priorities in the national Everglades restoration effort (Sklar & Van der Valk 2003).

Swamp bay (*Persea palustris* (Raf.) Sarg.) (Laurales: Lauraceae) is a common tree species of Everglades tree islands (Heisler et al. 2002), but ranges from dominant to absent in individual islands (Wetzel et al. 2008; Engel et al. 2009; Brandt et al. 2003). The tree also carries cultural significance in the Everglades as its bark and leaves are key reagents in traditional Seminole medicine (Snow & Stans 2001). Swamp bay is one of several members of the Lauraceae affected by laurel wilt in the southeastern USA. Laurel wilt is a vascular wilt disease caused by *Raffaelea lauricola* T.C. Harr. (Ophiostomatales: Ophiostomataceae), a symbiont of its vector, the exotic redbay ambrosia beetle, *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae: Scolytinae) (Fraedrich et al. 2008).

Xyleborus glabratus was first collected in the United States near Port Wentworth, Georgia in 2002 (Rabaglia et al. 2006), and by 2004, laurel wilt was associated with extensive mortality of redbay (*P. borbonia* (L.) Spreng.) (Fraedrich et al. 2008). Since then, the vector and its phytopathogenic symbiont have spread throughout the southern Atlantic coastal plain (USDA 2014), with localized losses of redbay populations exceeding 80% (Fraedrich et al. 2008). The beetle was first detected in Miami-Dade County just outside Everglades National Park (ENP) in Feb 2010 (Griffiths & Derksen 2010), and laurel wilt was confirmed on swamp bay only a few miles away from the initial capture in February 2011 (Ploetz et al. 2011).

Aerial surveys were conducted during Mar–May 2011, and May–Jun 2013 to determine the distribution and abundance of the wilt in and adjacent to the Everglades. Tree islands displaying symptomatic trees were recorded using a digital aerial sketch mapping system during planned invasive plant surveys (see Rodgers et al. 2014). Observers recorded presence and abundance of symptomatic swamp bay trees along fixed flight transects spaced 1-km apart, allowing for complete coverage of the survey area (Fig. 1). Observers digitized clusters of symptomatic trees as polygons using field mapping software (GeoLink® Sketchmapper™) and estimated percent cover of canopy damage for each polygon. Data were imported into a GIS (ESRI® ArcGIS Desktop™) to measure the proportion of tree island canopy with laurel wilt symptoms and range of occupancy (generalized area containing symptomatic trees within the survey area). Digital aerial imagery and tree island species composition data (Engel et al. 2009) were used to estimate the proportion of tree islands with swamp bay affected by the wilt.

Within 2 months of both surveys, sapwood samples were collected from a subset of symptomatic trees and submitted for testing to the FDACS Plant Pathology Laboratory in Gainesville, Florida. Fungi were isolated from samples following Fraedrich et al. (2008), and confirmed using the morphological and molecular methods described in Harmon & Brown (2009).

During the 2011 aerial survey, symptomatic trees were observed within a 4,925 ha range of occupancy in the eastern Everglades (Fig. 1). The greatest concentration of symptomatic trees occurred in tree islands and artificially elevated sites (ditch spoil mounds) within partially drained wetlands adjacent to ENP. Two tree islands within ENP harbored symptomatic trees. Sampling of 46 of the symptomatic trees confirmed that 80.5% tested positive for *R. lauricola*. The 2013 survey revealed a substantial increase in the range of occupancy (133,740 ha) (Fig. 1). Laurel wilt had spread further west into ENP, Water Conservation Area (WCA) 3, and Big Cypress National Preserve. The westerly expansion is not unexpected given the prevailing winds from the east and southeast, especially in the spring and fall

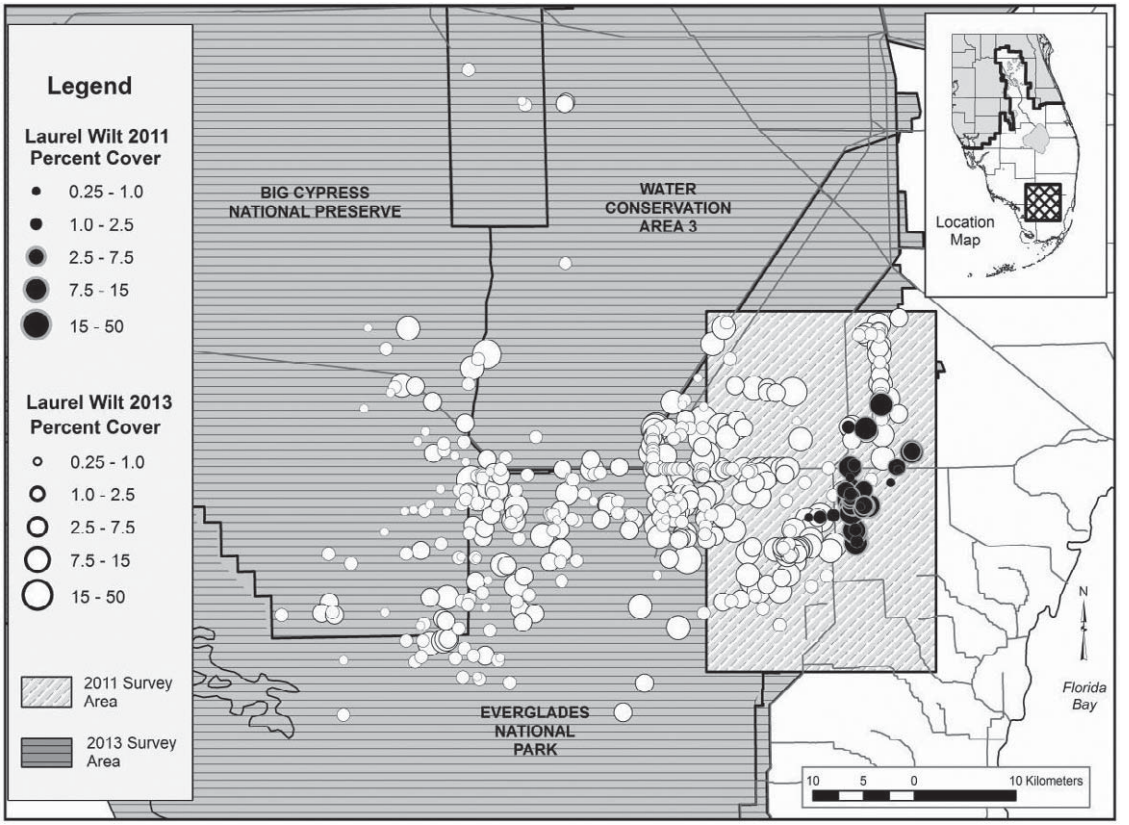

Fig. 1. The distribution and proportions of the canopy occupied by trees with symptoms of laurel wilt in Everglades natural areas (2011 and 2013).

when adult beetle emergence peaks (Brar et al. 2012; Maner et al. 2013). Symptomatic swamp bay were observed in 322 tree islands and along ditches, canals, and roads within the survey area. *Raffaelea lauricola* was recovered from 93.3% of the samples taken from symptomatic trees at 15 locations.

The western edge of the laurel wilt focus expanded by an average of 53.3 ± 1.5 SE km between 2011 and 2013. Assuming a constant rate of expansion during the 2 yr, laurel wilt spread across the east-central Everglades at 26.6 km/yr, which falls in the lower range of the Koch & Smith (2008) estimates (24 to 55 km/yr). Koch & Smith's expansion estimates were associated with highly variable habitats in more temperate environments and involved a different host species, redbay. Although the present data were from a relatively uniform subtropical habitat and another host species, swamp bay, they may provide a better estimate of how quickly laurel wilt can spread in the absence of anthropogenic movement. The clustered distribution of tree islands across the Everglades landscape may also provide insight into the capacity of *R. lauricola* vectors to naturally disperse long distances. A nearest neighbor analysis of tree islands with symptomatic trees revealed that the mean minimum distance between symptomatic tree islands was 1.0 km and the maximum nearest neighbor distance was 11.8 km.

In 2013, tree islands with at least 1 symptomatic swamp bay had a median canopy damage of 5.0% (interquartile range 2.5 to 10.0%). An analysis of tree island canopy composition (Engel et al. 2009) within the 2013 range of occupancy indicates that swamp bay importance values (sum of relative tree density and basal area) range from 0 to 43.4 (mean = 3.8), suggesting a wide range of potential canopy loss among tree islands. Tree islands with high swamp bay importance values are expected to sustain substantial canopy loss, as observed for some tree islands in this survey (maximum estimated canopy damage = 50%).

Within the current range of occupancy, 76% of the tree islands known to include swamp bay were not yet symptomatic, suggesting that laurel wilt will cause additional mortality. We note that the disease was rare in the southwest portion of Water Conservation Area 3 (WCA 3) (Fig. 1) where high importance values of swamp bay would predict the presence of laurel wilt. Factors

associated with this apparent low rate of wilt development should be identified.

The response of Everglades tree islands to sudden canopy loss is difficult to predict and warrants future evaluation. An abrupt loss of tree island canopy where swamp bay is an important component could reduce peat accretion rates (Cahoon et al. 2003) and lead to reduced tree island elevation and stability (Wetzel et al. 2005). Canopy disturbance also influences the ease with which communities are invaded (Eschtruth & Battles 2009). Lynch et al. (2009) reported increased colonization of Everglades tree islands by the exotic Old World climbing fern (*Lygodium microphyllum* (Cav.) R. Br.; Polypodiales: Lygodiaceae) after hurricane-induced canopy disturbances and Brazilian pepper (*Schinus terebinthifolius* Raddi; Sapindales: Anacardiaceae) colonizes canopy gaps and eventually dominates heavily impacted tree islands (Rodgers et al. 2014). Everglades land managers are encouraged to increase invasive plant monitoring and control efforts in tree islands where substantial canopy has been lost due to laurel wilt.

Summary

Laurel wilt, a vascular wilt disease caused by the vascular mycopathogen *Raffaelea lauricola* T.C. Harr. (Ophiostomatales: Ophiostomataceae), was first confirmed on *Persea palustris* (Raf.) Sarg. (Laurales: Lauraceae) in the Florida Everglades in Feb 2011. The abundance and range of occupancy of *P. palustris* symptomatic of laurel wilt were mapped in the Everglades tree islands in Mar 2011 and Jun 2013 using a digital aerial sketch mapping system. The disease's range of occupancy expanded from 4,925 to 133,740 ha during this 26-month period. Canopy disturbance was highly variable ranging from 0 to 50% canopy loss. However, tree island species composition data suggests that additional mortality of *P. palustris* is likely throughout the Everglades. The rapid loss of *P. palustris* in tree islands could lead to ecosystem level instability and invasion by exotic plant species.

Key Words: tree island, digital aerial sketch mapping, *Persea palustris*, *Raffaelea lauricola, Xyleborus glabratus*

Resumen

La marchitez del laurel, una enfermedad del marchitamiento vascular causada por la micopatógeno vascular *Raffaelea lauricola* T.C. Harr. (Ophiostomatales : Ophiostomataceae), fue confirmada por primera vez en *Persea palustris* (Raf.) Sarg. (Laurales: Lauraceae) en los Everglades de la Florida en febrero del 2011. Se hizo un mapa de la abundancia y el rango geográfico ocupado por los *P. palustris* con sintomos de la marchitez del laurel en las islas de árboles en los Everglades en marzo del 2011 y junio del 2013 utilizando un sistema para hacer mapas de imágenes aéreas digitales. El rango geográfico ocupado por la enfermedad incrementó de 4,925 a 133,740 hectáreas durante este período de 26 meses. El daño del dosel fue altamente variable de una pérdida del 0 a 50 % del dosel. Sin embargo, los datos de la composición de especies de árboles en las islas sugieren que probablemente hay mas mortalidad de *P. palustris* en los Everglades. La pérdida rápida de *P. palustris* en las islas de árboles podría resultar en la inestabilidad a nivel de ecosistemas y la invasión de especies exóticas de plantas.

Palabras Claves: isla árbol, hacer mapas de imágenes aéreas digitales, *Persea palustris*, *Raffaelea lauricola*, *Xyleborus glabratus*

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