Puccinia psidii (Pucciniaceae – Eucalyptus Rust, Guava Rust, Myrtle Rust) – a threat to biodiversity in the Indo-Pacific region

R.O. Makinson[1,2] & B.J. Conn[1]

[1]National Herbarium of New South Wales, Mrs Macquaries Road,
Sydney NSW 2000 Australia
bob.makinson@rbgsyd.nsw.gov.au
barry.conn@rbgsyd.nsw.gov.au
[2]Australian Network for Plant Conservation Inc.,
GPO Box 1777, Canberra ACT 2601 Australia

ABSTRACT. A biotype of the South American fungal rust pathogen *Puccinia psidii* Winter has become widely naturalised along the east coast of Australia since early 2010, reaching North Queensland in 2012. This pathogen is known globally as Eucalyptus Rust or Guava Rust, and in Australia as Myrtle Rust. It is pathogenic on a wide range of plants in the Myrtaceae. This pathogen constitutes a major threat to myrtaceous plants in natural habitats and in production systems in moister areas of Australia, and potentially on a wide scale in the Malesian region. The risk of spread to the Malesian region, from Australia or other sources, is high, and once naturalised in Myrtaceae-rich biomes, eradication is unlikely.

Keywords. Eucalytpus Rust, Guava Rust, Myrtle Rust, *Puccinia psidii*, Pucciniaceae

Introduction

In late April 2010, a disease was identified on cultivated specimens of native plants in the family Myrtaceae near Sydney, initially only in a few commercial plant nurseries. The disease pathogen was rapidly identified as an exotic rust fungus, either *Puccinia psidii* Winter (Pucciniaceae, order Pucciniales), or a close relative. *Puccinia psidii*, which is of South American origin and is internationally known as Eucalyptus Rust or Guava Rust, had been regarded for many years as a major potential threat to native Australian and Malesian species of the Myrtaceae if it ever arrived in the region. In Australia, the pathogen was initially regarded as the uredinial morpho-species *Uredo rangelii* J.A.Simpson, K.Thomas & C.A.Grgurinovic, a taxon putatively narrowly distinct from *P. psidii* (Simpson et al., 2006). The name *Uredo rangelii* was widely used for the Australian outbreak during 2010–2011. Subsequent genetic studies have concluded that this pathogen is a biotype of *Puccinia psidii* (Carnegie & Cooper, 2011; Carnegie et al., 2010; Pegg et al., 2013, 2014) and this is now the scientifically recognised name for the pathogen that is present in Australia, with Myrtle Rust being the vernacular name that is in wide use. Much of the electronic and printed material on the Australian incursion dating from 2010–2012 used the name '*Uredo rangelii*'.

The change of preferred scientific name does not invalidate that literature in most other respects, although host-lists and range reports from that period are now greatly outdated. In this paper, we use the term Myrtle Rust for the variant (biotype) present in Australia, and the composite term Eucalypt/Guava Rust for the total species (*Puccinia psidii*) of which it is part. Note that Myrtle Rust is not to be confused with 'Myrtle Wilt'; a fungal disease of Myrtle Beech (*Nothofagus cunninghamii* (Hook.) Oerst., Nothofagaceae) caused by the pathogen *Chalara australis* J.Walker & G.A.Kile (Smith, 2004).

Myrtle Rust was initially known only from nursery and cut-flower production facilities, and eradication was attempted (Cannon, 2011; Carnegie & Cooper, 2011), with infected stock being traced and destroyed. However, by October 2010 there were many reports along the New South Wales coast, most resulting from human movement of infected plant material, and the first reports of naturalisation. In late December 2010 the pathogen was deemed to be ineradicable and the emergency response was discontinued. In 2011, the disease naturalised along the east coast of Australia from southern New South Wales to south-eastern Queensland, and has since spread north as far as Cooktown in northern Queensland. Outbreaks have occurred in the southern State of Victoria since late 2011, mainly in and around Melbourne; the disease is now regarded as endemic in that State but, to June 2014, occurrences there remain confined to plants in open cultivation and to plant production and distribution facilities and it has not naturalised in natural vegetation (D. Smith, Victorian Department of Environment and Primary Industries, pers. comm. June 2014).

This paper briefly reviews the biology, ecology and global spread of this pathogen, its host range, field recognition and symptoms, effects on individual hosts, implications for conservation, and the available management guidelines, information and training resources.

Potential scale of the problem

In the early stages of contingency planning for *Puccinia psidii* a national scoping document (Commonwealth of Australia, 2006) rated it as "one of the most serious threats to Australian production forests and natural ecosystems ... It has a potential to cause direct mortality in the estimated 10% of all Australian native forest plant species (and the great majority of dominant species) that belong to the family Myrtaceae, and with indirect effects that may include habitat loss for native fauna and flora, retarded regeneration and recruitment of younger trees and successional species, greater impact of fire, and abiotic effects as a result of canopy decline including erosion, reduced water quality, reduced water retention in soil and vegetation and potentially large losses through lost production to the forestry industry." In the later National Contingency Plans (Plant Health Australia, 2008, 2009), the pathogen was assessed as having a high potential for entry into Australia, a high establishment potential, a high-to-extreme spread potential, a high environmental impact, and a high-to-extreme economic impact. It was stated that "The climate in Indonesia and Papua New Guinea is expected to be very hospitable for *P. psidii*" (Plant Health Australia, 2009, p. 73 & Fig. 4), based on the predictive map of Magarey et al. (2007) which used broad climatic factors (temperature and rainfall) to indicate that most of New Guinea and Indonesia are potentially suitable for the establishment of *Puccinia psidii*.

Most pre- and post-arrival impact assessment and planning for Australia has been by primary industries organisations (Cannon, 2011; Nursery & Garden Industry Australia, 2012; Plant Health Australia, 2009; Tommerup et al., 2003), with an emphasis on horticultural and forestry systems. Planning and assessment for natural biodiversity has lagged behind badly, although given some attention by Glen et al. (2007), NSW Office of Environment and Heritage (2011); NSW Scientific Committee (2011); Pegg et al. (2013). Planning and impact assessment has been hampered by inadequate taxonomic and epidemiological knowledge for the several to many variants of *Puccinia psidii*, and by an unavoidable early reliance on mainly South American data regarding host range and climatic tolerances.

Global spread of Eucalypt/Guava Rust (*Puccinia psidii*)

The presumed origin and centre of diversity of *Puccinia psidii* is in Brazil and Uruguay (South America). In this region, the effects are usually mild on native host species (Glen et al., 2007; Pérez et al., 2011). The pathogen came to notice through its sometimes severe effects on crop species of Myrtaceae that are not native to the region, including species of *Psidium* L. (Guava) and *Eucalyptus* L'Hér. *sens. lat*.

In the first half of the twentieth century *Puccinia psidii* spread to the Caribbean, where the allspice industry (*Pimenta dioica* (L.) Merr.) was severely damaged. In 1977, a variant arrived in Florida (U.S.A.), where among other hosts it attacked the Australian species *Melaleuca quinquenervia* (Cav.) S.T.Blake, a naturalised woody weed of the Everglades.

In 2005 a variant arrived in Hawaii, and within a year had spread to nearly all the Hawaiian Islands, where it is now known as Ohia Rust. Its effects have been severe on one native Hawaiian species, the already endangered *Eugenia koolauensis* O.Deg., with "a very high proportion" of plants killed (Cannon et al., 2010, p. 47). It has affected some naturalised non-Hawaiian Myrtaceae, especially Rose Apple, *Syzygium jambos* (L.) Alston (Loope, 2010).

In 2007 Eucalypt/Guava Rust was reported from Japan (Kawanisihi et al., 2009), where it may have since been eradicated, in 2011 from Hainan, China (Zhuang & Wei, 2011), and in 2013 from New Caledonia (Giblin, 2013) and South Africa (Roux et al., 2013).

In Indonesia, Hardiyanto & Tridasa (2000) report a '*Puccinia* sp.' rust disease on sapling eucalypts in 1998 during forestry trials in Kalimantan and Sumatra. The host eucalypts were hybrids developed in China but involving parent stock from Brazil. The disease seems to have died out at these sites and has apparently not been confirmed as *Puccinia psidii*.

The mode of arrival in Australia is not known, and the plant nursery sites where it was first reported seem not to have been arrival sites.

On the Myrtaceae

The Myrtaceae has its centre of diversity in the Australasian region, where it is structurally and floristically dominant in many ecosystems, and ecologically significant in many more.

Australia has about 2,253 native species of the family Myrtaceae in 88 genera (B. Lepschi, Australian National Herbarium, pers. comm., Aug. 2010). Myrtaceae comprise about 10% of Australia's native flora. Roughly half the Australian species occur in the climatic zones likely to be most conducive to Eucalypt/Guava Rust.

The Malesian region has a less speciose and less generically diverse myrtaceous flora than Australia, but the family is still very well-represented. Comprehensive data are lacking, but exemplar numbers are available for some areas. New Guinea and the Solomon Islands have about 300 species in 28 genera (Höft, 1992). A similar number of myrtaceous species, in about 30 genera, occur in Indonesia (Craven et al., 2003), with 26 species, in 6 genera in Central Kalimantan (Campbell, 1999). 216 tree species, in 9 genera are recorded for Peninsular Malaysia (Kochummen, 1978), and more than 205 species, in 14 genera in Sabah and Sarawak (Malaysia) (Ashton, 2011).

The Indo-Pacific region as a whole is very depauperate in rust fungi that parasitise Myrtaceae (Walker, 1983). In this region, nearly all rusts on Myrtaceae are, or are likely to be, of introduced (non-native) origin. Only two rusts on myrtaceous plants are known to occur naturally in Australia and both are rare (Simpson et al., 2006). Walker (1983, pp. 116 & 117) reports "two unconfirmed records from India of *Melampsora* … on two introduced Australian species of *Eucalyptus*". As a result of the near-total isolation from myrtaceous rusts, the Myrtaceae of the region are thought to be epidemiologically 'naïve' to these pathogens, with no co-evolved defences. However, resistance of various sorts may exist through autochthonous traits.

Biology and ecology of *Puccinia psidii*

Taxonomic and pathotypic knowledge of *Puccinia psidii* is still incomplete, but there appear to be several biotypes, all of which infect only plants of the Myrtaceae. These biotypes may differ in host preferences, severity on different hosts, and environmental tolerances.

The life cycle of *Puccinia psidii* is described in Glen et al. (2007), and, with some new information, in Morin et al. (2014). In brief, *Puccinia psidii* is functionally autoecious (it can complete its life cycle on a single host plant), and hemicyclic (no spermogonia and aecia ever observed – Glen et al. (2007), but see Morin et al. (2014) for qualifications). The asexual uredinial life cycle can be completed an indefinite number of times and produces infective urediniospores in great numbers (e.g. Uchida

& Loope, 2009). The uredinial cycle may take as little as 10 days from infection to sporulation under suitable conditions. Urediniospores disperse readily by wind, by animal vectors, and through human movement of infected material. At least some variants, including the one in Australia, also produce sexual teliospores, which are fewer, larger, and less mobile, but may allow adaptive variation (Glen et al., 2007), although their functionality in the life cycle of the Australian variant is uncertain (Morin et al., 2014).

Both the germination and pustule growth stages of the pathogen require susceptible host species, suitable tissues (typically new leaves and very young stems), and favourable ambient conditions. The spore germination stage requires wet leaf surfaces at night within a suitable temperature range. Both germination and pustule formation require moderate temperatures, usually cited (e.g. Glen et al., 2007) as 13–22(–25)^{o}C based on South American data. However, there are indications that, in the Myrtle Rust variant, pustules may still form at lower temperatures (albeit at lower frequency), with early winter overnight minima as low as of 8^{o}C (G. Guymer, Queensland Herbarium, pers. comm. 2011) or even 2–5^{o}C (D. Smith, Victorian Department of Primary Industries, pers. comm. June 2012).

In Hawaii, *Puccinia psidii* "has been found statewide … attacking Myrtaceae from near sea level to elevations of about 1200 m in areas with rainfall ranging from 750–5000 mm" (Loope, 2010, pp 1 & 6). In Australia, occurrences of sporulating Myrtle Rust from higher elevations have been recorded at 600 m (Canberra, latitude 35^{o}S); 1000 m (Mount Tomah, NSW, 33^{o}S); 700 m (Toowoomba, Queensland, 27.5^{o}S), and c. 1000 m (Mt Hypipamee National Park, Queensland, 17.4^{o}S).

Urediniospores are very light and very mobile in the air column. There is a noticeably high incidence of infections starting on the lower surface of leaves, only later penetrating to the upper surface. Nursery inspection strategies need to take account of this.

Some South American data (Zauza et al., 2010b) suggest a gradient of infection frequency with height in plantations of eucalypt saplings, attributed to higher spore loads lower in the air column, and to the upper canopy being drier at night compared to lower leaves and hence less conducive to spore germination. Several South American studies suggest lower levels of infection in mature eucalypts, even on seasonal new growth, as opposed to juvenile (sapling stage) plants.

The hyphae of germinating spores penetrate the plant though the waxy cuticle, not through the stomates as with some other rusts (K. Old in Cannon et al., 2010; Hunt, 1968). Initial symptoms can appear within 5–7 days of infection. The whole uredinial reproductive cycle can occur in 10–12 days in warmer months, and depending on the initial number of infection sites a massive outbreak of pustules with a very high new spore load can develop very quickly. The cycle slows or stalls in cold months at temperate latitudes.

Spore longevity is generally cited (often following Glen et al., 2007) as 90 days for reduction to low levels of viability, but probably varies greatly with ambient conditions. Lower longevity occurs at temperatures >30^{o}C. Salustiano et al. (2008) report the survival levels of spores under various storage conditions, noting that spores in deep-freeze and liquid nitrogen storage maintained significant levels of viability at 150 days. Although timber and pulp production facilities were likely to receive spores in "very low numbers, the adverse environmental conditions encountered in these areas and during overseas transport do not favour spore survival. Thus, the risk of spread of this pathogen into new areas in the absence of infected host plants is considered extremely low to inexistent" (Lana et al., 2012, p. 1). This finding is inconsistent with the report of Grgurinovic et al. (2006) that viable spores were detected on a wood shipment to Australia from South America. Further study of longevity is required to enable general and specific risk assessments, including for seed-banks handling potentially contaminated seed-lots. Long-distance transmission to new areas via spore loads on human clothing and equipment (e.g. hats, rucksacks, tents) is distinctly possible (Tommerup et al., 2003).

Phylogeny and taxonomy of the pathogen

Separate lines of DNA investigation confirm that *Puccinia psidii* is phylogenetically misplaced in genus *Puccinia* and the family Pucciniaceae (van der Merwe et al. 2008; Pegg et al., 2013; Tan et al., 2014; E. Liew et al. unpublished data, pers. comm. June 2014). Its affinities within the order Pucciniales are as yet unresolved.

Host species taxonomic range

Since the arrival of *Puccinia psidii* in Australia, over 300 native taxa (>10% of the total Australian Myrtaceae) have been recorded as hosts of the pathogen, either in field situations (wild or cultivated), or under laboratory test conditions (for Australian State host lists, see below; Carnegie & Lidbetter, 2011; Morin et al., 2012). The number of hosts is expected to increase further. Based on field studies, almost 45% of the Australian myrtaceous genera (51 out of 88, see Appendix) have one or more species known to be susceptible, affecting almost all Myrtaceae tribes represented in Australia (14 tribes out of 17).

Separate but overlapping lists of Australian hosts have been maintained by the Australian States in which Myrtle Rust currently occurs, and are accessible via links from Plant Health Australia (2012); these lists are however not fully up to date as at June 2014. Consolidated and up to date global and Australian host lists are now (October 2014) available on-line (Giblin & Carnegie 2014a, b).

There is no clear phylogenetic pattern of host susceptibility, with wide variation in apparent susceptibility of species within genera, and sometimes within species. Susceptibility may vary with host genetic factors (resistance of a species or individual plant), host physiological and stress factors, growth stage, and environmental factors including host density, local spore load, and suitability of conditions for spore germination and pustule growth. Severity ratings are as yet tentative and, to date, are only being gathered and published by the Queensland Department of Agriculture, Fisheries and Forestry.

Syzygium jambos is very susceptible in both Australia and Hawaii, with young leaves, flower buds and petioles all prone to conspicuous levels of pustule formation (Fig. 1). This makes it an excellent indicator species, but also a prime source of local spore load if not dealt with promptly.

It is likely that several of the Australian native host species will undergo severe decline over time as a result of repeated cycles of infection by *Puccinia psidii*, and that some species not currently regarded as threatened with extinction will become so – this is already evident for the hitherto common mesic shrubs *Rhodomyrtus psidioides* (G.Don) Benth. and *Rhodamnia rubescens* (Benth.) Miq. (A. Carnegie & G. Pegg, unpublished data, pers. comm. March–May 2014). Some of the more susceptible species are important floristic elements in native ecological communities, and their decline may have a pronounced effect on those communities. The high susceptibility of new growth on *Melaleuca quinquenervia* (Cav.) S.T.Blake, *M. leucadendra* (L.) L. and *M. viridiflora* Sol. ex Gaertn. is of great concern, given the extensive floodplain and riparian associations in which they occur in northern Australia.

The potential long-term effects on eucalypts are unclear. Some 80 eucalypt taxa, not counting hybrids, are recorded as susceptible - 69 taxa in *Eucalyptus*, eight in *Corymbia*, and three in *Angophora* (A. Carnegie, G. Pegg, F. Giblin unpublished data, pers. comm. March 2014; Morin et al., 2012). However, in *Eucalyptus* itself a majority of these records are from experimental laboratory trials, including on non-eastern Australian species, and only a minority have infection confirmed in the natural environment. No eucalypts are regarded as highly susceptible at this point, but there is a lack of observations for nearly all species on the critical life stages of seedlings and coppice growth (e.g. post-fire epicormic shoots). Infection of cotyledons in cultivated seedlings of *Eucalyptus planchoniana* F.Muell. resulted in death of the whole batch (Pegg et al., 2013). This suggests a potential for high mortality during the seedling phase of susceptible eucalypts subjected to high rust spore loads in conditions favourable for spore germination.

Field recognition of *Puccinia psidii*

Puccinia psidii is not known to utilise as host any plants other than members of the Myrtaceae (including Heteropyxidaceae). Suspected occurrences of *Puccinia psidii* should be reported as soon as possible to national and local biosecurity authorities and lead conservation agencies. The initial report should be accompanied, if possible, by digital photographs of the symptoms and of the host plant, the latter showing enough features to enable identification. Australian diagnostic services may be able to assist (biosecurity@industry.nsw.gov.au or www.daff.qld.gov.au/4790_20842.htm – for phytosanitary reasons, send photographs only, *not* samples). Laboratory confirmation of the pathogen may be needed.

For images of the various stages of *Puccinia psidii* infection on a variety of host species and tissues, refer to Plant Health Australia (2012) for links to websites maintained by the Australian State governments of New South Wales, Queensland and Victoria. Early symptoms of infection, small purplish or brown-grey lesions, are not obvious and are difficult to distinguish from other minor damage; they typically occur on new stem and leaf tissue, but also on soft fruits and parts of inflorescences in some hosts. Leaf infections often start on the lower surface, penetrating to the upper surface in 2–4 days. Within a few more days sporulating pustules develop.

The sporulation (pustule) stage is the easiest to recognise. By the time this stage is obvious, spores are ready to disperse – handling and disposal of plants at this stage can easily spread the spores unless strict protocols are followed. The most prolific form is the uredinial pustule, typically bright yellow or yellow-orange (Fig. 1, 2). Less common are light- to mid-brown telial pustules, producing sexual teliospores.

After the spore masses have dispersed, the effects on the plant may remain obvious (e.g. dead shoots, defoliated new stems, distorted new stem structure and overall habit) but are not easy to attribute definitely to being a *Puccinia psidii* infection in the absence of pustules.

Effects of infection

The effects of severe infection may include a loss of new seasonal or regenerative growth, some loss of photosynthetic capability, loss of some or all reproductive capacity if flowers or fruits (soft-fruited species) are infected or if flowering can only occur on new growth, exhaustion of growth potential, and death or retardation of seedlings and juveniles. Whole plant death is known in plantations of some eucalypt and other species in South America after repeated infection cycles. Whole-plant mortality in Australia has, so far, mainly been seen in some seedlings, nursery stock, and new bush regeneration plantings, but is now increasingly seen in naturally occurring plants of the highly susceptible *Rhodamnia rubescens* and *Rhodomyrtus psidioides.*

Repeated infection cycles on highly susceptible hosts may cause decline in population size or density, with effects on pollination systems and gene flow. Animals dependent on myrtaceous species may be affected. Regional or total extinction of very susceptible species is possible, as are structural and ecological changes in vegetation communities and faunal assemblages.

Climatic & geographic prediction modelling

Predictive modelling has been limited, and largely dependent on matching South American climatic, microclimatic and epidemiological data (often from plantation conditions and of uncertain *Puccinia psidii* biotypes) to Australian and Melanesian bioclimatic profiles.

Fig. 1. Uredinial pustules of *Puccinia psidii* on new growth of cultivated *Syzygium jambos* (Rose Apple), Brisbane, Queensland, Sept. 2011. (Photo: R.O. Makinson)

Booth et al. (2000) produced a preliminary assessment of high risk areas for the Northern Territory, Queensland and New South Wales. A revised continental risk-predictive map by Booth & Jovanovic appeared in Glen et al. (2007) (as a pers. comm.; refer Booth et al., 2000, and Booth & Jovanovic, 2012 for the methodology used to develop map) and was reproduced in Plant Health Australia (2009). The latter publication also featured an alternative map (p. 14) by R. Magarey that includes

Fig. 2. Uredinial pustules of *Puccinia psidii* on hypanthium and ovary summit of *Rhodomyrtus psidioides* (Native Guava), Wamberal Nature Reserve, New South Wales, Dec. 2010. (Photo: R.O. Makinson)

Australia, New Guinea and most of Indonesia, taken from a global risk analysis (based on distributions in South and Central America) later published as Magarey et al. (2007). The Malesian zones on this map are assessed as having a very high likelihood of permanent Eucalypt/Guava Rust establishment. Elith et al. (2012) developed a model for investigating the differences in distribution of artificially grouped locations in Australia that they deemed represented different strains of the rust.

The most recent modelling, of relative climate suitability for *Puccinia psidii* at global and Australian scales, is that of Kriticos et al. (2013). This shows most of Malesia and parts of mainland South-east Asia as having moderately to highly suitable climatic parameters for the permanent establishment of *Puccinia psidii*, assuming favourable local climatic regimes and the presence of susceptible host species.

Impact assessment and management guides for production systems

The most comprehensive management guide available for the horticultural sector is the *Australian Nursery Industry Myrtle Rust Management Plan* (Nursery & Garden Industry Australia, 2012). This contains detailed monitoring, biosanitation, and fungicide treatment protocols for production and wholesale/retail 'greenlife' facilities. This Plan is also applicable to forest nurseries and to some plantation situations.

Short management guidelines for various situations in the Australian context, including domestic and rural properties, and for industries based on the myrtaceous oils and foodstuffs, are available via the Queensland and New South Wales primary industries department websites (Plant Health Australia, 2012). The *New South Wales Road Transport Authority Biodiversity Guidelines* provide model procedures for reducing the risk of spread by utilities providers and contractors (NSW Roads and Maritime Services, 2011).

A broad assessment of the potential impact of this disease on the Australian commercial forestry sector is provided by Cannon (2011), who comments that long-term effects will depend partly on whether other strains of Eucalypt/Guava Rust are introduced. Carnegie et al. (2010) and Pegg et al. (2014) provide details of methods used for rapid screening of (eucalypt) forestry species for susceptibility. Some recent research projects funded by the Australian Government have a bearing on resistance in the production context (publications pending by: B. Thumma *et al*., CSIRO Plant Industry, resistance genes in eucalypts; C. Kulheim *et al*., Australian National University, genetic markers for resistance in non-eucalypt Myrtaceae, and metabonomic responses to infection; K. Sandhu & R.F. Park, University of Sydney, genetic basis of pathogenicity; M. Horwood, University of Sydney, chemical control).

A considerable literature, mostly from South America, exists for the eucalypt plantation forestry sector, including research on pathotypes, resistance genetics, and resistance breeding – key recent papers, with more or less extensive reference lists, are da Silva et al. (2014), Graça et al. (2011), Mamani et al. (2010), Martins et al. (2011) and Zauza et al. (2010a). A consolidated interim global bibliography for *P. psidii* (Makinson 2014) is now available on-line, although still incomplete for South America.

Prescriptions for the assessment of impact and the management of *Puccinia psidii* in forestry and in the wild are at an early stage of development in Australia. The impacts of the pathogen, and the (limited) options for its management, are gradually becoming apparent. There is a time-limited opportunity, especially in those susceptible areas not yet infected by Myrtle Rust, to gather baseline data and to establish long-term monitoring. In the absence of any likely biological control, effective management in extensive Myrtaceae-rich systems of a multi-vector disease with such a wide host range is inherently problematic.

Impact assessment and management guides for wild biodiversity

Impact assessment for Australian native (*in situ*) biodiversity has been slow in developing, and only sparse, mostly qualitative data are available. One early assessment with some national applicability, is for the state of New South Wales (NSW Scientific Committee 2011). Work in progress by G. Pegg (Queensland Department of Agriculture, Forestry and Fisheries) and A. Carnegie (New South Wales Department of Primary Industries) on a few wild species represents the main organised research on the impacts on natural species to date. They report (pers. comm. May 2014) severe declines in seasonal growth, reproductive capacity and recruitment in the mesic shrubs *Rhodomyrtus psidioides* and *Rhodamnia rubescens*.

There are no 'good' management solutions for Myrtle Rust infection in natural vegetation. Fungicidal treatments are rarely possible on the scale needed and have unwanted effects on other biodiversity. Physical removal of susceptible species is usually ineffective and too expensive except in small areas, and may be incompatible with conservation management objectives. However, such a strategy may have value (e.g. along high-use tracks) in reducing spore load on visitors likely to then travel to rust-free zones. Fire is unlikely to be an effective control given the potential for re-infection and the preference of the rust for new growth.

The likely behaviour of Myrtle Rust in relation to local floristic composition and recruitment, microclimate, disturbance (especially fire), and regeneration is not known. In climatically marginal areas, or where highly susceptible host species are lacking (or die out), infections in natural vegetation may be transitory or seasonal.

Some first-generation bushland policy/management documents are now available, including NSW Office of Environment and Heritage (2011). Summary advice for minimising arrival risk and impact on natural plant communities, including hygiene protocols, is available as brochures and webpages (refer the Australian government primary industries sites of affected States: Plant Health Australia 2012).

Conclusion

Puccinia psidii poses a significant threat to the Myrtaceae flora of the Malesian and Australasian regions, and to at least some ecological communities. It is understood that some level of regional information exchange has been developed through primary industries and quarantine agencies. It is highly desirable that this be formalised and expanded to include environmental organisations (government and non-government), and other stakeholders.

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Appendix. Host genera of Myrtle Rust (Puccinia psidii) in Australia, to 22 June 2014.

Legend: ***Bold*** = one or more species of genus infected in wild or in cultivation; *underlined* = infectivity in one or more species of genus by artificial inoculation under laboratory conditions only (Morin et al., 2012); * = genera entirely exotic to Australia; **† =** genera native to Malesia. Generic recognition follows Wilson et al. (2005) note that some other published lists follow differing lists of recognised genera. Unpublished data courtesy of J. Lidbetter and A. Carnegie (New South Wales Department of Primary Industries), F. Giblin (University of the Sunshine Coast), and G. Pegg (Queensland Department of Agriculture, Forestry and Fisheries). Note that susceptibility of a species in a genus does not necessarily imply susceptibility of all congeners. ***Acmena, Acmenosperma, Agonis,*** *Allosyncarpia,* ***Anetholea, Angophora, †Asteromyrtus, Austromyrtus, Backhousia,*** **†***Baeckea*, ***Barongia,*** *Beaufortia,* ***Callistemon, Calothamnus,*** *Calytrix*, ***Chamelaucium, Choricarpia, Corymbia, Darwinia, †Decaspermum, †Eucalyptus, †Eugenia, †Gossia, *Heteropyxis, Homoranthus, Hypocalymma,*** *Kunzea,* ***Lenwebbia, †Leptospermum, †Lindsayomyrtus, Lithomyrtus, Lophomyrtus, †Lophostemon, †Melaleuca, †Metrosideros, Mitrantia,*** *†**Myrciaria**, *Myrtus, †Osbornia, Pilidiostigma,* ******Pimenta*, ***Plinia,*** ***†***Psidium*, *Regelia,* ***†Rhodamnia, †Rhodomyrtus, Ristantia, Sphaerantia, Stockwellia, Syncarpia, †Syzygium,*** *Thryptomene*, ***Tristania, †Tristaniopsis, *Ugni, †Uromyrtus,*** *Verticordia*, ***Waterhousea***, ***Xanthostemon***.