Recent plant eradications on the islands of Maui County, Hawai‘i

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Abstract The state of Hawai‘i (USA) has few regulations to limit plant introductions. A network of interagency island-based invasive species committees has evolved over the past decade to address this vulnerability, with the aim of stopping invasions before they threaten natural areas. On Maui, Moloka‘i, and Lāna‘i, which comprise three of the four islands of Maui County, single-island eradications have been achieved for 12 plant species and eradication is likely imminent for an additional eight species. The islands vary in size, population, and land ownership. We explore the relative importance of those variables in achieving successful eradications along with target species selection, detection strategies, and public support.

Keywords: Invasive plant, *Cortaderia jubata, Cryptostegia grandiflora, Enchylaena tomentosa, Macaranga mappa, Macaranga tanarius, Melastoma sanguineum, Melastoma septemnervium, Parkinsonia aculeata*, *Pennisetum setaceum, Rhodomyrtus tomentosa, Rubus ellipticus*, *Ulex europaeus*

INTRODUCTION

Compared with most locations, species introduced to the Hawaiian Islands establish more readily, can become invasive more rapidly with a shorter lag phase (Daehler 2009; Loope 2011), and often have more severe effects (Denslow 2003). For perspective, Hawai’i has 50 (Loope 2011) of the “One Hundred of the World’s Worst Invasive Alien Species” (Lowe *et al*. 2000) listed by the International Union for the Conservation of Nature (IUCN) Invasive Species Specialist Group (ISSG). Of the 32 invasive species classified as “land plants”, Hawai‘i has 20. In this paper, such species are annotated as [IUCN 100].

The Hawai‘i Department of Agriculture can list species as state “noxious weeds”, in which case their introduction or transport into uninfested areas is prohibited by state law. This list identifies 79 species, but there have been no updates since 1992 (HDOA 1992). Hawai‘i noxious weeds have been denoted in this text as [HNW].

Given the presence of Hawai‘i Volcanoes and Haleakalā National Parks with their high native biodiversity, and over 300 federally-listed endangered species within the state, especially rigorous efforts might be expected in order to prevent and combat invasions. Such has not been the case, though the amount of effort is probably no worse than that in the USA overall (Loope and Kraus 2009). Conservation management in Hawai‘i has evolved from limited efforts by a few key stakeholders in the 1970s toward substantial and diverse conservation programmes by multiple federal, state and non-governmental agencies. There is also strong support for better measures to prevent and address biological invasions in the age of globalisation (Fox and Loope 2007). However, there are limits on agencies’ abilities to adequately address invasive species issues within the state (Kraus and Duffy 2010).

Island-based Invasive Species Committees (ISCs) were formed to help fill identified gaps, starting with an inter-agency group in 1991 on Maui to address the invasion of *Miconia calvescens* [IUCN 100] (Conant *et al.* 1997; Kraus and Duffy 2010). ISCs now cover the six largest Hawaiian islands, with three of those islands in Maui County (Maui, Moloka‘i, and Lāna‘i) served by the Maui Invasive Species Committee (MISC – Maui and Lāna‘i) and the Moloka‘i-Maui Invasive Species Committee (MoMISC).

Statewide efforts are progressing to institute weed risk assessments (Daehler *et al.* 2004), prevent sanctioned planting of pest plants, and stop new invasive introductions to individual islands and the state despite the limited regulation of plant introductions. The ISCs are poised to address this vulnerability, with the principal aim of stopping invasions before they threaten natural areas.

In Maui County, challenges posed by invasive species include protecting about 120 federally endangered plant species from weed and pest incursions, plus operating across three different islands, a diversity of habitats, and a range of socio-economic conditions. Habitats in the county stretch from sea level to >3000 m, in rainfall zones from very wet (annual rainfall > 8000 mm) to very dry (annual rainfall < 300 mm), including coastal shrub, dryland, mesic, and rain forest and alpine vegetation zones (Ziegler 2002). Many species of invasive plants already occupy a wide range of climatic zones on the islands and pose immediate or eventual threats to endemic species of plants, animals, and natural areas.

People are a crucial component of invasive species management programmes (García-Llorente *et al.* 2008). Introductions of exotic species are likely to increase with island area, population size, economic activity, and accessibility to air travel (Denslow *et al.* 2009; Kueffer *et al*. 2010). Introduction rates affect whether targeted species can be detected in all locations and the potential for reintroduction. Thus, information about the physical and socioeconomic conditions of Maui County may be relevant to evaluating overall success.

Our paper describes progress with advanced efforts to eradicate 12 plant species, with an additional eight species on target for eventual eradication. We consider programmatic and socio-economic factors associated with successful eradications. For purposes of this paper, eradication means: removal of all known individual plants for a given species from all known locations. For some species, the eradication process includes ongoing visits to address recruitment from known seedbanks.

MATERIALS AND METHODS

Study area

The islands of Maui County are linked politically but vary in size, population growth, and extent of private and publicly owned lands (Table 1). Maui is the largest and most populated island. From 2000-2010, Maui experienced a 13% growth rate, in contrast to Moloka‘i at 1%, and Lāna‘i, which slightly decreased. The islands vary in accessibility. Maui is served by direct flights from

Pages 325-331 In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

Table 1 Island size, population growth, and land tenure.

Island	Size[1] (km^2)	Population[2] (2010)	Population 2000-2010 % Change[3]	Ownership: Private/Public[4] %
Maui	1884	144,444	+12.8	65/35
Moloka‘i	674	7345	+1.2	70/30
Lāna‘i	364	3135	-1.8	99/1

[1]Juvik and Juvik 1998.
[2]U.S. Census Bureau, 2010 Redistricting Data (Public Law 94-171) Summary File P1.
[3]U.S. Census Bureau, Census 2000 Summary File 1: Hawaii.
[4]Based on Maui County GIS tax map information.

the mainland and all other Hawaiian islands. Flights to Moloka‘i are available only from Maui and O‘ahu, while Lāna‘i is accessible by regular commercial airlines only from O‘ahu. In 2009, Maui had nearly 1.9 million arriving air passengers, compared to approximately 48,000 for Moloka‘i, and 61,000 for Lāna‘i. (Maui County Data Book 2010). Maui has more than 60 plant providers or landscapers, many of which import plants from the island of Hawai‘i and the U.S. mainland. Moloka‘i has no major plant supplier and Lāna‘i has a single nursery that provides plants to two resort areas on the island. Land ownership varies by island. The highest percentage of private land ownership (ca 99%) is on Lāna‘i.

Target selection

There are two ways for an invasive plant species to become targeted for eradication in Maui County: review during an annual priority-setting process held by each ISC, or as a rapid response to a newly-discovered species brought to the committee's attention at a regular (bi-monthly) meeting. New discoveries of incipient species are typically made by committee members, staff, or other resource professionals in the community. With the exception of several species targeted for containment, such as *Miconia calvescens* or *Cortaderia jubata* on Maui, the objective for any new plant species is eradication.

Evaluation criteria include: risk to the island's environment, health, agriculture or economy, with special emphasis on environmental threats, feasibility, and cost of management options. Information about the relative risk posed by a potential target derives from several sources, including the expert knowledge of committee members and other local botanists, use of the Hawai‘i Pacific Weed Risk Assessment (HPWRA) (Daehler *et al.* 2004; www.hpwra.org), and literature review, including Internet searches and general references such as Randall (2007) and Weber (2003). For early eradication targets, the HPWRA tool was not available during initial feasibility analyses. Eradication feasibility considers biological factors such as seed dispersal mechanisms and seed longevity, and extent of infestation. Many of the species reported herein were identified as potential eradication candidates as the result of a roadside survey and expert interviews conducted in 2000 (Starr *et al.* 2011).

Survey and Management Techniques

Any eradication campaign against plants must adequately address three components: delimitation or determining the known extent of the invasion (Panetta and Lawes 2005), containment (no evidence of spread), and extirpation (Panetta 2007). Delimitation methods included active and passive strategies (Dewey and Anderson 2004), which involved roadside surveys, backyard searches in residential areas, and ground sweeps in rural or wildland areas. These were all conducted by a trained field crew at the initial detection site and surrounding areas. Roadside surveys on Maui were conducted in 2000 and 2009 (Starr *et al.* 2011) by two botanists driving all paved roads searching for a list of specific plants, including those covered in this paper.

Facilitation of passive surveys focused on teaching the public how to identify target species. Activities included 19 early detection workshops since 2008 for conservation workers; field professionals such as county road workers and parks and recreational staff, dock workers, federal agricultural inspectors; and members of the general public. Participants received an informative field guide about the target species (http://pbin.nbii.org/reportapest/maui/mauiearlydetectionguide_2008052.pdf). Publication of articles in the local newspaper highlighted early detection targets. (http://www.hear.org/misc/mauinews/). Outreach professionals attended community events and worked with local schools to inform the public about target species. The U.S. Geological Survey's Pacific Basin Information Node spearheaded a multi-agency reporting system to facilitate rapid response to incipient pests, which includes an online reporting tool (www.reportapest.org). These activities have resulted in valid reports from the public.

Management work at each infested site was conducted by ISC staff or partner agencies. Work on private lands was performed after obtaining permission from the landowner. Eradication techniques included hand-pulling or treatment with herbicide. Seed heads from flowering grasses were typically cut and bagged before treatment with herbicide. Geospatial information was collected at each infested site. More specific information about eradication techniques and plant locations is available on request. Eradications

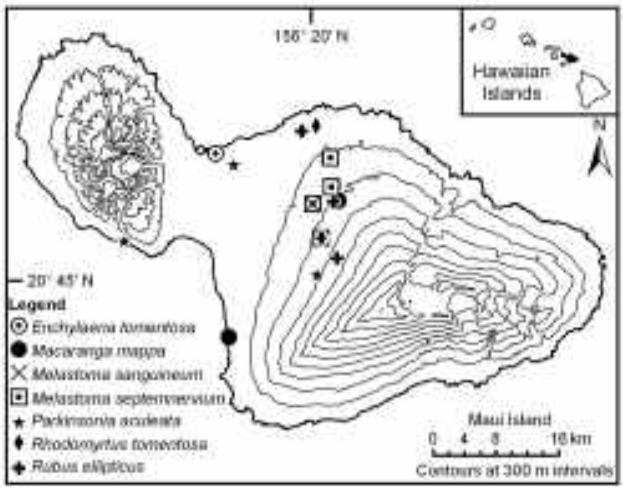

Fig. 1 Plant eradications on Maui, Hawai‘i.

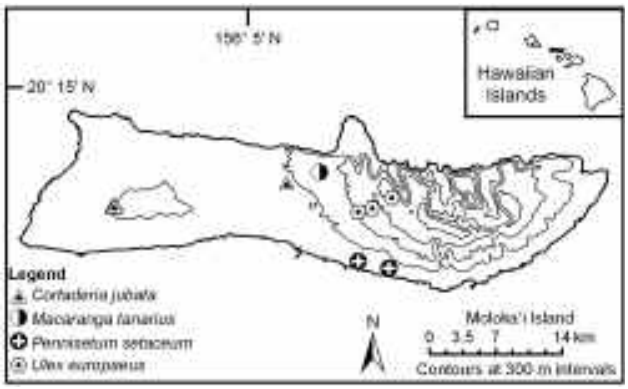

Fig. 2 Plant eradications on Moloka‘i, Hawai‘i.

Table 2 Number of plants removed by year, 2001-2009.

Island	Species	2001	2002	2003	2004	2005	2006	2007	2008	2009
Moloka'i	*Cortaderia jubata*	5	-	-	-	-	-	-	-	1
Lāna'i	*Cryptostegia grandiflora*	-	-	-	-	-	3	-	-	-
Maui	*Enchylaena tomentosa*	4	10	-	-	-	-	-	-	-
Maui/Lāna'i	*Macaranga mappa*	-	-	-	3	-	1	2	6	1
Moloka'i	*Macaranga tanarius*	-	-	-	-	-	-	1	-	-
Maui	*Melastoma sanguineum*	-	-	-	1	-	-	-	-	-
Maui	*Melastoma septemnervium*	-	1	-	-	-	1	-	-	-
Maui	*Parkinsonia aculeata*	17	-	-	-	-	-	-	-	-
Moloka'i	*Pennisetum setaceum*	-	-	4	2	-	-	-	-	-
Maui	*Rhodomyrtus tomentosa*	-	152	12	1	-	-	-	-	-
Maui	*Rubus ellipticus*	1	1	-	-	-	-	-	-	1
Moloka'i	*Ulex europaeus*	-	24	36	17	8	2	-	-	-

were achieved by repeat visits to known infested sites at intervals designed to ensure that plants did not fruit or set seed. Information about seed longevity was considered in determining the likelihood that a remaining seedbank had been exhausted. Site visits and surveys of surrounding areas continue to be made around all known locations of target species.

RESULTS

Seven plant species were eradicated from Maui: *Enchylaena tomentosa, Macaranga mappa, Melastoma septemnervium, Melastoma sanguineum, Parkinsonia aculeata, Rhodomyrtus tomentosa,* and *Rubus ellipticus* (Fig. 1, Table 2). Four species were eradicated from Moloka'i: *Cortaderia jubata*, *Macaranga tanarius*, *Pennisetum setaceum*, and *Ulex europaeus* (Fig. 2, Table 2). Two species were eradicated from Lāna'i: *Cryptostegia grandiflora* and *Macaranga mappa* (Fig. 3, Table 2).

Two species were on the IUCN list of 100 Worst Invaders and approximately half (7) were Hawai'i noxious weeds; all but one subsequently scored as "High" risk under the HPWRA (Table 3). None of the species was present on more than three sites on any island. The largest number of plants killed was 165 plants of *R. tomentosa*. Excluding

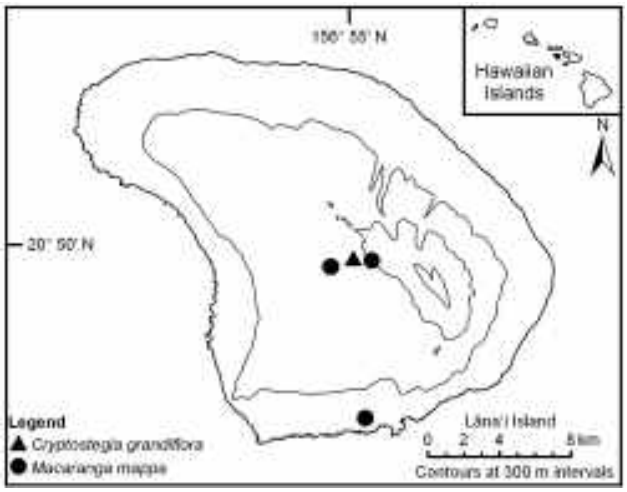

Fig. 3 Plant eradications on Lāna'i, Hawai'i.

Table 3 Characteristics of plant species eradicated in Maui County.

Species	# of Sites[1]	# of Plants	Effort (hrs.)	Area[2] (ha.)	State Noxious Weed[3]	HPWRA Rating[4]	Land Tenure	Seed Longevity[4]
Cortaderia jubata	3	6	16	11	X	High	Private	< 1 yr
Cryptostegia grandiflora	1	3	1	0.3		High	Private	1-5 yrs
Enchylaena tomentosa	1	14	14	0.4		Low	Public	> 1 yr.
Macaranga mappa[5]	3/3	7/6	15/13	3/8.2		High	Private	> 1 yr
Macaranga tanarius	1	1	2	0.4		High	Roadside	Unknown
Melastoma sanguineum	1	1	2	0.1	X	High	Private	Unknown
Melastoma septemnervium	2	2	8	1.1	X	High	Private	Unknown
Parkinsonia aculeata	3	17	8	0.3		High	Roadside	> 1 yr.
Pennisetum setaceum	3	6	33	1.9	X	High	Private	6 yrs.
Rhodomyrtus tomentosa	2	165	91	4.5	X	High	Private	> 1 yr
Rubus ellipticus	3	3	1	1.6	X	High	Private	> 1 year
Ulex europaeus	2	87	47	2.2	X	High	Prvt/Public	> 30 yrs

[1]A site is defined by property ownership.
[2]Area (hectares) is the infested area or area surveyed.
[3]Listed as a noxious weed by the Hawai'i Department of Agriculture, Hawai'i Administrative Rules § 4-68.
[4]See www.hpwra.org for Risk Assessments & references for seed longevity.
[5]Data for Maui/Lāna'i.

roadside surveys, no area surveyed was >11 hectares. Most eradications were on private land, the only exception being *E. tomentosa*, which was solely on public land. The second roadside survey (Starr *et al.* 2011) was conducted nine years after the first and helped boost our confidence that the infestations had not spread beyond known areas; no new locations of the eradication targets were discovered during the 2009 surveys.

The following outlines the justification for each of the target species discussed in this paper and highlights eradication efforts.

Cortaderia jubata **(Lem.) Stapf. – Poaceae [HNW]**

Maui has two *Cortaderia* spp., *C. jubata* (jubata grass, pampas grass) and *C. selloana* (pampas grass). Both species are ornamental bunch grasses capable of long distance wind dispersal and are known as aggressive weeds in numerous locations (Weber 2003). So far, only *C. jubata* is highly invasive on Maui (Loope 1992), but in California (the most likely genetic source of both species for Hawai'i), *C. selloana* is equally if not more invasive and damaging (Lambrinos 2001). *Cortaderia jubata* is native to Bolivia, Ecuador and Peru; horticultural stock apparently consists of a single genotype and is from southern Ecuador (Okada *et al.* 2009).

In Hawai'i, *C. jubata* was introduced for ornamental planting and was discovered invading natural areas on Maui in 1989. This species has established in numerous areas of rain forest as well as bogs on East and West Maui and has been detected and controlled in Haleakalā National Park. With *C. selloana*, *C. jubata* comprises the second highest plant priority for MISC; management efforts span thousands of hectares and involve ground work in residential and wildland areas and aerial operations in more remote areas. The limited distribution of *C. jubata* on Moloka'i made it a strong candidate for eradication. The species was first discovered at two sites in 2001 and considered eradicated after seven years of monitoring, when another site was detected during island-wide surveys for the *Babuvirus* (banana bunchy top virus) [IUCN 100]. The landowner had purchased seeds over the Internet. The homeowner was given a native plant as a replacement, and *C. jubata* at the new site was removed in 2009 before it set seed.

Cryptostegia spp. **- Asclepiadaceae**

Cryptostegia (rubber vine) is a genus endemic to Madagascar. There are two species, *Cryptostegia grandiflora* R. Br. and *C. madagascariensis* Bojer ex Decne.(GRIN n.d.), both of which are usually identified as *C. grandiflora*. Careful inspection has revealed that nearly all Hawaiian cultivated plants are *C. madagascariensis* (Staples *et al.* 2006). Both species have been spread by the plant trade, have become invasive in far-flung locations of the world, and have sap toxic to livestock. In Australia, *C. grandiflora* is a "Weed of National Significance" notorious for invasion of 40,000 km^2 in the Australian wet tropics, where it covers whole forests (Tomley and Evans 2004). *Cryptostegia madagascariensis* has recently been discovered invading unique riverine forests of northeastern Brazil (da Silva *et al.* 2008). Biological control exploration and testing has been underway for agents for *C. grandiflora* since 1985 in Australia and is now underway for *C. madagascariensis* in Brazil (da Silva *et al.* 2008).

Cryptostegia was recorded as naturalised on several of the main Hawaiian islands, including Moloka'i (Staples *et al.* 2006) and O'ahu (Frohlich and Lau 2008). On Lāna'i, the species was detected at a single residential location in Lāna'i City during 2006. The cooperative landowner had removed the plants by mid-2007. No recruitment has been observed at the site and it is considered eradicated from Lāna'i. On Maui, *Cryptostegia* is on several residential properties where it has been planted as an ornamental, but eradication remains elusive owing to landowner recalcitrance. These sites are potential sources of further invasion via the readily wind-dispersed seeds. On Moloka'i, *C. madagascariensis* Bojer has been the subject of an aggressive eradication campaign, and although root suckers remain, the species is considered en route to eradication.

Enchylaena tomentosa **R. Br - Chenopodiaceae**

Otherwise known as ruby or barrier saltbush, this small shrub is native to Australia, and had been reported as naturalised in New Caledonia (Imada *et al.* 2000) and Israel (Danin 2000). The invasiveness of *E. tomentosa* in New Caledonia is perhaps questionable, since it is not cited by local botanists (J. Munzinger, Herbarium IRD pers. comm.). Development of the Weed Risk Assessment tool occurred in Hawai'i after control of this species and subsequently ranked it as a "Low" risk. In Hawai'i, *E. tomentosa* was known only from one location on Maui (Imada *et al.* 2000), within Kanahā Pond, a state coastal wildlife sanctuary in Central Maui. Removal of four *E. tomentosa* plants was considered an early (2001-2002) success. An additional 10 plants were removed and no additional plants have been detected at this site, which is regularly surveyed by state wildlife personnel (F. Duvall, Hawai'i Department of Land and Natural Resources, Maui pers. comm.).

Macaranga mappa **(L.) Müll. Arg. - Euphorbiaceae**

Commonly called bingabing, this species is native to the Malesian biogeographic region of Malaysia but has naturalised in Hawai'i on the islands of O'ahu and Hawai'i (Wagner *et al.* 1999). Its abundance in some areas is attributed to forestry plantings in the late 1920s (Skolmen 1980). The species has spread into the forested areas of the eastern coast of Hawai'i, where stands of the large-leaved *M. mappa* create deep shade, its dense growth habit crowds out other vegetation, and it demonstrates strong regeneration capacity associated with its large seed bank (Cordell *et al.* 2009).

Macaranga mappa and *M. tanarius* are easily identified by their large umbrella-like leaves. A single large *M. mappa* tree in upcountry Maui was found during roadside surveys (Starr *et al.* 2011). This intentional planting was removed in 2004. The species was subsequently detected and removed at two additional locations on Maui, with no apparent connection to the initial site (Fig. 1). *Macaranga mappa* was detected on Lāna'i at three sites in small numbers in 2007 and 2008. Two of the three Lāna'i *M. mappa* sites were apparently the result of contaminated soil or nursery stock from the island of Hawai'i and this was likely the case for the two other sites on Maui.

Macaranga tanarius **(L.) Müll. Arg. - Euphorbiaceae**

This parasol leaf tree is native to Southeast Asia, Papua New Guinea, and Australia (GRIN n.d.). Similar to *M. mappa*, the species was an intentional forestry introduction in the 1920s, now forms dense thickets where it has become established, and is naturalised on O'ahu and Kaua'i (Wagner *et al.* 1999). Extensive infestations are also in the valleys and disturbed areas of West Maui; on East Maui it has been the target of localised removal. *Macaranga tanarius* was detected in a single location on Moloka'i and removed in 2007; no recruitment was ever observed at the site.

Melastoma spp. **– Melastomataceae [HNW]**

Hawai‘i has two invasive *Melastoma* species. *Melastoma septemnervium* Lour. (Asian melastome) is native to southern China, Vietnam, Taiwan, the Ryukyu Islands and southern Japan; and *M. sanguineum* Sims (red melastome) is native to the Malay Peninsula, Java, Sumatra, Vietnam, and southeastern China (Staples and Herbst 2005). The two similar species have been recognised as serious pest plants in Hawai‘i since about 1960 (Plucknett and Stone 1961). The entire *Melastoma* genus has state noxious weed status. Both species were grown as ornamentals for their showy flowers, shrubby habit, and attractive foliage. However, they outcompete native plants by forming dense monospecific thickets, growing up to 2 m tall, at elevations up to 900 m. Extensive infestations of *M. septemnervium* (aka *M. malabathricum,* but name misapplied) are now found on Kaua‘i and Hawai‘i, and a relatively recent infestation was found on O‘ahu (as *M. candidum*, a synonym, Conant 1996). *M. sanguineum* is naturalised only on the island of Hawai‘i. *Melastoma septemnervium* was found and removed at two sites on Maui, where it was last detected in 2006. *Melastoma sanguineum* was removed from one site on Maui in 2004.

Parkinsonia aculeata **L. - Fabaceae**

Commonly called Jerusalem thorn, this species is native to South America and the West Indies (Staples and Herbst 2005) and probably other sites in Southwestern North America. It is most notoriously invasive in Australia, where it forms dense, thorny, impenetrable thickets, with seeds dispersing along rivers, streams, and gulches; it is one of about 20 Australian “Weeds of National Significance” (www.weeds.org.au/WoNS/) and is a biological control target in Australia (van Klinken 2006). On O‘ahu, the species was introduced by the U.S. Army (Staples and Herbst 2005), but eradication was requested by the Hawai‘i Territorial Board of Agriculture before 1920. *Parkinsonia* is likely to be sparingly naturalised on Kaua‘i and O‘ahu. On Maui, *P. aculeata* was detected at two locations, with one of those removed voluntarily by the landowner. A single planting on West Maui was also targeted for eradication. All plants were removed by 2001.

Pennisetum setaceum **(Forssk.) Chiov. – Poaceae [HNW]**

Commonly known as fountain grass, this aggressive early coloniser of lava fields and dry forests covers tens of thousands of hectares on the island of Hawai‘i. It destroys native communities by increasing fire frequency and limiting germination, survival, and growth of native dry forest species (Williams *et al.* 1995; Cabin *et al.* 2002). The native range of *P. setaceum* spans much of the Middle East and North Africa, but is primarily arid coastal regions of the Sahara Desert (Williams *et al.* 1995; Le Roux *et al.* 2007). The species thrives from sea level to 2800 m elevation in Hawai‘i despite lack of genetic variation (Williams *et al.* 1995), and is now on all the main Hawaiian islands (Wagner *et al.* 1999; Starr *et al*. 2011). On Maui, *P. setaceum* has been targeted for eradication since about 1976 (Loope 1992), with the successful exhaustion of seedbanks from nine known small populations. A much larger infestation exists on Lāna‘i, where the species is targeted for containment. *Pennisetum setaceum* was known from only two sites on Moloka‘i, detected at two different times. One involved contaminants from bird seed and the other site had plants brought to Moloka‘i from the island of Hawai‘i. Removal on Moloka‘i was completed by 2004, with no subsequent detection.

Rhodomyrtus tomentosa **(Aiton) Hassk. – Myrtaceae [HNW]**

This downy rose myrtle, which is native to Southeast Asia, is established and invasive on Kaua‘i, O‘ahu and Hawai‘i (Wagner *et al.* 1999). The evergreen shrub is fire-adapted, can tolerate a wide range of environmental conditions, and is highly invasive in Florida (Langeland and Burks 1998) and on the island of Raiatea in French Polynesia (Meyer 2004). On Kaua‘i, *R. tomentosa* blankets portions of the lower-elevation landscape, covering thousands of hectares (Burney and Burney 2007). The species was detected on Maui at two locations; eradication efforts, which began in 2002, had concluded by 2004.

Rubus ellipticus **Sm. - Rosaceae [IUCN 100] [HNW]**

Commonly called yellow Himalayan raspberry, this thorny thicket-forming shrub has long (to 4 m) trailing shoots, is native to areas of temperate and subtropical Asia, exhibits aggressive growth, and is difficult to control. In Hawai‘i, *R. ellipticus* has become well established in the Hawai‘i Volcanoes National Park and surrounding areas, where it threatens native resources (Stratton 1996). The species has been transported to Maui as a contaminant in mulch or tree fern trunks (*Cibotium* spp.), which are sold and shipped from the island of Hawai‘i.

Rubus ellipticus was first discovered on Maui in 1997. Eradication efforts over the next five years by MISC partners ensured that plants never fruited (S. Anderson, Haleakalā National Park, Maui pers. comm.). There have been two discoveries since then, in each instance the result of contaminated plants shipped between islands. One site is a botanical garden, where there was repeated regeneration from stock deep in the trunk of a tree fern, despite the owner’s attempts to eradicate it (F. Starr, University of Hawai‘i, Maui pers. comm.). Efforts to manage *R. ellipticus* must realistically be regarded as a “serial eradication” as long as unregulated interisland transport of plants continues.

Ulex europaeus **L. – Fabaceae [IUCN 100] [HNW]**

Widely known as gorse, this notorious woody shrub is native to Britain and parts of Europe, forms impenetrable thickets, excludes grazing animals, and makes land unusable where it persists. *Ulex europaeus* has extensively invaded pasturelands and native ecosystems on Hawai‘i and Maui; substantial biocontrol efforts in Hawai‘i to date have not been effective (Markin *et al.* 2002). Gorse’s long seed viability, reported as 50 years or more, make this a challenging target for eradication (Motooka *et al.* 2003). The discovery of low numbers on Moloka‘i (Conant 1996) at three locations, including a forested area, suggested eradication was still feasible. No plants have ever been detected outside the treatment area and none observed since 2006.

Other species

In addition to the successes outlined above, eight more invasive plant species are on target for eventual eradication within Maui County: on Maui these are *Acacia retinodes*, *Maclura pomifera*, *Silybum marianum*, and *Verbascum thapsus*; on Moloka‘i these are *Arundo donax* [IUCN 100], *Cryptostegia madagascariensis*, *Salsola kali*, and *Setaria palmifolia*. The known extents of these populations have been delimited and efforts are focused on exhausting seedbanks or controlling sprouts from vegetative re-growth.

DISCUSSION

Efforts to eradicate 12 species in Maui County have been relatively successful and were accomplished at low cost, consistent with the concept that early detection and rapid response are cost-effective means of addressing invasive species. All but one species targeted for eradication were known to be highly invasive plants.

Key factors for successful eradications included: appropriate target selection, including low numbers of plants on few properties; persistent efforts by trained crews; and cooperative landowners. Most eradications were completed within a one- to two-year time frame, with the longest effort extending over five years for *Ulex europaeus*. Seedbanks exist for some species; thus, continued vigilance is essential, although only *U. europaeus* has a particularly persistent propagule bank. Precise geospatial information along with the institutional memory of key staff and partners boost our confidence that seedbanks can eventually be exhausted for all target species. Continued financial support from local, state, and federal agencies will be necessary to ensure repeat site visits.

Maui's larger population and higher rate of population growth, its enhanced air accessibility, and more horticultural businesses, mean more opportunities for weedy plants to be introduced to the island. Its larger overall size and more private properties also complicate detection efforts. In contrast, field staff are able to regularly survey the single nursery on Lānaʻi for target species and visit almost every property on the island during annual surveys. Molokaʻi has not had a commercial nursery in recent years and its smaller community makes it possible to reach most residents during major outreach events. Thus, the level of confidence associated with eradications on Maui must be considered lower than those for Molokaʻi and Lānaʻi. The possibility of reintroduction exists on all islands, as demonstrated by the Internet purchase of *Cortaderia jubata* seeds on Molokaʻi and reinvasion of *Macaranga mappa* and *Rubus ellipticus* as contaminants in nursery stock from the island of Hawaiʻi.

In the absence of meaningful regulations mandating removal of invasive species, eradications can only be achieved through landowner cooperation. All but two of the eradications were achieved on private lands, underscoring the importance of strong public support. On Molokaʻi, initial resistance to control of *Cortaderia jubata* was overcome. Eradication efforts on Lānaʻi were facilitated by strong cooperation from Lānaʻi residents, the majority of whom live in the island's main town, and access to open areas by the primary landowner. Eradication remains elusive for *Cryptostegia* and *Acacia podalyriifolia* on Maui because landowners are refusing to cooperate. Landowner recalcitrance is also thwarting efforts to control the more entrenched *C. jubata* and *C. selloana* on Maui, even though *C. jubata* is a state noxious weed.

While these eradications are viewed as successes, they do not constitute the major focus of work, at least on Maui. Compared to MISC's work on all invasive species, resources devoted to the reported eradications represented approximately 1% of total personnel effort over the period of the project. In contrast, over $1 million is currently being spent annually to contain *Miconia calvescens* and *Cortaderia* spp. on Maui. Smith (2002) articulated Hawaiʻi's need to accelerate efforts at biological control for some of the most damaging invasive plant species to avoid obliteration of large expanses of native ecosystems; the need remains. *Miconia calvescens* is by far the greatest threat to biodiversity and endangered plant species, but other ominous threats include the shrub–tree strawberry guava (*Psidium cattleianum* [IUCN 100] Myrtaceae); the large herb kahili ginger (*Hedychium gardnerianum* [IUCN 100] Zingiberaceae); the shrub *Clidemia hirta* [IUCN 100], another member of the Melastomataceae; and several other serious weeds (Stone *et al.* 1992). For certain widespread, high-impact weeds, biological control is an essential part of the mix needed for conservation of the biodiversity in Hawaiʻi – given that there appears to be no other conceivable long-term solution. Despite this urgency to expand biocontrol efforts, the current focus on measures to exclude potential new invasive species and eradicate incipient invasives is a continuing high priority (Kraus and Duffy 2010).

ACKNOWLEDGEMENTS

The successful eradications of plant species from Maui County could not have occurred without the support of numerous agencies and individuals, including MISC and MoMISC partners. MISC and MoMISC are projects of the University of Hawaiʻi Pacific Cooperative Studies Unit, under the able direction of David Duffy. The initial experimental eradication project was funded by the U.S. Fish & Wildlife Service. Special thanks to the dedicated field staff of MISC and MoMISC, especially Mike Ade and Kamalani Pali. Early control efforts by Committee members, including Steve Anderson, helped ensure success. Brooke Mahnken provided cartographic assistance and Forest and Kim Starr (University of Hawaiʻi) played a major role in these eradications through pioneering early detection efforts. We also thank Chuck Chimera (Hawaiʻi Invasive Species Council) and Chris Buddenhagen (Florida State University) for their helpful review of this manuscript.

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