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The growing role of botanic gardens to mitigate the impact of Invasive Alien Species

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Preamble

New Zealand faces immense, insidious and often irreversible economic, environmental and social impacts from Invasive Alien Species (IAS), including pests, diseases and weeds, to our valued productive and natural plant systems. Because of New Zealand's economic reliance on primary production, and our unique flora and fauna, this country is especially vulnerable to IAS. New Zealand's defence from IAS (i.e. border biosecurity) has been the top priority for our productive sector for the last nine years (KPMG 2019) and is a concern of many New Zealanders. Additionally, Biosecurity 2025 Strategic Direction 1 (1 of 5) "A Biosecurity Team of 4.7 Million" aims to make all New Zealanders aware of the importance of biosecurity and to get them involved in pest and disease management (MPI 2018). The goal of the Canterbury Botanical Society is "to promote interest in the study of botany, especially that of New Zealand, and in the preservation of plants and habitats, and to disseminate current scientific information specific to New Zealand botany". It is therefore within the stated concern, interest and capability of its members to become part of the solution to mitigate the impact of IAS to New Zealand's valued plants, species and systems. This article illustrates three areas where the New Zealand botanic community, and specifically botanical gardens, can make a difference to mitigate the impact of IAS in the areas of biosecurity risk assessment, surveillance and awareness raising.

Introduction

New Zealand's relative isolation has provided it with a natural advantage to exclude the many pests, diseases and weeds that attack valued plant and animal systems overseas. However, the biosecurity challenges New Zealand faces are intensifying with changing trade, tourism and climate, and we need to respond accordingly. Despite a few well-publicised setbacks, there are positive signs that our biosecurity system is working. Analysis of invasion data indicates decreasing and static rates for the establishment of invasive insects and fungal pathogens, respectively. Overall the number of newly recorded insect species in New Zealand steadily increased from 1769 with pulses of establishment during 1920–25 and 1975–80, but since then the rate of non-native insect species establishing in NZ has been slowly decreasing (Edney-Browne et al. 2018). Similarly, the annual arrival rate of new fungal pathogens in New Zealand increased from 1880 to about 1980, but subsequently stabilised. Pathogen arrival rates for crop and pasture species declined in recent decades, but arrival rates increased for forestry and fruit tree species (Sikes et al. 2018). Notwithstanding the reasonable claim that New Zealand has one of the best biosecurity systems in the world, it cannot create perfect biosecurity. There will always be an ongoing need to do better.

Better Border Biosecurity (B3)

Better Border Biosecurity (B3) (http://b3nz.org/) acts as the pre-eminent research provider for science-based plant border biosecurity solutions in New Zealand and provides a single point access to the New Zealand science system for plant biosecurity research. B3's mission is to provide "science-based border biosecurity solutions underpinning the vitality of New Zealand's natural and productive plant landscapes (forestry, horticulture, arable, pastoral) and other plant-based industries, through a research-industry-government collaboration delivering world-leading science and technology development, enabling stakeholders to implement results for *better border biosecurity*". B3 especially targets cross-sectoral issues where plant pests, diseases and weeds do not respect the productive and natural system boundaries. Research Parties include: Plant & Food Research, AgResearch, Scion, Manaaki Whenua – Landcare Research and the Bio-Protection Research Centre hosted by Lincoln University. End-user Parties include: Ministry for Primary Industries (MPI), Department of Conservation, Forest Owners' Association, Horticulture NZ, The Environmental Protection Authority, and Beef and Lamb. Science provides the basis for an effective biosecurity system and B3 parties (science, government, and industry) co-innovate to ensure that research within the B3 suite of science projects is implemented into biosecurity outcomes. B3 researchers are increasingly involved with the translation of science to the broader community, including hāpu/iwi, and are therefore playing an active role in growing New Zealand's "Biosecurity Team of 4.7 Million" as part of Biosecurity 2025 (MPI 2018).

Biosecurity 2025 re-emphasises our unquestionable need to reduce the cumulative impact of IAS on New Zealand's valued productive sector and natural ecosystems. The magnitude, complexity and sheer importance of the biosecurity challenge New Zealand faces dictate that everyone in New Zealand needs to be actively involved and the New Zealand botanical community, especially New Zealand botanic gardens, can have an ever increasing part to play in this.

There are many compelling reasons why **botanic gardens** can play an important role in plant border biosecurity. Botanic gardens have experienced staff with a wealth of knowledge of plant systems. They provide an incomparable source of curated plant specimens from a range of native and non-native species – often with known provenance; they often contain novel pest/plant host associations; they employ knowledgeable, experienced and enthusiastic people, sometimes with access to diagnostic capabilities; they have strong professional international connections; and they have access to informative international databases. Gardens can provide a source of easily accessible plants growing outside their native range. It is estimated that the more than 3000 botanic gardens worldwide have a wide geographical distribution and house an estimated 30–40% of known plants (K McDonnell/BGCI pers. comm.). The **International Plant Sentinel Network (IPSN)** (https://www.plantsentinel.org/) is a network of over 40 botanical gardens and arboreta from 17 countries including botanic gardens in Auckland, Wellington, Christchurch and Dunedin. It aims to provide an early warning system to recognise new and emerging pest risks and provide a network for exchanging information on plant health. IPSN sustains a network for both national and international partnerships between scientists and botanic gardens and arboreta around the world. B3 is a founding member of IPSN and maintains a role on the IPSN International Advisory Group.

This article provides some outstanding examples where botanic gardens can make a tangible difference to mitigate the impact of IAS through biosecurity risk assessment, surveillance and awareness raising.

Sentinel (expatriate) plants for biosecurity risk assessment

This concept is based on plant species being grown in overseas botanic gardens or arboreta where these plants may be exposed to pests and diseases they would not encounter, for example New Zealand plant specimens present in botanic gardens or arboreta overseas. B3 has developed a database for international gardens that contain significant planting of New Zealand native/indigenous plant species (http://b3.net.nz/expat/view.php) (Fig. 1). Information from these novel pest/plant interactions might then provide useful guidance on the potential damages caused if these pest and diseases were to invade New Zealand. The sentinel/expatriate approach can be particularly useful for native/indigenous plants that are predominantly grown in their native range and have limited international distribution and exposure to pests and pathogens. New Zealand native plants grown in botanic gardens and arboreta overseas offer an elegant tool for biosecurity risk assessment for these plant species. The support from professionals located in international botanic gardens where New Zealand plants are present is critical to the success of this approach. B3 has been an international leader in the development of the sentinel/expatriate plants concept for plant border biosecurity (Fagan et al. 2008, Mansfield et al. 2019).

Figure 1. The New Zealand native/indigenous plant collection in the Royal Botanic Gardens Melbourne.

Perhaps the most useful example of this approach is a study by Groenteman et al. (2015) examining the status of the deadly plant pathogen *Xylella fastidiosa* and New Zealand indigenous plant species in California. Important information was gained on the host status of this plant pathogen on a range of New Zealand indigenous plant species. Another, but less successful example, is a project examining the status of myrtle rust on New Zealand Myrtaceae in international gardens (Marroni et al. 2018). Very little useful information for biosecurity risk assessors was obtained from this study. The sentinel plant concept works in the other direction as well, where New Zealand botanic gardens can inform other countries about the unique pest/plant associations found here. Such an approach was taken by B3 and Christchurch Botanic Gardens researchers to assess novel pine aphid/conifer tree interactions (Redlich et al. 2019). The study identified numerous novel insect-plant interactions that are likely to materialise if these aphids colonise new host plants, confirming the utility of the plant sentinel approach.

Botanic gardens and arboreta provide a unique opportunity to assess the pests and diseases found inhabiting and damaging foreign plant species outside of their native distribution. However, the information gained from these assessments must be treated with some caution as foreign botanic gardens and arboreta will not necessarily reflect the conditions or factors represented in the disease triangle, an established plant pathology paradigm that is used to explain plant disease interactions. The host plant and plant pathogen factors are represented in foreign gardens but suitable or comparable environment conditions for disease expression may be absent.

Plant pest surveillance in botanic gardens

The combination of the wide range of plant species and experienced professionals within botanical gardens provides an opportunity to undertake strategic surveillance for pests, diseases and weeds.

In New Zealand, the Auckland Botanic Gardens carried out some of the first (and thereafter regular and ongoing) surveillance for myrtle rust starting in 2014 before this disease was found in New Zealand. Following detection in New Zealand, the main botanical gardens in Auckland, Wellington, Christchurch and Dunedin all contributed to the national surveillance programme for myrtle rust with additional data from a range of alternative sources (Campbell and Teulon 2018). There is no doubt that having more gardens involved in this programme would have been beneficial in understanding the distribution of myrtle rust as it spread throughout New Zealand (Fig. 2, p. 33). Auckland Botanic Gardens also hosts one of the many MPI High Risk Surveillance Sites where regular monitoring of plants occurs near likely points of pest entry, such as airports, seaports and container devanning sites (Stevens 2008).

New Zealand botanic gardens have also been involved in the development of a new surveillance initiative in Australia to establish a programme of plant pest surveillance within botanic gardens and arboreta facilitated by Plant Health Australia (http://www.planthealthaustralia.com.au/plant-pest-surveillance-in-botanic-gardens/). This is intended to become part of the Australia National Surveillance Framework. Australia has over 150 botanic gardens and arboreta that are spread around Australia holding a range of native flora, exotic species and relatives of crop species, and are visited by millions of people each year. This initiative recognises the unique resource of living plant collections in these gardens to provide vital information for plant health. A number of activities are underway to fully implement the programme, including: identification of priority target species based on the characteristics and location of each garden; the Australian National Priority Plant Pest list and the draft Environmental Priority Pest list; development of surveillance training methods and communication materials (i.e. for generic biosecurity/specific targets); agreement on the diagnostic resources needed for each garden; and access to appropriate data capture resources.

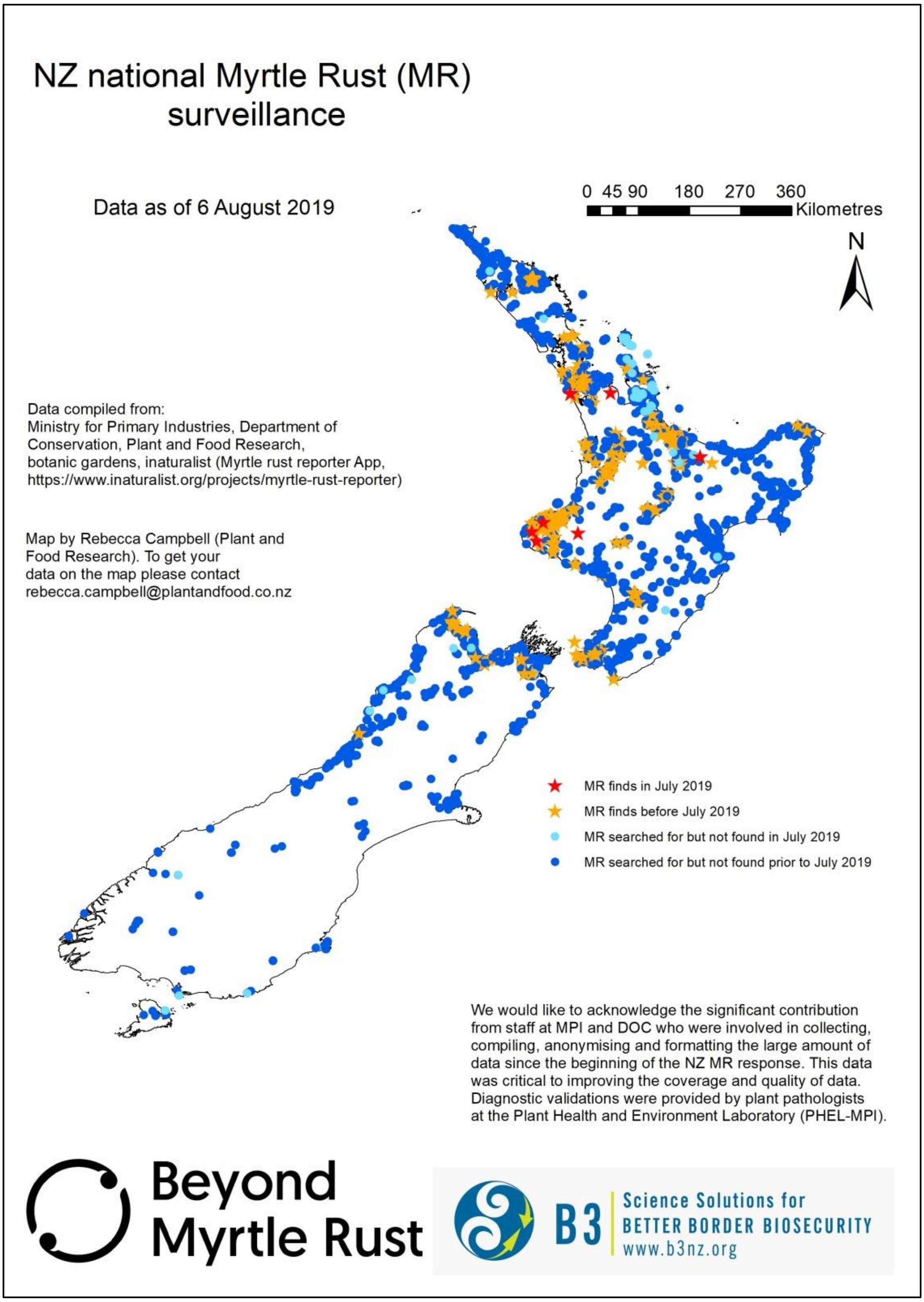

Figure 2. Myrtle rust distribution in July 2018. Four botanic gardens contributed surveillance data.

As noted above, *Xylella fastidiosa* is a devastating pathogen of many plant species, vectored by xylem-feeding insects. The pathogen is not found in New Zealand but it is of considerable biosecurity concern to both our introduced and indigenous plant species. One of the known vectors of *Xylella*, the exotic spittlebug *Philaenus spumarius* is found in New Zealand, as are several indigenous spittlebugs and indigenous cicadas (Hamilton and Morales 1992) of unknown vector status. Botanic gardens in the United Kingdom (UK) took part in a crowd-sourced survey to improve understanding of host plants of spittlebugs in the UK (Fig. 3). Spittlebugs provide an ideal model for 'citizen' participation because of the very obvious spit ('cuckoo spit') they produce when feeding. The results from this survey expanded the list of potential hosts of spittlebugs for the UK, demonstrated the range of managed and unmanaged habitats that spittlebugs can been found in, emphasised the widespread distribution of spittlebugs in the UK, and provided information on the time of year when spittlebug larvae are active. Similar information could be useful in New Zealand and could be co-ordinated through the New Zealand botanic gardens network.

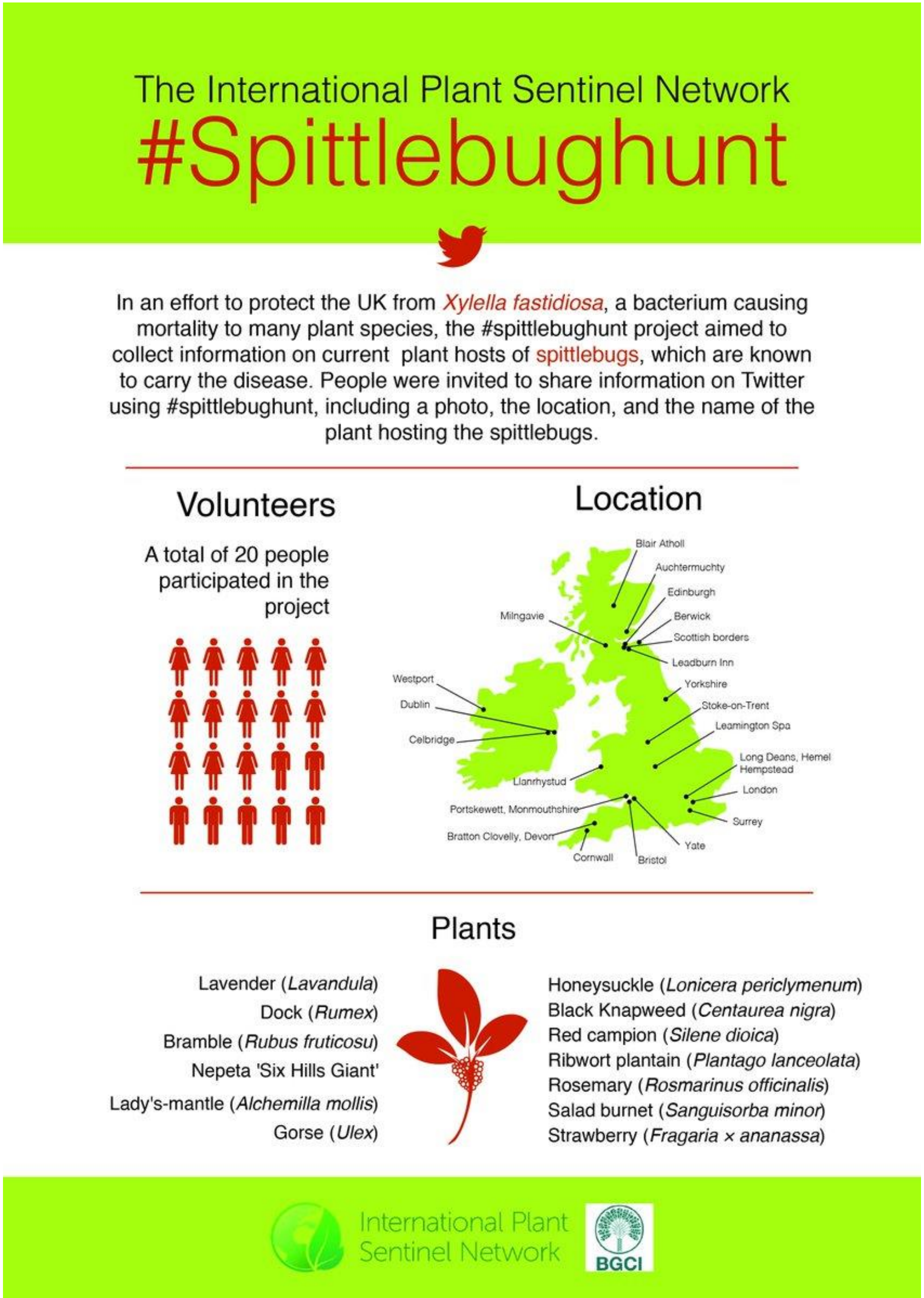

Figure 3. The International Plant Sentinel Network spittlebug hunt in the United Kingdom (IPSN no date).

Biosecurity trail

Botanic gardens receive millions of visitors each year with interests in the plants found within those gardens and presumably their continued health. This provides a great opportunity to get across the important issues relating to plant biosecurity. A new walking trail at the Auckland Botanic Gardens provides an opportunity for local and overseas visitors to learn about New Zealand's flora as well as their potential role in protecting it. The Biosecurity Trail is a collaboration between B3 and the Auckland Botanic Gardens. Visitors can embark on a 1.8-km walk around the garden and discover biosecurity facts at their own pace as they admire more than 10,000 native and exotic plants. *Ko Tātou This Is Us,* an initiative under Biosecurity 2025 (https://www.thisisus.nz), is also promoted within the trail. *Ko Tātou* recognises the role that every New Zealander needs to play in preventing pests and diseases from getting into New Zealand, or helping to stop their spread if they do get here. Brief information about pests and diseases that threaten New Zealand's flora and primary industries, including brown marmorated stink bug, myrtle rust and kauri dieback, is displayed at each of the 12 check points along the path (Table 1). Visitors can scan the QR code at each checkpoint to be directed to either a video or website for additional information on the pest or the disease and how to prevent its spread (Fig. 4, p. 36). While locals are encouraged to experience the trail, the project team wanted to raise biosecurity awareness amongst overseas visitors too.

Table 1. Pest and disease organisms profiled in the Auckland Botanic Gardens Biosecurity Trail

Site	Common name	Species	Organism	Primary system
1	Red imported fire ant	*Solenopsis invicta*	Insect	Natural
2	Myrtle rust	*Austropuccinia psidii*	Pathogen	Natural
3	Queensland fruit fly	*Bactrocera tryoni*	Insect	Horticulture
4	Brown marmorated stink bug	*Halyomorpha halys*	Insect	Horticulture
5	Pierce's disease of grape	*Xylella fastidiosa*	Pathogen	Horticulture
6	Nun moth	*Lymantria monacha*	Insect	Forest
7	Maize rough dwarf disease	*Fijivirus* spp.	Pathogen	Pasture
8	Pitch canker	*Fusarium circinatum*	Pathogen	Forest
9	Kauri dieback	*Phytophthora agathidicida*	Pathogen	Natural
10	Ceratocystis wilt	*Ceratocystis fimbriata*	Pathogen	Natural
11	Clover weevil	*Sitona hispidulus*	Insect	Pasture
12	Asian citrus psyllid	*Diaphorina citri*	Insect	Horticulture

Figure 4. Visitors to the Auckland Botanic Gardens Biosecurity Trail can scan the QR code at each check point to be directed to either a video or website for additional information on the pest or the disease and how to prevent its spread (photo credit Plant & Food Research).

Auckland Botanic Gardens has about 1.2 million visitors per year with about 15% of them coming from overseas, and the Gardens could be the first stop for many of them. The intention of the trail is that visitors can apply the new knowledge they gain to the rest of their stay in New Zealand to help to control existing diseases, e.g. by cleaning their shoes before and after heading into the forest to help stop the spread of kauri dieback. While the trail will help raise the profile of invasive pests and diseases with overseas visitors and the general public, aligned research on the trail will be used to improve New Zealand's biosecurity system. The insights that visitors gain on the Auckland Botanic Gardens Trail can be a significant way of engaging them with this important topic. The trail entered a 12-month trial period in April 2019, during which time it will continue to be improved on from the experience gained by feedback from visitors. Information sheets in other major languages, in addition to English, will become available at this time.

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What do we do with the weeds of Canterbury?

Emerging biosecurity risks for Canterbury's natural biota and timely responses

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Summary

Canterbury's biodiversity, natural heritage and landscape character of forest, woodland, shrubland, grassland, and wetland is dependent on maintaining a critical mass of un-cultivated habitat (>10% of total area – Meurk and Hall 2006), protecting viable populations of all indigenous species by removing degrading factors and processes (browsing and predatory mammals, and competitive exotic plants), and promoting the positive (habitat restoration and landscape/habitat patch connectivity). A culturally necessary complement to this is a strong visibility of native species, vegetation and wildlife that engender identity and protectiveness. The continual invasive and deliberate spread of visually dominating exotic species undermines this outcome. This paper draws on our latest understanding of weed threats on a national and Canterbury regional scale. It extracts the ranked threat level of ca. 200 exotic species from the iNaturalist NZ – Mātaki Taiao citizen science website. We comment on priority and nuanced management of exotic plants based on well-established,