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Rapid Communication

Recent discovery of small naturalised populations of *Melaleuca quinquenervia* (Cav.) S.T. Blake in South Africa

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Abstract

The discovery of a naturalised population of *Melaleuca quinquenervia* in South Africa in 2009 prompted an evaluation of the species' distribution across South Africa. We found records at seven localities in two of the nine provinces of South Africa, with naturalised populations at two sites — ~300 plants were discovered over 0.3ha in a confined-seep on a mountain slope, while at an old arboretum 12 large, planted trees and 9 naturalised trees were found. An additional herbarium record from Mozambique suggests that this global invader is present at other sites within the sub-region, and so while the extirpation of populations in South Africa is recommended and looks feasible, further work is required to determine the status and evaluate whether eradication from the sub-region as a whole is possible.

Key words: early detection, eradication, invasive tree, Myrtaceae

Introduction

The publishing of new records for naturalised and potentially invasive tree species is important for a number of reasons (Wilson et al. 2014). It helps inform risk assessment and allows for appropriate response planning and for rapid information dissemination (Lucy and Panov 2012). This helps in the compilation of lists of invasive species which are widely used by scientists, managers and policy makers. These lists can, however, be prone to a range of errors (McGeoch et al. 2012), highlighting the importance of publishing accurate records for introduced species.

Melaleuca quinquenervia (Cav.) S.T. Blake, the broad-leaved paper-bark, is a tree (up to 25 m tall) native to eastern Queensland and New South Wales in Australia, and to parts of Indonesia, New Caledonia and Papua New Guinea (Blake 1968; Serbesoff-King 2003). In its native range, it typically occurs in coastal wetlands that are temporarily inundated, along freshwater stream banks and in brackish water adjacent to mangrove swamps (Turner et al. 1998).

The species has been widely disseminated throughout the world mostly as an ornamental species, but occasionally to aid with draining wetlands (in particular in the United States of America). It is known as invasive in the Americas and on islands in the Pacific and Caribbean, but has not previously been recorded as naturalised in Africa (Rejmánek and Richardson 2013) (definitions for naturalised and invasion are as per Blackburn et al. 2011). It is most notorious as a transformer species (*sensu* Richardson et al. 2000) of the Florida Everglades of the United States, where, by 1998, it had invaded an estimated 202 000 ha (Turner et al. 1998; Dray et al. 2006; Martin et al. 2009; TAME 2014). Plants form extensive monocultures that exclude native vegetation and provide large fuel loads for fires, leading to substantial ecosystem level impacts. Between 1989 and 1999 the US government spent US$ 25million on controlling the species (Serbesoff-King 2003).

Table 1. Records of *Melaleuca quinquenervia* from southern Africa (also see Figure 1), with invasion status as per Blackburn et al. (2011). None of the populations can be definitively classed as fully invasive (E under the Blackburn scheme). While the source of both the Wolseley and Krantzkloof plants is not known, at neither population has dispersal to and reproduction at multiple sites been recorded.

Site	Population size	Status	Landscape context	Herbarium specimens
Durban Botanical Gardens, Kwa-Zulu Natal S29.84585 E31.00601	One tree	B2, planted	Botanical gardens in an urban setting	NH-72446 (BJ Pienaar 345),
Krantzkloof Nature Reserve, Kwa-Zulu Natal S29.76243 E30.85594	Unclear, one plant found on resurvey	Probably D1–E, not planted, presumed naturalised	Nature reserve in a valley surrounded by urban areas	M. Cheek 946
Paarl Arboretum, Western Cape S33.85710 E18.49742	2 large adult trees	B2, planted	Arboreta in an urban setting, but with opportunities for recruitment	none
Tokai Arboretum, Western Cape S34.05745 E18.42323	12 mature very large individuals in rows (> 73 cm stem diameter); 9 juveniles (3-4 m high) recruited, flowering and producing seeds	C2 or C3, naturalised	Picnic site adjacent to the oldest arboretum in South Africa	NBG-269274 (M Tywalana 64)
Wolseley, Western Cape S33.43422 E19.14405	~300 mature individuals over 0.28 ha	C3 or D2, source unknown, naturalised	Previously commercial forestry land, 570 meters above sea level	NBG-0262932 (E van Wyk 2)
Durban, KwaZulu-Natal, no specific locality given	Unknown	Unknown	Urban setting (uncertain)	NH-41052
Durban, KwaZulu-Natal, Pine Town, Bamboo Lane S29.8206 E30.8692	Unclear, presumed to be 1 plant in 1982. Survey required	B2 or B3, presumed planted	Urban setting	NH-75265 (AM Rowe s.n.), NH-39297
Ponta Barra Falsa/Pomene, Mozambique Coordinates undetermined	Unclear, adults and seedlings present. Survey required	C3 at least, potentially E	In and around a wetland	PRE-855502

In May 2009, a small population of *M. quinquenervia* was found by a field ranger in a moist seep in the mountains near the town of Wolseley in the Western Cape Province of South Africa. Given the species' history of invasiveness elsewhere, it was deemed to be of high risk and was prioritized for further evaluation and management (van Wyk et al. 2011). Here we document the localities and their invasion stage in South Africa (and southern Africa more broadly), explore possible introduction histories and conduct a qualitative assessment of risk.

Methods

Determining current distribution in South Africa

Publicity leaflets were developed and 1000 were distributed (Appendix 1) as part of a country-wide survey strategy. We targeted land managers (mainly conservation and forestry) and invasive plant researchers (at national workshops and conferences) as a basis for knowledge of where these plants may be. In addition to these publicity efforts, we searched for records of the species in herbaria (Table 1), with specimens confirmed as *M. quinquenervia* by the *Melaleuca* taxonomic authority in Australia (B. Lepschi, pers. comm.). Table 1 lists the records that we found and indicates the invasive status of each instance. In a national survey of tree collections, respondents have been asked to specifically submit historical and current records of *Melaleuca* plantings (including *M. quinquenervia, M. styphelioides* and *M. parvistaminea*). To determine and understand the introduction history of *M. quinquenervia* at each site, we reviewed historical records and interviewed relevant land managers.

At Wolseley we conducted systematic surveys of the area in 2009 and in 2012 to determine the extent of the population. This was done by walking parallel transects using a handheld GPS (Figure 2) and recording any plants that were

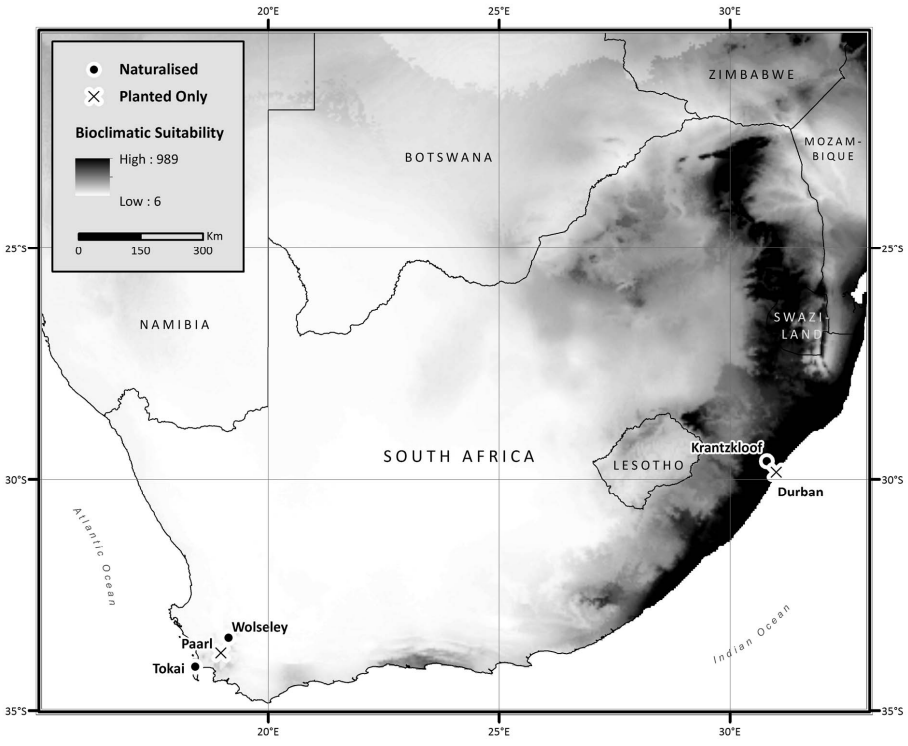

Figure 1. Known records of *Melaleuca quinquenervia* in South Africa indicating planted or naturalised status at each location. The predicted climatically suitable range of the mean consensus of models run in BIOMOD is indicated by the shading (darker areas are more suitable).

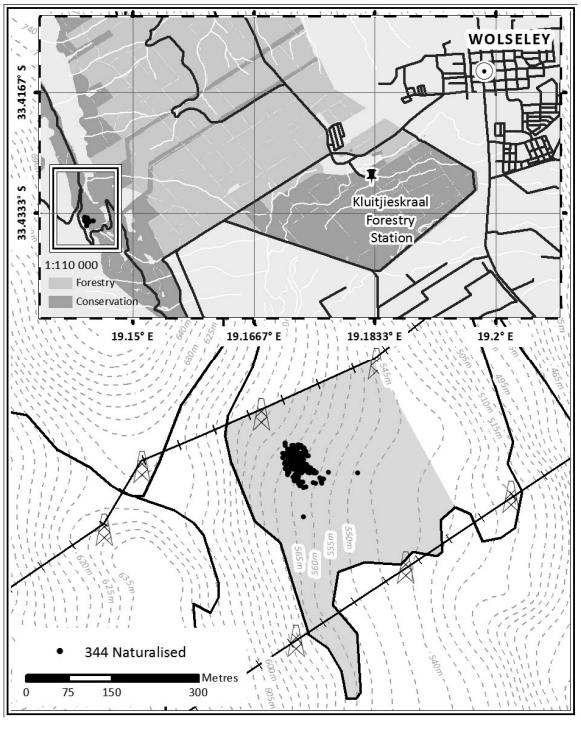

Figure 2. Distribution of the largest known population of *Melaleuca quinquenervia* at Wolseley, Western Cape. Grey shading indicates the area that was surveyed.

found. At Tokai, we searched for recruitment in an area around the planted trees (Figure 4). To further delimit the extent of the two naturalised populations, we investigated likely dispersal pathways, i.e. along watercourses.

Invasive potential and risk assessment

To assess the potential invasiveness of the species in the region, different bioclimatic models were developed using BIOMOD (Thuiller 2003). All BIOCLIM variables (http://www.worldclim.org/bioclim) were used with an aspect of 2.5 arc minutes resolution (4.6 km × 4.6 km). Native range localities were selected from Australia's Virtual Herbarium (http://www.avh.ala.org.au), and the Global Biodiversity Information Forum (http://www.gbif.org). For projection onto South Africa, both naturalised (Table 1) and native range localities were used.

To collate species information, determine invasive potential and identify areas requiring more research, the Australian Weed Risk Assessment (WRA) (Pheloung et al. 1999) was used. This WRA has been applied widely and is reported to be consistently accurate (Gordon et al. 2008, 2010; Hulme 2012). It also provides a standard method for collating information on potential impacts.

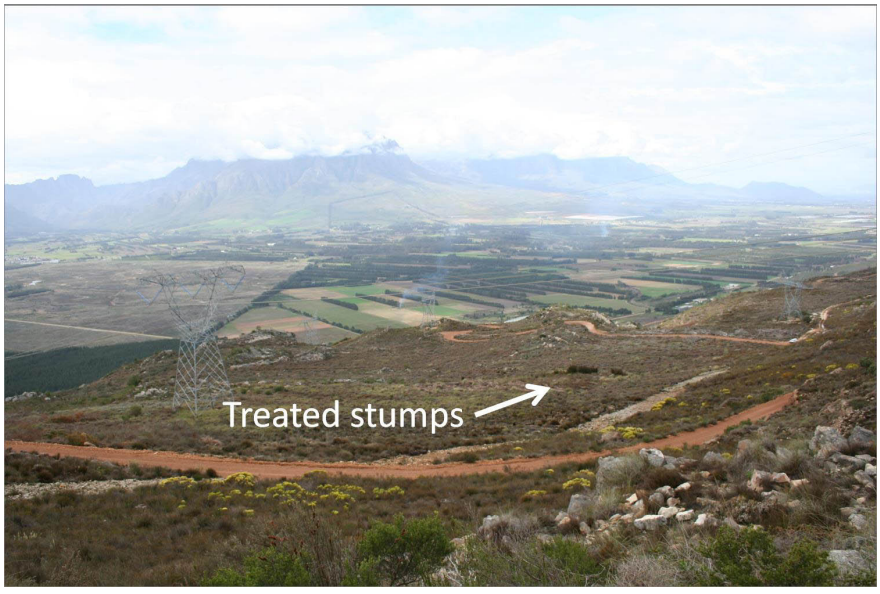

Figure 3. Contextual landscape setting indicating the situation of the treated stumps of the *Melaleuca quinquenervia* population on a fynbos mountain slope above Wolseley in the Breede River valley. The main land uses in the valley are for agriculture and silviculture. Photograph by John Wilson.

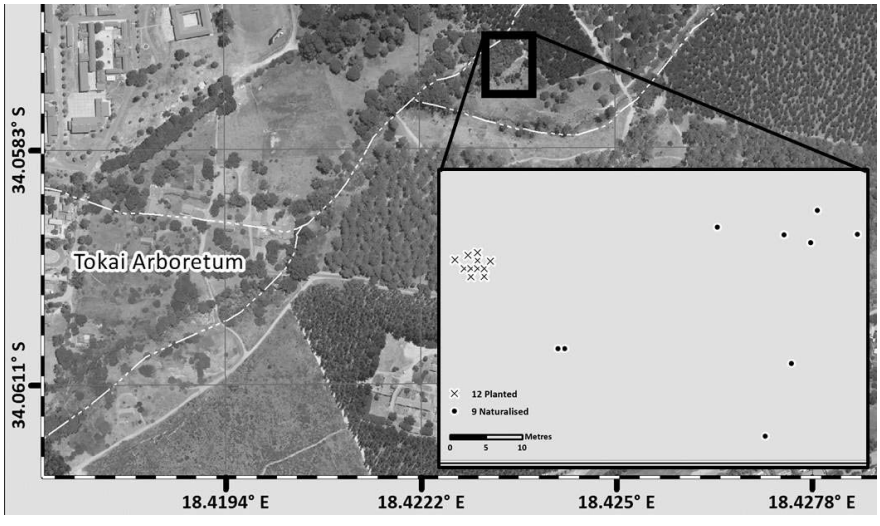

Figure 4. The naturalised population at the Tokai plantation in Cape Town, Western Cape, indicating proximity to the arboretum and surveyed area in grey (inset).

Results

Determining current distribution in South Africa

Of the eight records we found, naturalised populations occur at Tokai and Wolseley in the fynbos region of the Western Cape, Krantzkloof (Durban) in the subtropical KwaZulu-Natal province of South Africa and in the tropical Mozambique (Table 1). The herbarium specimen collected in Mozambique stated that the species was naturalised. No records were reported through leaflet (Appendix 1) distribution.

The naturalised populations at Tokai (Figures 4, 5) and Wolseley (Figures 2, 3) were not very extensive, 21 and ~ 300 plants respectively (Table 1). At Krantzkloof, apparently the reserve managers had identified *M. quinquenervia* as being problematic in the early 2000s and over three field seasons had made a concerted effort to eradicate it from the area (J. Vermeulen, pers. comm.). A complete survey of the area is still required to assess the success of the control operations and the possible introduction routes by which the plant arrived in the area.

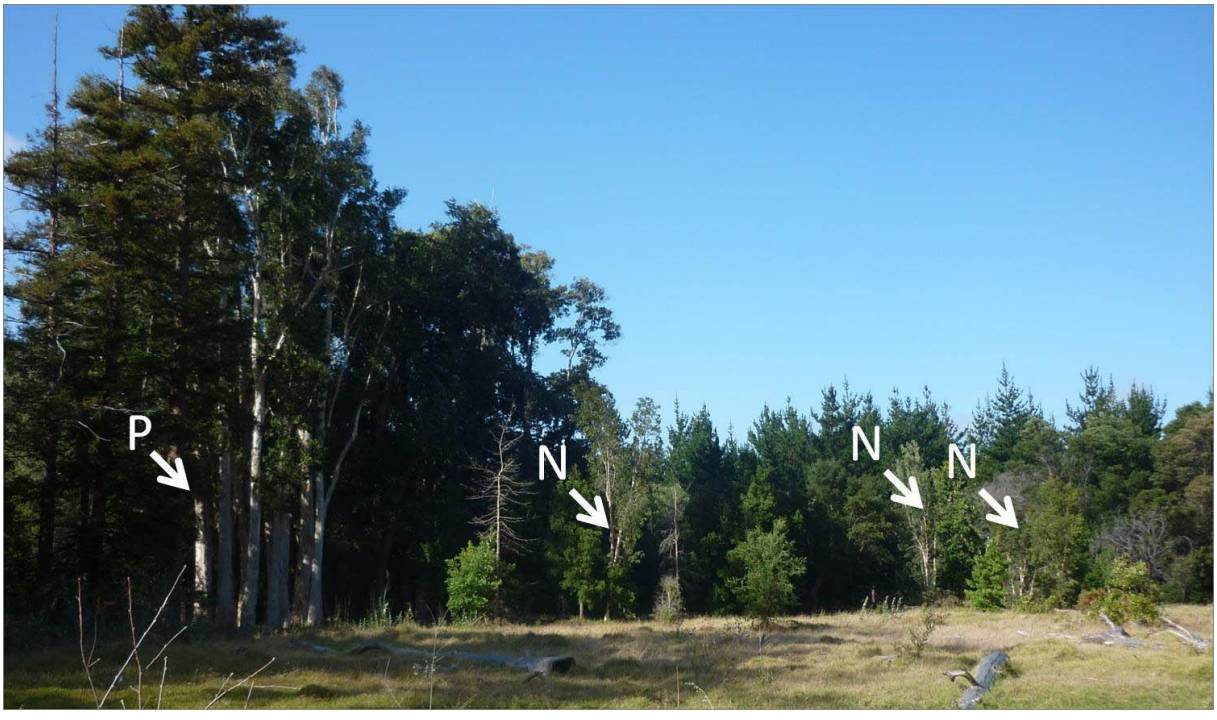

Figure 5. The planted (P) and naturalised (N) *Melaleuca quinquenervia* plants at the Tokai plantation, Cape Town, Western Cape. Photograph by John Wilson

Invasive potential and risk assessment

The models gave qualitatively similar results in line with other distribution models for this species (e.g. Watt et al. 2009), with sensitivity and specificity higher than 98% (Figure 1, Appendix 2). Although the known localities of *M. quinquenervia* in the southern Western Cape were included in the models, this region was not predicted to be highly suitable. Instead, the sub-tropical east coast and savanna ecosystems in South Africa are most at risk of invasion (Figure 1).

We derived a score of 21 from the Australian WRA (Appendix 4), indicating the considerable risk the species poses in South Africa. Among the undesirable traits as an invader (identified in the WRA) is the ability of *M. quinquenervia* to form dense thickets, increase fire hazard, prolific seed production and persistent canopy seed bank. A synopsis of *M. quinquenervia* at this invasion stage (naturalised) in South Africa is given in Appendix 3, as per the recommendations of Wilson et al. (2014).

Discussion

Melaleuca quinquenervia is naturalised at four sites in southern Africa, but is likely present at several more sites, posing an invasion threat considering the species' invasiveness elsewhere (Rejmanek and Richardson 2013). Indications from bioclimatic modelling and risk assessment further support this invasive threat status in the sub-region. Thus far however, the species appears to have only been introduced at a limited number of sites. With several World Heritage Sites and Wetlands of International Importance (Ramsar sites) in the region (iSimangaliso Wetland Park, parts of the Cape Floristic Region, Okavango Delta), this species should be put on watch lists across the region, and all historical plantings and naturalised populations removed. The bioclimatic modelling did not, however, predict that the Tokai or the Wolseley sites where naturalisation occurred were climatically suitable. We suspect that this might be because the species is more

limited by micro-site conditions for germination than broad-scale climate, but equally this might explain its low rate of spread at both sites. Further work is required on this, but without a strong mechanistic explanation for why the CFR is not suitable, we would recommend a precautionary approach and that the species should be intensively managed wherever it is found in the region.

There are various elements which contribute to the success and failure of eradication projects (e.g. Mack and Lonsdale 2002; Simberloff 2009). Of these, several factors bode well for the eradication of the species from South Africa: (1) naturalised populations are apparently extremely localised and small; (2) plants require a wet soil surface or dry-wet cycles to germinate so are restricted to specific habitat types (Rayamajhi et al. 2002; Van et al. 2005); (3) seed viability in the soil is usually less than two to three years (Rayamajhi et al. 2002; Van et al. 2005); (4) flowering *M. quinquenervia* plants (i.e. before seed-set) are highly visible in the matrix of native vegetation thereby facilitating detection; and (5) current institutional arrangements are in place to ensure diligent attention to monitoring and treatment. This study supports the prioritization of this species by the South African National Biodiversity Institute's Invasive Species Programme for eradication from South Africa (Wilson et al. 2013), and suggests the species should be listed as an eradication target (i.e. category 1a) under South African invasive species regulations (Department of Environmental Affairs 2014). Dawson et al. (2008) identify the role botanical gardens play at various stages of invasion. Thus given the landscape context of the naturalised and planted records (Table 1), we suggest that arboreta, botanical gardens and forestry stations should provide some focus for future search efforts.

A major issue that remains to be resolved is how the naturalised plants got to their current locations. The Wolseley population is on land previously managed by the Kluitjieskraal Forest Station, established in 1884 (King 1938; J. Storr-Lister, undated Compilation of Annual Reports). Although *M. quinquenervia* is not mentioned, nursery import records for Kluitjieskraal from the late 1800s show that *Melaleuca parvistaminea* Byrnes and *Melaleuca styphelioides* Sm. were imported and planted as potential hedges and wind-breaks. While both *M. parvistaminea* and *M. styphelioides* have since become invasive in the wetlands adjacent to the nursery at Kluitjieskraal, no *M. quinquenervia* plants have been found in this area (Jacobs et al. 2014; van Wyk et al. 2011). The naturalised population of *M. quinquenervia* is some 3.5km from the nursery site on a slope 300m above the valley floor. The nearest confirmed extant *M. quinquenervia* plants are in Paarl Arboretum about 40km away (Figure 1) over a range of mountains. As the site is next to power-lines and a road (Figures 2, 3), the population may have originated from seed brought to the site accidentally with equipment during the construction of these facilities or during maintenance or harvesting of commercial forest plantations in the area. The Krantzkloof Nature Reserve is in an urban context and the population could have come from neighbouring gardens (reserve surrounded by properties with extensive gardens). There are anecdotal records of historical plantings close by, but more needs to be done to ascertain the source. The only other extant individuals are at Durban Botanic Gardens >20 km away and several hundred metres lower in altitude.

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. Publicity flyers issued to conservation agencies and land-owners.

Appendix 2. Distribution of *Melaleuca quinquenervia* as predicted by Generalised Additive Model for the native distribution range.

Appendix 3. Species report for *Melaleuca quinquenervia* in South Africa based on the scheme proposed by Wilson et al. (2014).

Appendix 4. Australian Weed Risk Assessment for *Melaleuca quinquenervia* in South Africa. With a total score of 21, the species would have been rejected at a pre-border evaluation.

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