Fensham, R.J., Carnegie, A.J., Laffineur, B., Makinson, R.O., Pegg, G.S. & Wills, J. (2020). Imminent extinction of Australian Mytaceae by fungal disease. *Trends in Ecology & Evolution*, Vol. 35, Iss. 7, Pp 554-557.

DOI: https://doi.org/10.1016/j.tree.2020.03.012

Imminent extinction of Australian Myrtaceae by fungal disease

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Running title: Extinction by fungal rust

Type of Article: Forum article

Key words extinction; myrtle rust; Myrtaceae; plant disease

Abstract word count: 57

Manuscript word count: 1172

Abstract

Myrtle rust is a fungal disease that has spread rapidly across the globe, arriving in Australia in 2010. The tree species *Rhodomyrtus psidioides* is nearly extinct in the wild as a result of the disease, leading to potential disruption of ecosystem function. Many other Myrtaceae may also be threatened and unprecedented impacts of the disease are predicted.

A new fungal disease in plants

Infectious fungal diseases in the plant kingdom usually have a relatively small number of host species and rarely push species to extinction [1]. There are some exceptions, the American chestnut (*Castanea dentata*) has declined dramatically in the wild through the impact of chestnut blight (*Cryphonectria parasitica*) [2] and the Florida torreya (*Torreya taxifolia*) has suffered a similar fate due to an unidentified fungal pathogen [3]. The iconic ʻōhiʻa (*Metrosideros polymorpha*) has declined suddenly in Hawai'i some 20 years following the introduction of *Ceratocystis* spp. [4], and in southern Australia the cinnamon fungus (*Phytophthora cinnamomi*) has taken locally endemic plant species to the brink of extinction [5]. Infectious diseases are only rarely invoked as a threat to plant species using formal listing procedures [6] despite an assessment of global disease alerts suggesting that fungal pathogens pose a particularly egregious future threat [7].

A newly established plant disease in Australia is having novel, dramatic and sudden effects. The disease is known as myrtle rust, caused by the fungus *Austropuccinia psidii*, and is simultaneously impacting many species in an extremely large and iconic plant family, the Myrtaceae. The wild origin of the fungal pathogen is theorised to be South America and was first identified occurring on common guava (*Psidium guajava*) in Brazil [8].

The invasive nature of myrtle rust has become evident as over the past dozen years the disease has swept around the globe, being detected in Hawai'i in 2005, then Japan in 2007, China in 2009, Australia in 2010, New Caledonia and South Africa in 2013, Indonesia and Singapore in 2016, and New Zealand in 2017 [9]. In Australia it was first detected in New South Wales in April 2010 and it rapidly colonised the humid areas of the east coast reaching the northern tropics by 2012. Myrtaceae in continents that have not co-evolved with the pathogen are considered 'naïve hosts', and therefore highly susceptible to *A. psidii*.

Within two years of arriving in Australia the global host range for myrtle rust doubled and it has now been found on 358 native Australian species and more than 480 species globally [8,10]. The rust infects newly expanding leaves and shoots, causing dieback and mortality with repeated infection, and also attacks flowers and fruit rendering plants infertile. Seedlings are highly susceptible so even if some seed remains viable regeneration is suppressed.

A case study of decline

Rhodomyrtus psidioides (native guava) is a shrub to small tree that occurs in subtropical environment across 7 degrees of latitude on the east coast of Australia (Fig. 1) [11], Its preferred habitat is the margins of rainforest and it can reproduce asexually by coppice growth or root suckering. In 2018, a total of 66 populations were located throughout the geographic range of the native guava and assessed for myrtle rust damage [12]. In an earlier assessment in 2014, 50% of individuals in 18 populations had been killed within three years of myrtle rust establishing [11]. In 2018, 23% of surveyed populations are either extinct or could not be located, and another 61% have been reduced to root suckers following the death of the canopy (Fig. 2a). These suckers are highly susceptible to infection (Fig. 2b). All populations exhibited evidence of myrtle rust infection, and only two populations (3%) had less than 10% of their branches infected (i.e. low impact levels). Flowers are highly susceptible to infection (c.f. Figs. 2c and d) and no mature fruit have been seen since the disease established. An ordinal regression revealed that mean annual rainfall, maximum temperature and elevation were unrelated to the infection levels of *R. psidioides* ($P > 0.05$) indicating that myrtle rust impacts across the range of environments where populations occur (Mean annual rainfall (mm): 941 – 2182; Tmax (°C): 18.2 – 25.8; Elevation (m): 2 – 926).

The native guava is on a steep trajectory towards extinction. There is one population that survives with <10% of branches killed by myrtle rust infection (Fig. 1b). However, even this population does not produce viable seed. There may be individuals that exhibit some resistance and these need to be identified and monitored.

The consequences of the disease

The invasion of myrtle rust into the Pacific region is pushing the endangered *Eugenia koolauensis* in Hawaii and the threatened *Eugenia gacognei* in New Caledonia to extinction [13]. In Australia it is already realised that numerous tree species other than the native guava are highly susceptible to the disease [8,11]. However these indications are not yet supported by systematic field surveys as provided here. Nursery trials do not necessarily reflect field sensitivities [8] and there is an urgent need to conduct similar field-based assessments throughout the environmental range of Myrtaceae species to determine the magnitude of the threat of myrtle rust. If a large number of species within a large plant family are affected then the impact is globally unprecedented.

The extirpation of native tree species by myrtle rust may alter ecosystem function. The native guava is a pioneer species in disturbed environments and was formerly a common tree in these habitats. This niche is also occupied by the exotic species lantana (*Lantana camara*) in these environments. During drought, lantana provides a ladder-fuel between the ground and the canopy and can render fire-retardant dry rainforest flammable [14]. The loss of native guava and replacement by lantana will increase the flammability of rainforest. More than 100 species of insectivorous pollinators have been associated with *Rhodomyrtus psidioides*, with the invasion by myrtle rust resulting in the local extinction of both the floral resource and disruption of associated plant-insect relationships [15].

To avoid the extinction of species susceptible to myrtle rust e*x situ* populations in locations beyond the environments suitable for myrtle rust may be required. Our data (Figure 1a) suggest that in subtropical areas ‘Myrtaceae rescue forests’ will need to be situated in areas with less than 900 mm mean annual rainfall, and thus require ongoing watering for survival. Individuals and populations exhibiting the greatest resistance (Fig. 1b) should be selected for propagation and may include important genotypes for species survival. Myrtle rust is now recognised as a globally invasive disease [9] and its emergence as a virulent pathogen has primarily resulted from global spread through trade and transport to new environments and naive hosts. These are some of the factors that underpin the predicted increase of fungal pathogens as a threat to biodiversity [7] and myrtle rust may be a harbinger of developing diseases that will provide a particularly pervasive threat to plant diversity with potential to disrupt ecosystem function. A critical step for mitigating disease is too develop a thorough epidemiology of its impact and distribution, and this study identifies a simple technique that should be used to assess a broad range of Myrtaceae species and populations. We also provide an appropriately informed response for the native guava that has undergone pervasive effects of the myrtle rust disease in a remarkably short time span.

Acknowledgements

This study was supported by funding from the Australian Government's National Environmental Science Programme through the Threatened Species Recovery Hub.

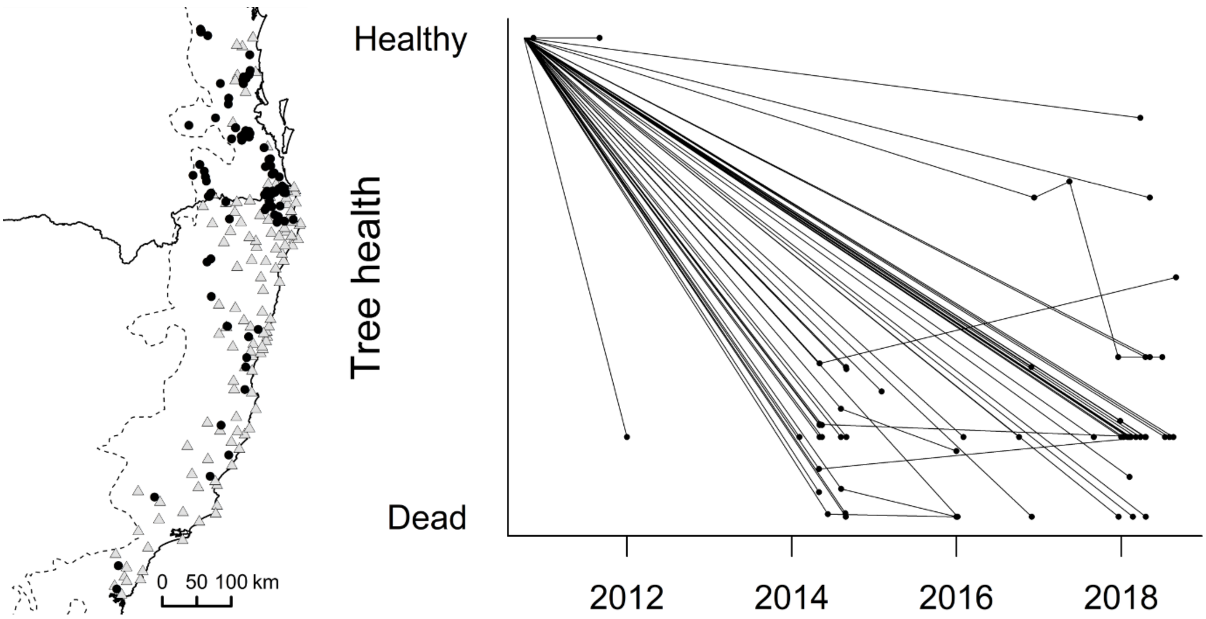

Figure 1. Left panel: Distribution of the native guava (*Rhodomyrtus psidioides*) in NSW and Queensland (black circles), and all other records of myrtle rust from wild populations (grey triangles) with the 900 mm isohyet (dashed line) [12]. Right panel: Population decline of native guava populations since the arrival of myrtle rust in Australia in 2010. We assume that all populations were healthy in 2010 prior to the arrival of myrtle rust [12]. Levels of damage of individual trees in the populations were assessed on a scale from 0, no branches dead; 1, <10% branches dead; 2, 10-50% branches dead; 3, 50-90% branches dead; 4, branches dead; 5, tree branches dead and re-shooting from base; 6, tree entirely dead.

Figure 2 a) Dead stand of native guava (*Rhodomyrtus psidioides*) killed by myrtle rust; b) root sucker of native guava shoot tip infected by myrtle rust; c) healthy flowers of native guava prior to the arrival of myrtle rust in Australia; d) flowers infected by myrtle rust.

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