Lord Howe Island Weed Eradication Program
Results 2004–2014

NSW GOVERNMENT

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Front cover (Main: Jack Shick; Insets: LHIB):
Main: Lord Howe Island.
Left: The Battle for Transit Hill (Weed Management Block TH026) – Ground Asparagus, 2009.
Middle: The Settlement near Stephens Reserve – Cherry Guava thicket, 1995.
Right: The coal face, Intermediate Hill (Weed Management Block IH008) – Cherry Guava, 2006.

Back cover (Main: LHIB; group photo: Chelsea Scott Photography):
The Lord Howe Island Board Weed Team and volunteers, February 2016.

JANUARY 2016

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- NSW Environmental Trust (NSW State Government)
- Caring for Our Country (Federal Government)
- Northern Rivers Catchment Management Authority
- North Coast Local Land Services (NSW)
- Natural Heritage Trust (Federal Government)
- Lord Howe Island Board
- NSW Department of Primary Industries
- Foundation for National Parks and Wildlife
- Winston Churchill Memorial Trust

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This report is dedicated to Jenni Le Cussan and her vision to help protect paradise.

Executive Summary

The Lord Howe Island Weed Eradication Program is possibly one of the most ambitious weed eradication programs being undertaken in the South Pacific – if not globally – given the diversity, density and extensive distribution of invasive weeds on the island when the program began in November 2004.

This report summarises the results for the first 10 years (2004–14) of the overall 30-year program, and reviews progress towards the weed-eradication goals established in the 2006 *Weed Management Strategy for Lord Howe Island* (LHIB 2006). This report will also be used to inform the revision of the 2006 Weed Management Strategy and the adaptive development of the Weed Eradication Program.

Over the first 10 years, there has been an 80% reduction in the abundance of all weeds detected and removed following repeat visits to weed-management blocks and a 90% reduction in the number of mature weeds removed, comparing first and last treatments. Results show the program has been and is effective and has aided the protection of Lord Howe Island's World Heritage values and its unique ecosystems from the immediate threat of dense and widespread weed infestations.

Funding

During the first 10 years of the Weed Eradication Program, 2004–14, just under $6.49 million has been invested in the eradication of weed species on Lord Howe Island, primarily by the Lord Howe Island Board (LHIB) and State and Commonwealth Governments. The sources of funds for the program are summarised below (see Appendix 2 for full details of funding). Agencies external to the LHIB have provided 70% of program resources. The external funding has supported additional staff, contractors, volunteers, helicopter and rope access programs and provision of materials.

Sources of funding for the Lord Howe Island Weed Eradication Program 2004–14.

Agency	Funding ($)
NSW Environmental Trust	2,857,974
Lord Howe Island Board	1,835,937
Northern Rivers Catchment Management Authority & Natural Heritage Trust	600,000
Northern Rivers Catchment Management Authority	305,000
North Coast Local Land Service	30,710
Caring for our Country (Australian Government)	825,000
Foundation for National Parks and Wildlife	2,700
NSW Department of Primary Industries (noxious weed inspections 2004–14)	32,273
Total	**$6,489,594**

Achievements of the Weed Eradication Program

To mid-2014 (30 June), the investment in the Weed Eradication Program had resulted in the expenditure of a great deal of human effort and achieved a number of significant results:

- A total of 129,600 hours of labour searching and weeding 3941 hectares of land.
- An average of 394 ha searched and weeded per year for each of the 10 years, with the annual area covered ranging from 214 to 603 ha.
- Over 2 million weeds removed (see section 4, Results of the Weed Eradication Program).
- An 80% reduction in all weeds removed (over 1024 ha of Lord Howe Island) and in the number of weeds detected and removed per hour by a weeder (comparing first and last treatments, Year 1 to Year 10, for detailed analysis of Intermediate Hill, Lidgbird North, Lidgbird Remote, Malabar and Transit Hill landscape units of the island).
- A 90% reduction in mature weeds removed (comparing Year 1 to Year 10 as preceding point).
- Six species completely eradicated (all of which were originally limited in extent):

  Cat's Claw Creeper (*Dolichandra unguis-cati*) – 25 plants

  Cocos Palm (*Syagrus romanzoffiana*) – 3 plants

  Tipuana (*Tipuana tipu*) – 1 mature plant

  Turkey Rhubarb (*Acetosa sagittata*) – 1 plant

  French Broom (*Genista monspessulana*) – 1 plant

  Potato Vine (not Madeira Vine) (*Solanum wendlandii*) – 1 plant
- 40 invasive weed species trending towards eradication, with less than 1000 individuals estimated or known to remain (with localised or uncommon occurrence in the PPP or Settlement), including recently declared noxious weeds.
- An 80% reduction in the abundance of common and widespread weeds targeted for eradication from the PPP (Lord Howe Island Weeds Database 2004–14). Total counts for the top 10 weed species and number of **individual plants** removed (in order of abundance):

  Cherry Guava (*Psidium cattleyanum* var. *cattleyanum*) – 704,266 plants

  Ground Asparagus (*Asparagus aethiopicus*) – 665,831 plants

  Ochna (*Ochna serrulata*) – 485,168 plants

  Bridal Creeper (*Asparagus asparagoides*) – 110,794 plants

  Sweet Pittosporum (*Pittosporum undulatum*) – 84,729 plants

  Climbing Asparagus (*Asparagus plumosus*) – 53,840 plants

  Cotoneaster (*Cotoneaster glaucophyllus*) – 26,211 plants

  Glory Lily (*Gloriosa supberba*) – 13,655 plants

  Night Jasmine (*Cestrum nocturnum*) – 13,380 plants

  Bitou Bush (*Chrysanthemoides monilfera* subsp. *rotundata*) – 3459 plants

Progress against the 2006 Weed Management Strategy

The five objectives of the 2006 Weed Management Strategy are:

Objective 1. Eradication of Category 1, 2 and 3 weeds as listed in Appendix 1, with ongoing searches for any new recruits and new invaders.

Objective 2

(2a). Prevent new weed threats arising through removal of latent invasive alien plants from settlement gardens as identified after completion of a garden plant inventory.

(2b). Prevent new weed threats arising through controls over plant importation.

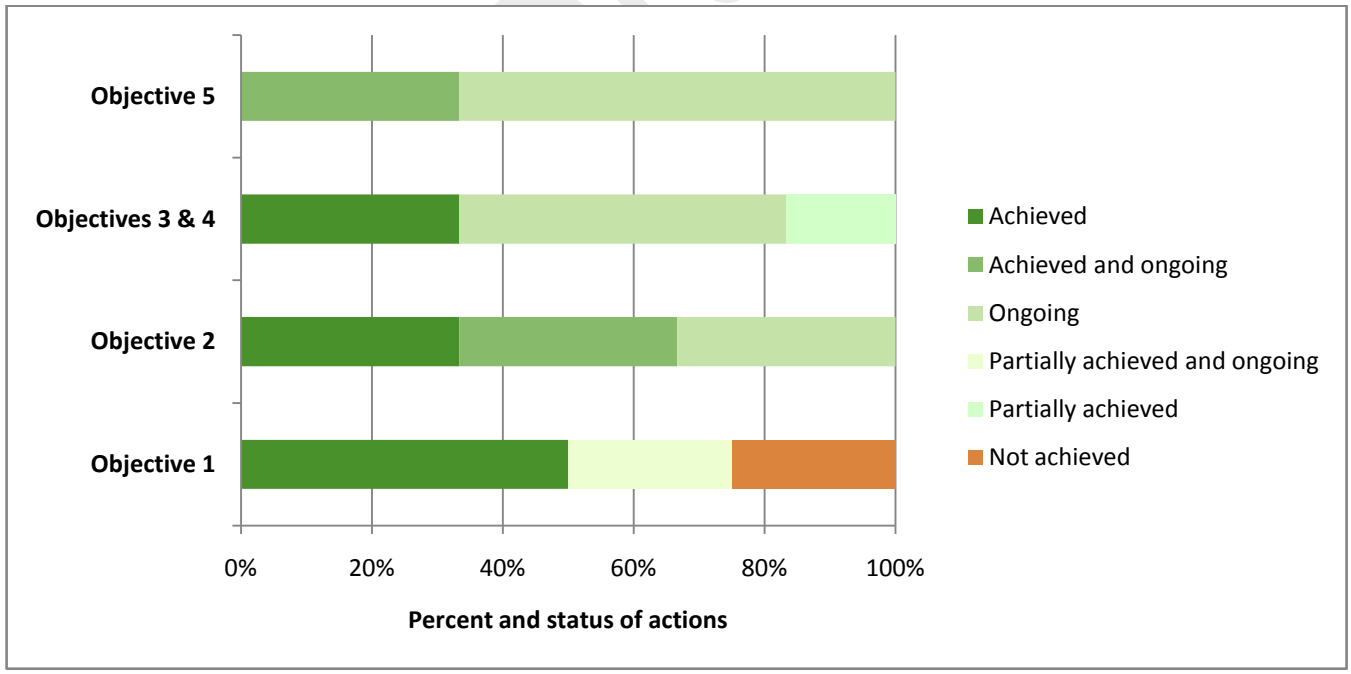
(2c). Prevent new weed threats arising by eradication of non-native weed seed dispersers.

Objective 3. Engender community support and introduce sustainable land-use planning **for the island.**

Objective 4. Explain the significance of the alien invasive plant problem to the Lord Howe Island community.

Objective 5. Continue research and monitoring to ensure best practices in management of weed species.

Under the objectives there are a series of 20 recommendations, targets or outcomes. There has been substantial progress or achievement of 18 of these (see Appendix 3), with the status of the objectives and actions ranked as achieved, ongoing or not achieved. The graph shows progress of the program against the objectives and actions of the 2006 Weed Management Strategy.



The strong downward trend in the number of weeds encountered annually suggests eradication of most target weeds is achievable within the forecast 30 years of the program, given adequate resourcing, the use of technical methods for rugged terrain and continued capacity building.

However, the combination of the success to date and the positive outlook for the future risks eradication fatigue and complacency at all levels from on-ground workers to the LHIB and funding agencies, and the lack of secure funding places the program at a critical stage. Sustained and adequate investment and ongoing agency support is needed to ensure a trajectory towards weed eradication is maintained for the long-term with the ultimate goal of protecting the Lord Howe Island's World Heritage values from the impacts of invasive weeds.

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List of abbreviations

DPI	NSW Department of Primary Industries
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FTE	full-time equivalent (in relation to staffing)
GIS	geographic information system
GPS	global positioning system
HBT	Herbicide Ballistic Technology
LCA	Local Control Authority (under NSW *Noxious Weeds Act 1993*)
LHI	Lord Howe Island
LHIB	Lord Howe Island Board
LHIG	Lord Howe Island Group
LHI Act	*Lord Howe Island Act 1953* (NSW)
LHI BMP	Lord Howe Island Biodiversity Management Plan (DECC 2007)
LHI WD	Lord Howe Island Weeds Database
Mt	Mount
NSW	New South Wales
NZ	New Zealand
OEH	Office of Environment and Heritage (NSW)
PPP	Permanent Park Preserve
TSC Act	*Threatened Species Conservation Act 1995* (New South Wales)
UAV	unmanned automated vehicles, or drones
WoNS	Weeds of National Significance

Standard units and their abbreviations are used, including: ha, hectares; km, kilometres.

1 Introduction

Lord Howe Island (LHI) is an isolated oceanic island in the Tasman Sea, located 780 km north-east of Sydney and 585 km east of Port Macquarie (31°33'29"S, 159°05'12"E), and is part of the state of New South Wales (NSW), Australia. The main island and its associated offshore islands and rocks are collectively known as the Lord Howe Island Group (LHIG) and were inscribed on the World Heritage List in 1982 in recognition of the Group's superlative natural landscapes and scenery, its rich terrestrial and marine biodiversity and as an outstanding example of an island ecosystem developed from submarine volcanic activity (UNESCO; see http://whc.unesco.org/en/list/186).

The main island is 11 km long and 0.6–2.8 km wide, with a total area of 1455 ha. The topography includes beaches rising to low hills and sheer mountain slopes and cliffs in the north and south, with the distinctive peaks of Mt Lidgbird and Mt Gower that rise to an elevation of 875 m (Figure 1).

Much of the island retains a high proportion of native vegetation cover (87%), with 239 native vascular plant species recognised, of which 47% are endemic to the LHIG (DECC 2007). The Island's flora has affinities with that of the Australian mainland, New Zealand, New Caledonia and Norfolk Island. Three-quarters of the area of the LHIG is protected within the Permanent Park Preserve (PPP). The Preserve has a similar status to a national park but differs in that it is managed by the Lord Howe Island Board (LHIB) rather than the NSW Office of Environment and Heritage (OEH).

The LHIB has responsibility for the care, control and management of LHI and its associated islands under the NSW *Lord Howe Island Act 1953* (*LHI Act*) and international obligations to manage the LHIG in respect of its World Heritage values: 'an outstanding example of an oceanic island of volcanic origin, having a unique biota with a high level of endemism and the world's most southerly true coral reef. It is an area of exceptional natural beauty and provides important breeding grounds for colonies of seabirds as well as habitat for rare and endangered species' (UNESCO; see http://whc.unesco.org/en/list/186).

The Lord Howe Island Biodiversity Management Plan (LHI BMP; DECC 2007) is a multispecies recovery plan for the island, and which identifies invasive species and introduced pathogens as the greatest risks to the terrestrial ecosystems and threatened species of the LHIG. The LHI BMP addresses risks to threatened and endangered flora and fauna species and their habitats listed under the New South Wales *Threatened Species Conservation Act 1995* (*TSC Act*) and Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (*EPBC Act*). The *Weed Management Strategy for Lord Howe Island* (LHIB 2006), including the Weed Eradication Program discussed herein, addresses actions in the LHI BMP.

1.1 A history of weed management on Lord Howe Island

Introduced and invasive plant species have been present on LHI, and affecting the ecology of the island, since settlement in 1834. In the 1930s, the Board raised concerns about, and urged residents to remove, asparagus ferns. Concerns about the threat posed by invasive weeds on LHI, particularly of Cherry Guava (*Psidium cattleyanum* var. *cattleyanum*), were first formally reported as part of the biological surveys of the island conducted by the Australian Museum and Royal Botanic Gardens, Sydney, in 1970 (Recher 1974; Pickard 1983). The surveys noted that 120 introduced species – including invasive species – had naturalised and recommended that the import of introduced species be prohibited. A garden plant inventory in 2002 identified over 670 introduced species on the island and, of these, at least 270 had invasive characteristics (DECC 2007).

With gardens being one of the primary sources of invasive species, communication and collaborative effort with the local community through the Noxious Weed Inspection process has enabled the removal of declared weeds from leases and detection of new weed risks.

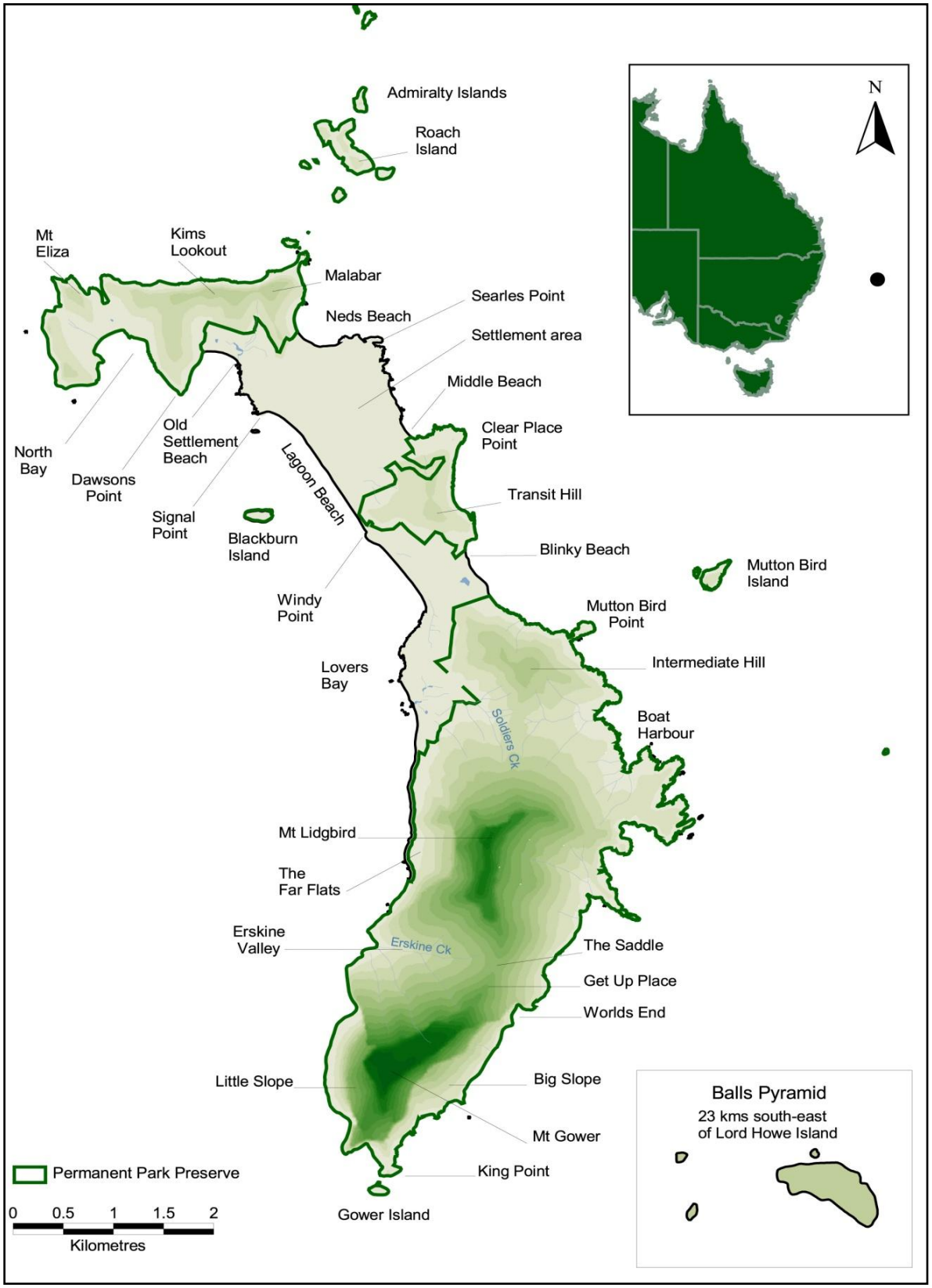


Figure 1 Lord Howe Island (from DECC 2007).

Previous weed management actions

Efforts to manage weed on LHI ramped up in the 1990s with the local community, volunteer groups and the LHIB focusing on the control of weeds at priority sites. Some of the major weed management decisions or actions that have taken place include:

- From 1994 to 2001, the LHIB applied significant effort to control 13 invasive weed species at key locations, including the back of the golf course, Grey Face, Lagoon Foreshore, the Settlement, northern hills, including Curio Point, and abseiling to remove Bitou Bush at the Nobbin on Mt Lidgbird, Kims Lookout and Malabar (LHIB 2002).
- 1995 saw the first Weeding Ecotour, which eventually led to the formation of the Friends of Lord Howe Island (in 2001). There have been 78 Weeding Ecotours under this program, in which volunteers pay to come and assist with weeding activities each morning and enjoy guided interpretive walks each afternoon. The volunteers have collectively contributed more than 24,000 hours of weeding and have helped significantly in the transformation of Transit Hill.
- In 1997, 16 weed species were declared noxious for LHI under the NSW *Noxious Weeds Act 1993* to provide a basis for beginning an all-tenure approach to managing the impacts of weeds on the island.
- In 1999 the NSW Department of Primary Industries (DPI) assisted by implementing a leasehold (urban) weed inspection program and introduced new selective herbicides, metsulfuron-methyl (for foliar spraying Ground Asparagus *Asparagus aethiopicus*) and triclopyr (for cut and paint of Cherry Guava and Ochna *Ochna serrulata*).
- In 2001:
    - The World Wildlife Foundation sponsored Ian Hutton to attend the conference on island invasives held in Auckland, New Zealand. This facilitated contact with the New Zealand Department of Conservation and their weeding programs on Raoul Island and raised awareness that Cherry Guava was potentially the worst weed occurring on LHI.
    - Ian Hutton and Jenni Le Cussan prepared an inventory of weeds on LHI and an outline for a weed control strategy.
    - The Friends of Lord Howe Island group was established.
- In 2001 and again in 2003, the NSW Environmental Trust awarded major grants (a total of $139,640) for two weed management projects: Stop the Spread of Pittosporum (2001; $71,240) and Cherry Guava in the Southern Mountains (2003; $68,400).
- In 2002, the Churchill Trust awarded a fellowship to Jenni Le Cussan (LHIB field officer) to investigate the impacts of weeds on Indo-Pacific islands. This research informed the 2006 LHI Weed Management Strategy (LHIB 2006).
- In 2002–03 landscape-scale mapping and monitoring was undertaken to quantify the extent of invasive weeds on LHI (Le Cussan 2003). This mapping found that eight weed species had spread extensively into the PPP and posed an immediate and serious threat to the terrestrial ecology of the island. The mapping identified the need for an island-wide and time-driven weed eradication program, without which the island would remain at risk to invasive weeds.
- In 2004, with the support of a grant of $1.2 million from the NSW Environmental Trust (NSW Government), the LHIB undertook to eradicate all noxious weeds (with the exception of Crofton

Weed *Ageratina adenophora* and Tiger Lily *Lilium formosanum*). This funding allowed the LHIB to commence its Weed Eradication Program discussed in this report.

- The position of Flora Management Officer was created in 2006.
- In 2006, the LHIB prepared and implemented the *Weed Management Strategy for Lord Howe Island* (LHIB 2006) with the aim of eradicating 25 species of weeds on LHI.
- In 2011 the program stopped using triclopyr and switched to a glyphosate–metsulfuron-methyl mix on all woody weeds.
- The NSW Noxious Weeds (Weed Control) Order 2014 (NSW Government 2014) – in effect for 5 years – lists all weeds declared noxious in NSW, including LHI, under the *Noxious Weeds Act*.
- Currently, 68 weed species are priority targets for eradication on the island, 40 of which are species with only small numbers and a limited distribution (estimated at less than 1000 individuals) and mainly close to the Settlement area.

1.2 Scope of this report

The LHI Weed Management Strategy (LHIB 2006) projected a 30-year time-frame for eradication of targeted weeds, based on 15 months of data collected from the start of the Weed Eradication Program in 2004. Year 10 is a critical point at which to measure progress and determine if the program is achieving an eradication trajectory, to forecast future costs, and to assess risks with the program and areas for improvement.

This report measures the outcomes of the program to date (2004–14) against the projections in the initial strategy (Appendix 3), reviews landscape-scale mapping undertaken in 2002–03 and repeated in 2013–14, and analyses data from the Lord Howe Island Weeds Database (LHI WD). The LHI WD stores all data on the weed eradication effort for each spatial weed management unit on the island, including hours of labour and total counts of weeds removed per plant life-stage. These data are used to forecast future costs, priorities for treatment and to monitor outcomes on the ground.

This report will also inform the current revision of the 2006 LHI Weed Management Strategy.

The following sections provide a summary of the noxious weeds of LHI, a detailed summary of the methodology of weed eradication on LHI used between 2004 and 2014, and of the results of the eradication program over those 10 years. They are followed by recommendations for future action and identification of the funding required to continue to meet the objectives of the 2006 Weed Management Strategy.

2 The weeds of Lord Howe Island

Weeds pose a significant threat to the biodiversity of the LHIG, by competing with native species and transforming habitats to the detriment of native species. Invasion of native plant communities by weeds is listed as a key threatening process under both the NSW *TSC Act* and the Commonwealth *EPBC Act*. Of the 670 species of plants known to have been introduced to the island, at least 40% – approximately 270 species – have invasive characteristics or can be considered weeds (DECC 2007). The diversity of life-forms of the invasive weed species of LHI and the strata of a native plant community they can occupy – from herbaceous and ground layering plants to shrubs, trees, vines and epiphytes – increases the cumulative impact and the risk to the island's ecology; over time a diversity of weed flora can dominate and replace native plant communities.

The weed species on LHI targeted for eradication or containment (control) are species that are known to alter habitats and ecosystems, have high environmental tolerance, and are capable of broad dispersal by wind, birds or, formerly, Pigs. Target species include species listed as Australian Weeds of National Significance, are recorded on the National Environmental Alert List for environmental weeds, listed among the World's 100 Worst Invasive Alien Species, have demonstrated invasive capacity on islands, or similar environments, in Australia and elsewhere, or have dispersal mechanisms that indicate potential to readily spread across the island.

Weeds of National Significance (WoNS) are those regarded as the worst weeds in Australia and require national effort owing to their degree of invasiveness, potential for spread, and their social, economic or environmental impacts in at least several states or territories; management of the weed must also benefit from national coordination (see http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/wons.html). Of the 32 listed WoNS, 11 occur, or formerly occurred, on LHI: Bitou Bush, African Boxthorn (*Lycium ferocissimum*), Bridal Creeper (*Asparagus asparagoides*), Climbing Asparagus (*Asparagus plumosus*), French Broom (*Genista monspessulana*), Ground Asparagus, Lantana (*Lantana camara*), Madeira Vine (*Anredera cordifolia*), Cat's Claw Creeper (*Dolichandra unguis-cati*; now eradicated), Salvinia (*Salvinia molesta*) and Water Hyacinth (*Eichornia crassipes*). All WoNS that occur on LHI are identified for eradication.

The **National Environmental Alert List** for environmental weeds lists non-native plant species in the early stages of establishment and with the potential to become a significant threat to biodiversity if they are not managed. The National Environmental Alert List currently identifies 28 species that have established naturalised populations in the wild in Australia and have the potential to become a significant threat to biodiversity (see http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/alert.html). Three species are, or were, recorded on LHI: Glory Lily (*Gloriosa superba*), Leaf Cactus (*Pereskia aculeata*) and Tipuana (also called African Rosewood *Tipuana tipu*; now eradicated).

The list of the **World's 100 Worst Invasive Alien Species** (Lowe *et al.* 2004; ISSG 2013; see http://www.issg.org/database/welcome/) lists invasive pest animals and weeds considered among the worst on the planet. Four species from this list are present on LHI: Cherry Guava, Ginger Lily (*Hedychium gardnerianum*), Singapore Daisy (*Sphagneticola trilobata*) and Giant Reed (*Arundo donax*).

NSW *Noxious Weeds Act 1993*[1] and the Noxious Weeds (Weed Control) Order 2014. Under the Act, noxious weeds are those plants that have the potential to cause harm to the community and individuals, can be controlled by reasonable means and have the potential to spread within an area and to other areas. Under the *Noxious Weeds Act*, weeds can be listed for Local Control Authority (LCA) areas or state-wide. A LCA has a responsibility for inspections and enforcement on private lands as well as control of noxious weeds on their own lands. The LHIB is the LCA for the Island. Declaration as a noxious weed under the Act enables an all-tenure approach to the management of weed species. The Noxious Weeds (Weed Control) Order 2014 lists all weeds declared noxious in NSW under the *Noxious Weeds Act*, their class (five classes of noxious weeds are defined; see Appendix 1: Table A4) and the area to which the order applies. Currently, 68 invasive weed species declared noxious under Weed Control Order 2014 occur on LHI and are targeted for eradication.

Other listings. The NSW Natural Resource Commission undertook a review of weed management in NSW (Natural Resource Commission 2014) and identified 22 extreme to high-priority invasive species that posed a threat to biodiversity in NSW, 14 of which occur on LHI and all of those are listed for eradication. Most of the 22 species are listed as noxious weeds under the *Noxious Weeds Act*, although some are only declared for a small number of LCAs, even though they are more broadly present in NSW, and more than half are WoNS (Natural Resource Commission 2014). A number of **native Australian plants** that are not indigenous to LHI have been introduced and spread across the island and are considered invasive. In order of current impact or spread on LHI they are Pittosporum (*Pittosporum undulatum*), Silky Oak (*Grevillia robusta*), Umbrella Tree (*Schefflera actinophylla*), Flame Tree (*Brachychiton acerifolius*) and Purple Cherry (*Syzygium paniculatum*).

Sleeper weeds are non-native plants that have naturalised but have not yet reached their potential to form large and widespread populations. Such plants can appear benign for many years, but may suddenly spread rapidly and widely. Plant naturalisations often lag half a century behind housing developments (Sullivan *et al*. 2004 in Bassett *et al*. 2016), meaning that today's gardening practises (if not yesterday's) will have future affects on the environment (Bassett *et al*. 2016). Sleeper weeds are often not recognised as significant problems until their impact becomes evident (http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/sleeper.html). There are many plants on LHI that can be considered sleeper weeds.

2.1 Target weed species

The 2006 *Weed Management Strategy for Lord Howe Island* (LHIB 2006) identified 25 weed species to be eradicated (see Appendix 1). Subsequent to the 2006 Weed Management Strategy, the Noxious Weeds (Weed Control) Order 2014 (NSW Government 2014) was gazetted. It lists all weeds declared noxious in NSW under the *Noxious Weeds Act* and supersedes the listing within the 2006 Weed Management Strategy.

Also subsequent to the 2006 Weed Management Strategy, a number of new and highly invasive weed species have been detected in gardens on LHI, including Cat's Claw Creeper, Climbing Nightshade (*Solanum seaforthianum*), Ming Fern (*Asparagus macowanii* var. *zuluensis*), Leaf Cactus and French Broom.

[1]The *Noxious Weed Act* is to be replaced by the new NSW *Biosecurity Act 2015*.

Currently, a total of 155 weed species that occur on LHI are declared noxious for NSW, with 68 declared species listed specifically for the LHI Local Control Authority (LCA) area. The top 10 noxious weeds of LHI are listed in Table 1.

Table 1 The top 10 noxious weed species of LHI (arranged in order of decreasing numbers removed through the Weed Eradication Program). All species are declared noxious weeds under the NSW *Noxious Weeds Act*. Other listings in which a species occurs: WoNS, Weeds of National Significance; Alert, National Environmental Alert List; IUCN, World's 100 Worst Invasive Alien Species; NRC, extreme (NRCx) to very high (NRCv) priority invasive species that posed a threat to biodiversity in NSW (Natural Resources Commission 2014). See Appendix 1 for a full list of species targeted for eradication.

Common name	Scientific name	Other listings
Cherry Guava	*Psidium cattleyanum* var. *cattleyanum*	IUCN
Ground Asparagus	*Asparagus aethiopicus*	WoNS, NRCv
Ochna	*Ochna serrulata*	NRCv
Bridal Creeper	*Asparagus asparagoides*	WoNS, NRCv
Sweet Pittosporum	*Pittosporum undulatum*	
Climbing Asparagus	*Asparagus plumosus*	WoNS
Cotoneaster	*Cotoneaster glaucophyllus*	
Glory Lily	*Gloriosa supberba*	Alert
Lady-of-the-Night	*Cestrum nocturnum*	
Bitou Bush	*Chrysanthemoides monilifera* subsp. *rotundata*	WoNS, NRCx

Eradication versus containment

The practicality of eradication of a weed species is a significant consideration in determining management priorities. The weed species identified for ***eradication*** on LHI are those species for which eradication is considered feasible given adequate resourcing, technical applications and the life-history traits of the species. Species targeted for eradication must be able to be removed from all areas across all tenures. Species for which eradication cannot be considered practical given current resources are identified for ***containment*** (control only). Pannetta & Timmins (2004) describe a range of criteria for determining the feasibility of ***eradication*** of terrestrial weed incursions. Some of these are relevant to LHI, including:

- The species can be readily detected at all life-stages (in differing vegetation types).
- The species responds to treatments.
- The species is prohibited from re-introduction to the island as per LHI Regulations 2014 and detailed in the LHI Plant Importation Policy 2014 (LHIB 2014).

- Long juvenile periods with low rates of persistence in seed-banks.
- The rate of removal can exceed the rate of reproduction.
- The extent of the infestation is known or can be determined (improved success with incursions less than 1000 ha in extent).

All of the **68 declared noxious weeds** listed specifically for the LHI LCA area **are targeted for *eradication*** (Table 2, Appendix 1). Although this may seem an onerous task, 40 of those species had small populations (an estimate of less than 1000 individuals on the island) or restricted distributions at only a limited number of sites, mainly close to the Settlement (Table 2). Early intervention for these 40 species will reduce future impacts and the cost to undertake their removal.

In addition to the 68 species targeted for eradication, **46 species are targeted for *containment*** (i.e. control only), none of which are declared noxious weeds (Table 2, Appendix 1). Of these, eight species should be considered potential species to be upgraded to targets for eradication.

Of the 25 species identified for eradication in the 2006 Weed Management Strategy, all but two remain the focus of eradication efforts. The remaining two – Mauritian Hemp (*Furcraea foetida*) and Sea Spurge (*Euphorbia paralias*) – are targeted only for containment as, firstly, they are not declared noxious weeds under the Noxious Weeds (Weed Control) Order 2014 (NSW Government 2014), and, secondly, it is not considered feasible to eradicate Beach Euphorbia as it will continue to be dispersed to LHI through sea-drift.

Table 2 Summary of declared noxious weeds on LHI and targets for eradication or containment (control). Declared noxious weeds are those identified in Noxious Weeds (Weed Control) Order 2014 (NSW Government 2014). LCA = Local Control Authority.

Declared noxious weeds	Number of species
Declared noxious weeds specified for LHI LCA area (see Appendix 1: Table A1)	68
Declared noxious weeds for NSW that occur LHI + declared weeds for LHI LCA area	155
Noxious weeds targeted for *eradication* on LHI	
Declared species targeted for eradication on LHI (see Appendix 1: Table A1)	68
Species targeted for eradication with 130,00–700,000 plants removed (classified as Common and Widespread to Localised) – Settlement and PPP	10
Species targeted for eradication with >1000 to <2000 plants removed (classified as Occasional to Uncommon) – Settlement and PPP	18
Species targeted for eradication with <1000 individuals removed (classified as Uncommon) – Settlement only	40
Weeds targeted for *containment* (control)	
Number of species targeted for containment and which have been subject to treatment and control (as recorded in LHI WD; see Appendix 1: Table A2)	46
Alert List – Sleeper weeds	
New garden escapes will be controlled as they are detected in the PPP during eradication grid-search and will be monitored for upgrading to eradication	Indeterminate

Based on the numbers of plants removed during the Weed Eradication Program (see following sections), the two most abundant species of weed were Cherry Guava (recorded from 165 weed management blocks) and Ground Asparagus (recorded from 192 weed management blocks) distributed over an area up to 1064 ha – an island-scale invasion range.

Most of the weeds targeted for eradication on LHI are able to be spread widely – dispersed by wind or by birds – and are capable of establishing in all habitats across the island (cliff-edges, from intact to disturbed forest, at a wide range of elevations and aspects). Some plant communities, such as *Howea* forest (DECC 2007), show a level of resilience to weed invasion but all habitats have been shown to be at risk from weed invasion. Further, the diversity of life-forms of the highly invasive weeds of LHI (vines, herbaceous and ground layering plants, shrubs, trees and epiphytes) can have a compound effect on habitats, resulting in a weed-dominated flora.

3 Methodology of the Weed Eradication Program

3.1 Target area

For the eradication of weeds, the entire 1455 ha of the island has been delineated into nine main landscape units (Figure 2):

- Malabar (191 ha)
- Settlement North (186 ha)
- Transit Hill (83 ha)
- Settlement South (92 ha)
- Intermediate Hill (170 ha)
- Lidgbird North (129 ha)
- Lidgbird Remote (155 ha)
- Lidgbird South (309 ha)
- Gower (255 ha)

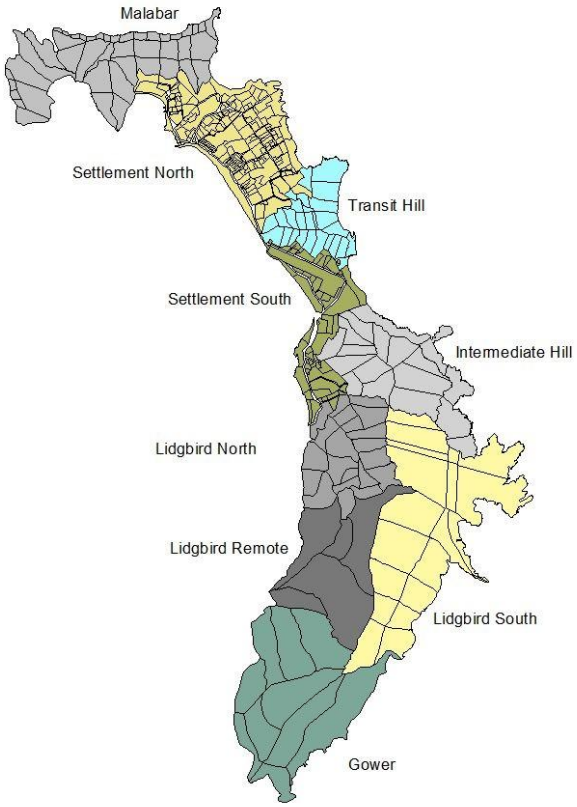


Figure 2 Map of LHI weed management units.

These nine units are further divided into a total of 395 weed management blocks, based on terrain, tracks or lease boundaries. Weed management blocks are simply marked on the ground by blue marker tape and are mapped in ArcView version 3.3 (ESRI, Redlands, CA) a geographic information system (GIS). Each weed management block is uniquely coded, which enables teams to locate their position and report on weeding effort for each block.

The LHIB is responsible for the management of weeds across the island (1455 ha)[2]. To rationalise the investment and priorities for weed search and control, 1024 ha of accessible terrain with known weed invasions is targeted for grid-search every 2 years. Within the Settlement, 160 ha of leasehold land is the responsibility of leaseholders. The remaining 271 ha of the island comprises remote terrain that is assumed to be weed-free based on surveillance, incidental surveys during searches for threatened species, and current patterns of the spread of weeds; these are currently not targeted as priorities for grid-search effort.

- 160 ha leasehold within Settlement areas (and the responsibility of leaseholders)
- 271 ha remote terrain, assumed to be largely or wholly weed free – surveillance only)
- 1024 ha accessible terrain with known weed infestations

Note throughout this report, that reference to the Settlement includes both the Settlement North and Settlement South landscape units.

[2]Note the areas given for each landscape unit above, and elsewhere in this report, are extracted from GIS shape files and include areas of marine, sand and rock, which sum to a total area greater than 1455 ha.

3.2 Search strategies and search effort

The LHI Weed Eradication Program is a multispecies program combining search and control, with all target weeds removed progressively as they are detected in a block. The 2006 Weed Management Strategy recommended repeat searches for each management block of the island at a maximum interval of 24 months within the 80% of the island (1164 ha) for which the LHIB is responsible (LHIB 2006). Such an approach was developed for weed eradication on Raoul and Little Barrier Islands by the New Zealand (NZ) Department of Conservation (Le Cussan 2004a). The procedure aims to detect, and remove, all mature plants in the early stages of the weed eradication program to prevent fruiting, or further fruiting, and the spread of seeds and to then, during follow-up grid-searches, detect and remove all missed plants, seedlings and re-shooting plants before they are able to mature and set fruit. This process eventually depletes seed-banks to deliver eradication.

To achieve the repeat treatment of priority weed blocks every 24 months requires a minimum annual search target of 500 ha per year. Nevertheless, while an area target is important, it should not be achieved at the expense of the quality of search effort.

Each weed management block is searched in a grid-pattern to ensure that all terrain is covered and target weeds both detected and removed. Effective searching requires weeders to be spaced no more than 5 m apart and even closer in dense bushland. Grid-searches are also used when working on rope and by helicopter (see below).

As stated above, searches and removal are preferably conducted every 24 months, but sites with Glory Lily (in summer) and Climbing Asparagus (in winter, outside of the breeding season of Flesh-footed Shearwater *Ardenna carneipes*) are treated annually.

On-ground search effort involves teams lining up along the edge of a block. They first progress along the boundary tape working in a staggered line ('emu parade') towards the end of the block. The person on the marked edge effectively leads the team. The weeder on the opposite end of the team deploys a stringline that delineates the next edge of search effort. The team leader retrieves the set stringline and progressively leads a new run of search effort while the person at the outer end of the search line deploys a new stringline. This is repeated until the weed management block has been fully searched and treated.

Grid-search effort is also applied by the LHIB on Crown Land in Settlement areas, and periodically on leasehold land, where the weed problem is complex. For example, sites with Climbing Asparagus are visited annually and sites with Madeira Vine visited at least three times a year. The LHIB recently assisted with the dismantling of recently listed tree weeds (e.g. Silky Oak and Flame Tree) owing to the cost and risks of the work. Weeding on leases is the responsibility of the leaseholder, but the LHIB works to achieve good weed outcomes on all tenures.

GPS

In 2014, all weed teams began using GPS (global positioning system) to record the track log of their search and removal effort. All weeders undertaking searches, including volunteers, carry a GPS. Figure 3 shows a sample of the GPS tracks of cumulative grid-search effort across the island in 2015. The GPS units also have a base map of the weed management blocks and their codes so weeding teams can locate their position at any point in the landscape.

The GPS-recorded search effort is analysed to determine if the search effort for a management block is adequate or complete. This analysis also helps to identify areas that cannot be readily accessed on foot and require access by helicopter or rope.

New or isolated infestations of weeds (mostly mature plants) are flagged on the ground with pink survey tape and are uniquely coded and marked with a waypoint using the GPS. This is referred to as 'INF-ING' – marking an infestation. INFs are marked where the detection of isolated weeds may be difficult and to alert weeders in the future to be alert for seedlings, re-shoots or potential missed mature plants when the block is revisited.

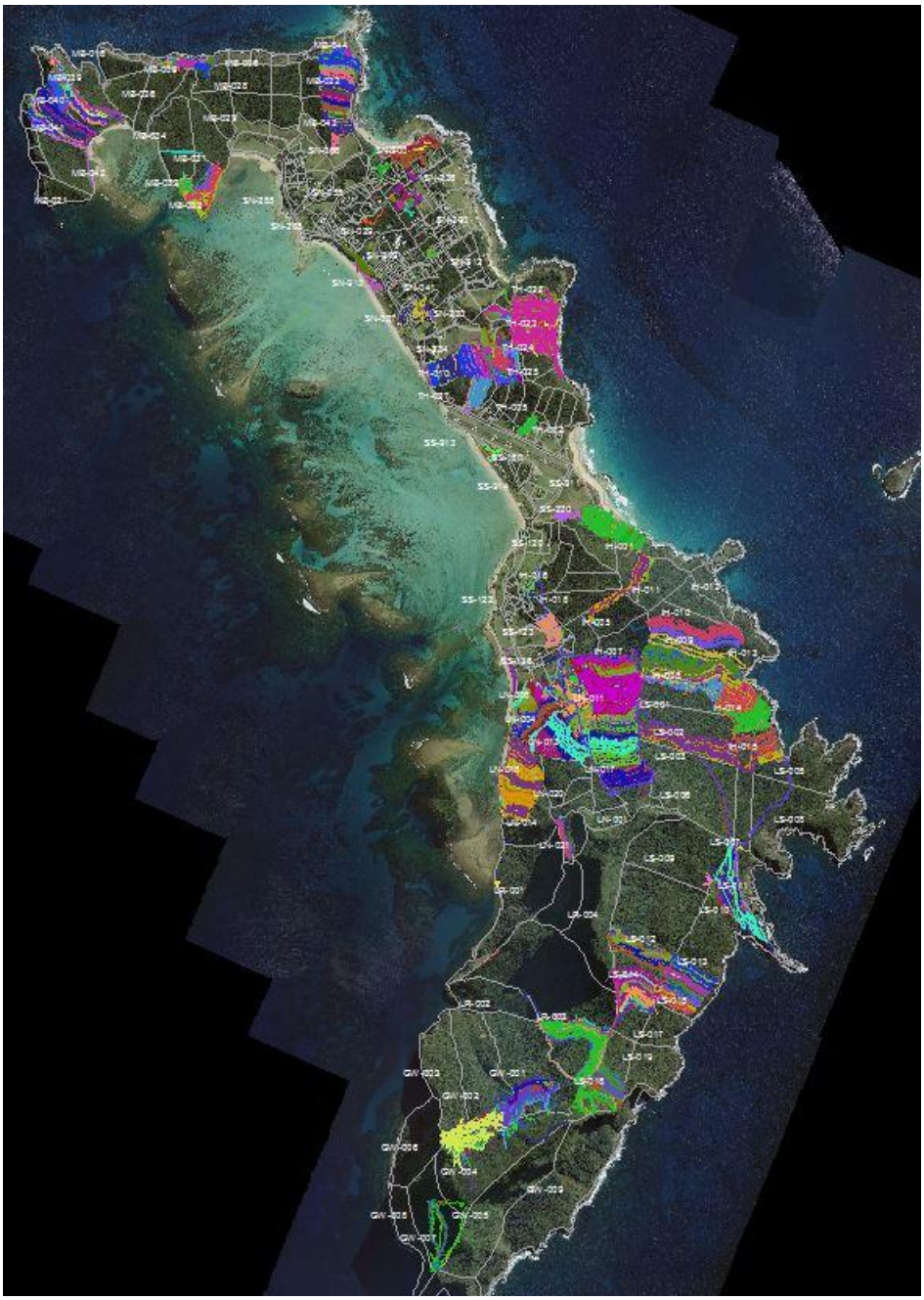


Figure 3 Example of GPS recorded weed search effort for 2015.

Weed removal

Weeds are controlled in several ways: removal by hand (crowning out); by cut, scrape and paint; scrape and paint; or foliar spray using spray packs (see LHIB 2015); or by splatter gun or applied by helicopter (see below).

All target weeds encountered are treated in the field and are recorded on daily record sheets. The life-stage of the weeds removed – mature, juvenile or seedling – are recorded. The weight of Madeira Vine and corms of Asparagus weeds are also recorded.

Triclopyr was used as a herbicide up until 2011, when its use stopped. Since then, a mix of glyphosate and metsulfuron-methyl has been adopted for control of woody weeds and Climbing Asparagus.

Lord Howe Island Weeds Database

All field data are entered into the LHI Weeds Database (LHI WD). The Database is used to monitor change in weed populations, determine priorities for treatment schedules and to forecast future costs and program needs. Analysis of these data over time can be used to assess if the program is effectively removing weeds before they mature and therefore trending on an eradication trajectory.

Remote and rugged terrain

Given the remote and rugged terrain of LHI, technical approaches are required to deal with weeds growing on cliff-edges, cliff-lines and in other difficult terrain where access by foot is not practicable. The island has approximately 34 km of cliff-line, including sea-cliffs, internal cliffs and mountain cliff-lines. About 12 km of north-facing sea-cliffs or mountain cliffs are known or are presumed to harbour target weeds, whereas south-facing cliffs are presumed to be weed free, based on preliminary helicopter surveillance in 2009 and the pattern of weed invasion elsewhere on LHI.

The extent of cliff-lines and remote terrain on LHI poses a challenge for weed control, and the development of effective techniques to search for and control weeds is paramount to the success of the Weed Eradication Program. The program has trialled several methods including terrestrial rope access (including contracting of rope specialists and training of staff in working safely at heights), winching teams into remote areas by helicopter, and aerial spot-spraying by helicopter (using cone sprays and lance-sprays).

Helicopters. Helicopter operations are costly, but can achieve desired outcomes in a shorter time and with lower workplace health and safety risks than terrestrial access to remote, rugged or inaccessible terrain. Remote area work is arduous and winch access by helicopter (heli-winch) enables teams to be on-site daily, unfatigued, and with more time to work over larger areas compared with access to remote or difficult sites by foot (Figure 4). All staff are required to walk out in the event that conditions make extraction by winch unsafe or impossible.

The funding for helicopter programs was initially based on NSW Office of Environment and Heritage (OEH) rates. Loss of services from OEH resulted in a lag in finding alternative operators and an increase in project costs. The increased costs limited the extent of operational days. However, it provided relevant estimates for future operations, which have now been used to forecast future helicopter operations.

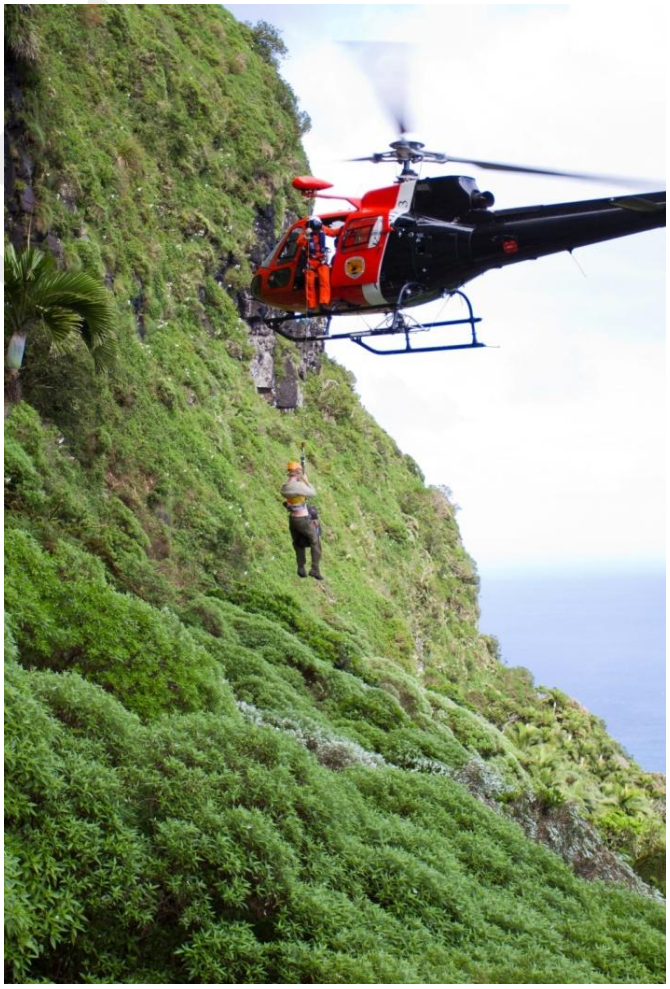


Figure 4 Helicopter winch access on Mt Gower. This access replaces a 4–5 hour return walk.

The helicopter program has trialled several helicopter platforms for winch access, including the MBB/Kawasaki BK117 helicopter, which has

Figure 5 The helicopter-mounted lance-spray unit from McDermott Aviation in action.

higher running costs than some of the other helicopters but is considered safer and more stable platform.

A targeted helicopter surveillance and spraying program using a forward-mounted lance-spray apparatus was trialled in winter 2015 to undertake search and treatment of Ground Asparagus and Bitou Bush on sheer cliffs. Over two operational days, 10 km of cliff-line and approximately 1500 individual weeds were detected and treated. The lance-spray program was a first trial application for Australia and proved to be very successful (Figure 5). Further funding is needed to complete the search and treatment of remote areas to be covered in this way and to provide follow-up treatment. This operation occurred outside of the 10-year 2004–14 period but provided a critical breakthrough in efficiently and effectively obtaining accessing to weeds across a network of cliffs.

Future methods

The LHIB has recently received funding to investigate the application of Herbicide Ballistic Technology (HBT) in remote terrain, a method developed by the University of Hawaii at Manoa (Honolulu) to target control of woody weeds using a pneumatic gun mounted on a helicopter to deploy pelletised herbicide, and also the use of unmanned automated vehicles (UAV), or drones, for monitoring and control of weeds. Further refinements and trials of new approaches will work to increase access to all parts of the island and to prevent the increase in weed populations in rugged terrain.

As the density and distribution of weeds are reduced over time, the program needs to consider the benefits of using multispecies weed-detector dogs, specifically for Asparagus weeds, Cherry Guava and Ochna. The NZ Department of Conservation have been successfully using multispecies weed-detector dogs on a number of island eradication programs (see http://blog.doc.govt.nz/2015/03/30/raoul-weed-dog/) and weed-detector dogs are currently being used in the Orange Hawkweed (*Hieracium aurantiacum*) eradication program in NSW (Hamilton *et al*. 2015; also see http://www.environment.nsw.gov.au/pestsweeds/OrangeHawkweed.htm).

3.3 Labour resources

The significant effort in searching for and removing weeds across the island over the 10 years to 2014 has been achieved through the work and efforts of the LHI community, the LHIB and its employees, external contractors and the volunteers supported by the LHIB and the Friends of Lord Howe Island (who pay to come and weed on LHI).

The following labour resources have been involved in the Weed Eradication Program, over the 10 years 2004–14:

- 66 people employed by the LHIB (casual, temporary or permanent positions)
- 35 bush regeneration contracts (over 11 contract providers)
- 4 rope-access contracts (over 2 contract providers)
- 752 Friends of Lord Howe Island volunteers
- 125 external volunteers (with individuals working for periods of 10–20 days over the 10 years)
- 30 local volunteers (individuals working for periods of 1–20 days over the 10 years)

Based on the total count of hours, including volunteer hours, a total of 79.4 full-time equivalent (FTE)[3] positions have been employed on the program over the 10 years (see section 3 Results below). The size of the program team has ranged between 3 and 15 staff, including volunteers, at any given time over the 10 years 2004–14, with staffing levels subject to available funding and availability of volunteers.

The LHIB currently employs a project manager (Flora Management Officer), a field supervisor, two bush regenerators (three FTE permanent weed eradication positions) and supports a volunteer program. The estimated current total annual expenditure by the LHIB on the Weed Eradication Program is $329,000.

At the start of the program in 2004, teams from the NZ Department of Conservation were seconded to help roll out program methodology on the ground and to train local staff in data recording systems. Volunteers and contractors are also engaged to help build the size of the program team, to assist in treatments in complex weed management blocks, and to increase skill sharing. The latter is important as LHI is an isolated location with limited ability for workers to network physically with other ecological restoration practitioners on new and emerging technologies.

Weed eradication and containment programs, such as this one, often confront the dual challenges of eradication fatigue and maintaining effective search and control efforts when faced with diminishing

[3] A FTE is estimated as a total of 1632 hours work per year (204 work days; exclusive of an estimate of wet weather and holiday and sick pay).

returns of weeds removed per unit effort over time. To address these issues, at least partly, the LHI Weed Eradication Program offers short-term casual positions or part-time working weeks to give staff opportunities to work on other projects, obtain other employment or undertake skills development. Detailed position descriptions specific to weed eradication work on LHI are critical to ensure prospective staff are well informed of the requirements of their position, including high levels of bush fitness, the capacity to deal with repetitive search effort, and a focus and intent to ‘get the last weed’.

4 Results of the Weed Eradication Program

The outcomes of the Weed Eradication Program are measured and evaluated by: (1) the area treated (hectares) per year, (2) the effort (hours of labour) expended on the ground annually in searching for and controlling weeds, and (3) the number of weeds removed per year. The effectiveness of the program is measured by the reduction in the numbers of weeds removed island-wide. The data for these analyses are extracted from the Lord Howe Island Weeds Database (LHI WD).

4.1 Treatment effort and area

From the start of the program in November 2004, a total of more than 129,000 hours of on-ground effort has been expended in searching for and removing target weeds over a cumulative area of 3941 ha[4]. Table 3shows the cumulative area searched and effort expended for each landscape unit, as well as the number of weeds removed. When a weed block has been completely searched it is entered into the LHI WD as 'complete'. Where targeted or localised weeding has been undertaken, or blocks partially treated, those blocks are entered as 'incomplete', indicating further search effort is required, or the actual area treated is entered to for reporting. The area (hectares) and extent of search effort in Table 3are complete and actual areas and search effort.

Over the 10 years, the annual search effort in terms of area covered ranged between 214 ha and 603 ha (average 394 ha per year; Figure 6). The area treated annually has fluctuated, largely as a result of the intermittent nature of funding allocations. Based on the first 15 months of data from the Weed Eradication Program, the 2006 Weed Management Strategy (LHIB 2006) estimated the expected area to be treated over the first 5 and 10 years of the program, equivalent to an overall average of 500 ha per year over 10 years. Comparing expected area treated against the actual area for these two periods, the program delivered 90% of the areal target over the first 5 years and 78% over 10 years (Table 4).

Annual effort in terms of hours on the ground ranged from 10,300 to 15,900 hours, equivalent to 6.3 to 9.7 FTE per year over the 10 years (average of 12,900 hours, or 7.9 FTE, per year over 10 years) (Figure 6). The 2006 Weed Management Strategy projected average resourcing, including volunteer hours, of 9.3 FTE per year on the ground, and a total of 46.4 FTE over 5 years. As with area searched, effort has varied annually, largely as a result of fluctuations in funding. In the 2010–11 financial year the program experienced a period when only 3 FTE staff were employed (and, notably, when Cherry Guava re-shoots were fruiting). This was followed by an injection of funds requiring expenditure at short notice, which elevated the actual effort (as FTE) for the year but failed to treat priority blocks and weeds at key times. Best results can be achieved with a consistent level of resourcing to ensure sufficient staff and technical approaches are deployed at key times to meet the annual area targets.

4.2 Number of weeds removed

The total numbers of weeds removed and of each plant life-stage for each landscape unit from 2004 to 2014 is given in Table 3. In that time more than 2,214,166 individual weeds have been removed as seedlings, or juvenile or mature plants. Overall, the number of weeds detected and removed per year through the Weed Eradication Program shows a strong downward trend over the 10 years of the program to date.

[4] NB: Weeds removed from leases under the Noxious Weed Inspection process are not comprehensively entered into the LHI WD and so not fully accounted here.

Table 3 Cumulative area searched and treated, number of hours, and numbers of weeds removed for each landscape management unit from 2004 to 2014 (LHI Weeds Database).

Landscape unit	Area (ha)	Effort (hours)	Number			Total weeds removed
			Seedlings	Juveniles	Mature	
Malabar	758	36,947	198,814	87,239	63,550	349,603
Settlement North	449	11,161	44,265	35,006	44,565	123,836
Transit Hill	265	21,701	276,700	120,705	52,263	449,668
Intermediate Hill	826	21,844	253,551	165,288	60,979	479,818
Settlement South	165	2,316	50,213	14,676	15,693	80,582
Lidgbird North	532	21,750	399,904	163,068	124,442	687,414
Lidgbird Remote	94	1,175	546	624	969	2,139
Lidgbird South	795	9,980	9,194	11,261	5,225	25,680
Gower	58	2,792	6,697	5,072	3,657	15,426
Total	**3,941**	**129,665**	**1,239,884**	**602,939**	**371,343**	**2,214,166**

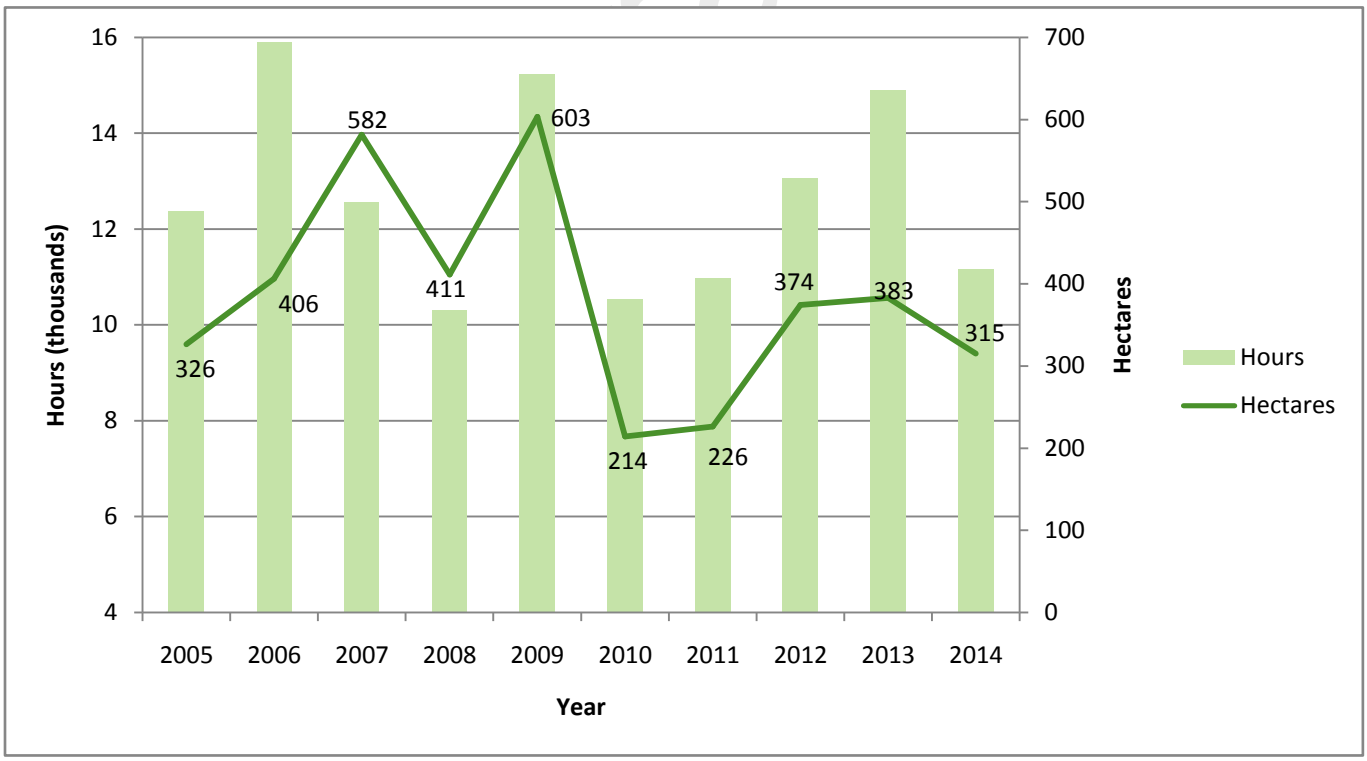


Figure 6 Weed search and removal effort (hours; vertical bars) and area treated (hectares; line) over 10 years, 2005–14.

Table 4 Expected and actual areas treated to Years 5 and 10 of the Weed Eradication Program. Actual data derived from the LHI WD. The Year 10 expected figure based on an average of 500 ha per year for Years 5–10 in addition to the Year 5 area.

	Expected (ha)	Actual (ha)	% achieved
Year 5	2531 ha	2328 ha	90%
Year 10	5031 ha	3941 ha	78%

Figure 7 shows the numbers of weeds of each life-stage removed annually, with corresponding annual effort (hours). The numbers of all weeds removed annually across the island (life-stages combined), with corresponding annual treatment effort, is shown in Figure 8, and the numbers of weeds removed with corresponding annual area searched, is show in Figure 9. These data show a strong downward trend in the numbers of all target weeds removed annually over the past 10 years, albeit with annual variations.

Figure 7 show that, as expected, a large number of weeds were removed at the start of the program, when the highest density weed infestations were targeted. The large number of weeds removed early in the program is an indication of the sheer extent of weed infestation on LHI, and the threat that weeds posed, and continue to pose, to the island, and is also testament to the enormous amount of work put in to remove weeds.

Figure 7 shows that the area treated in 2005–06 declined compared with the previous year owing to the effort needed to remove the dense weed infestations that were targeted (see cover images). The increase in the number of weeds removed in 2009 is thought to relate to the start of removal of dense Ground Asparagus infestations at Transit Hill when additional funding became available, and in 2012 the number of weeds removed again increased as a result of another injection of funding. The increase in numbers of weeds removed in 2014 reflects the increased effort undertaken on Cherry Guava on Mt Gower. However, the increase in numbers of weeds removed in 2014 is not matched by an increase in the area treated, which declined from the preceding year. A possible explanation for the discrepancy is that not all blocks for which treatment started in 2014 were completed in that financial year, which may have skewed the results.

Within the PPP, the number of weeds targeted for eradication that were detected and removed in 2005 to 2014 has declined by 80% for all life-stages and by 92% for mature plants.

Despite not meeting the 2006 Weed Management Strategy treatment target of 500 ha per year, the program has proved to be effective in achieving a significant downward trend in the number of weeds removed annually over the first 10 years (Figure 7Figure 9). Meeting the 500 ha per year areal target would have driven a stronger eradication trajectory than achieved. Sustained funding and corresponding labour inputs, with improved capacity, in the future will only drive stronger downward trends.

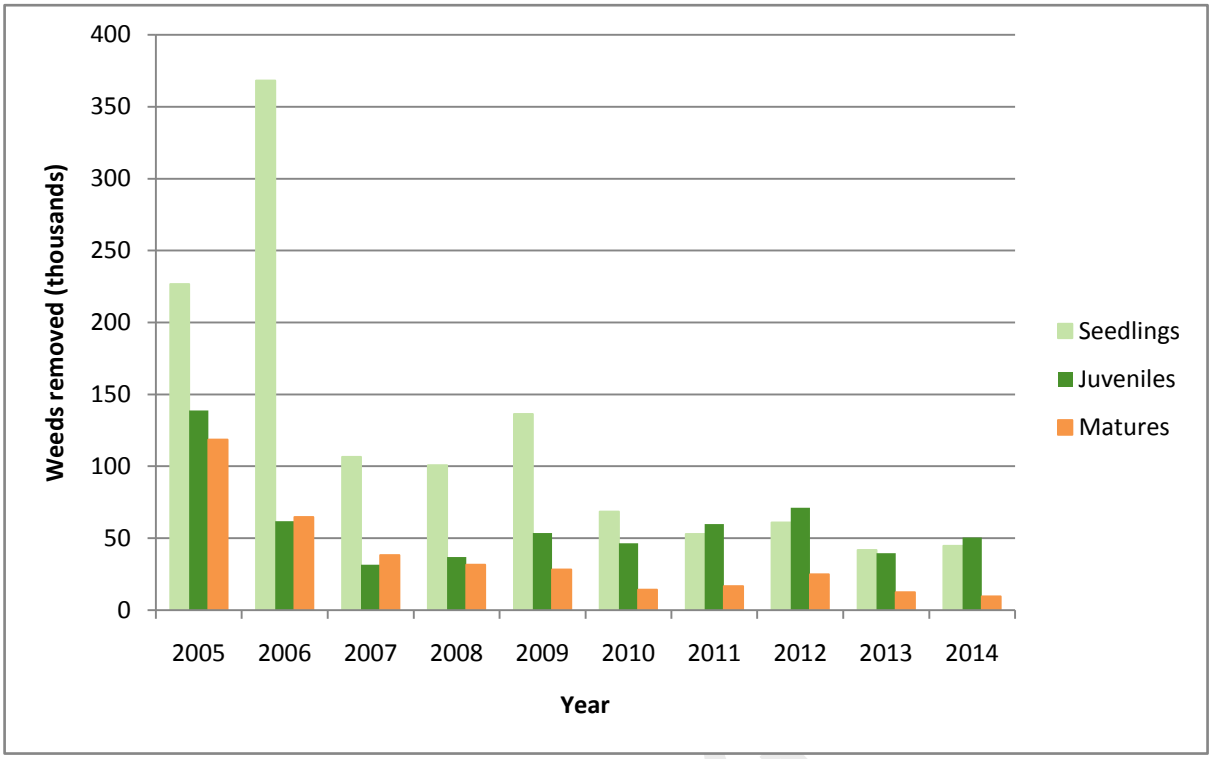


Figure 7 **Numbers of all weeds removed at each life-stage annually across LHI, 2005–14. (An additional 40,000 weeds removed during 2 months of weeding effort at the start of the program in November–December 2004 not included on graph.)**

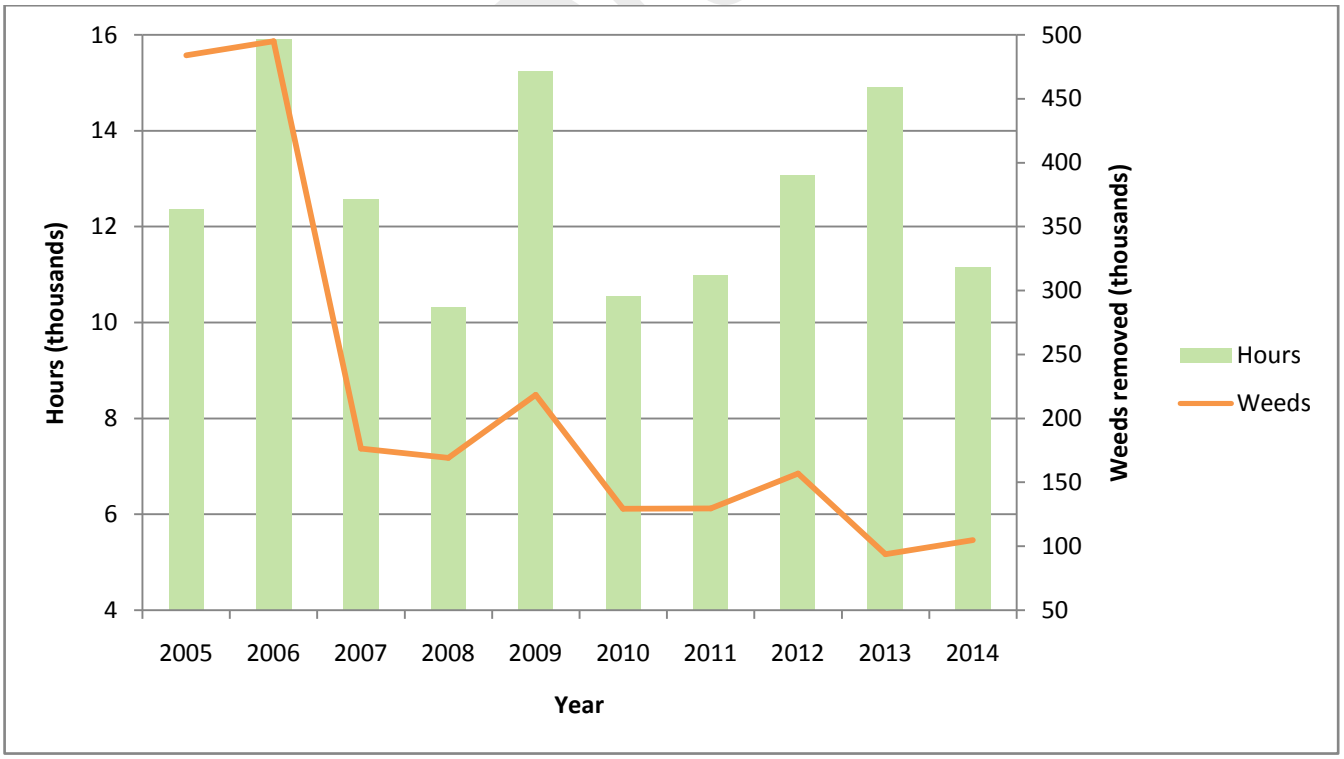


Figure 8 **Numbers of weeds removed and annual search effort (hours) across LHI, 2005–14.**

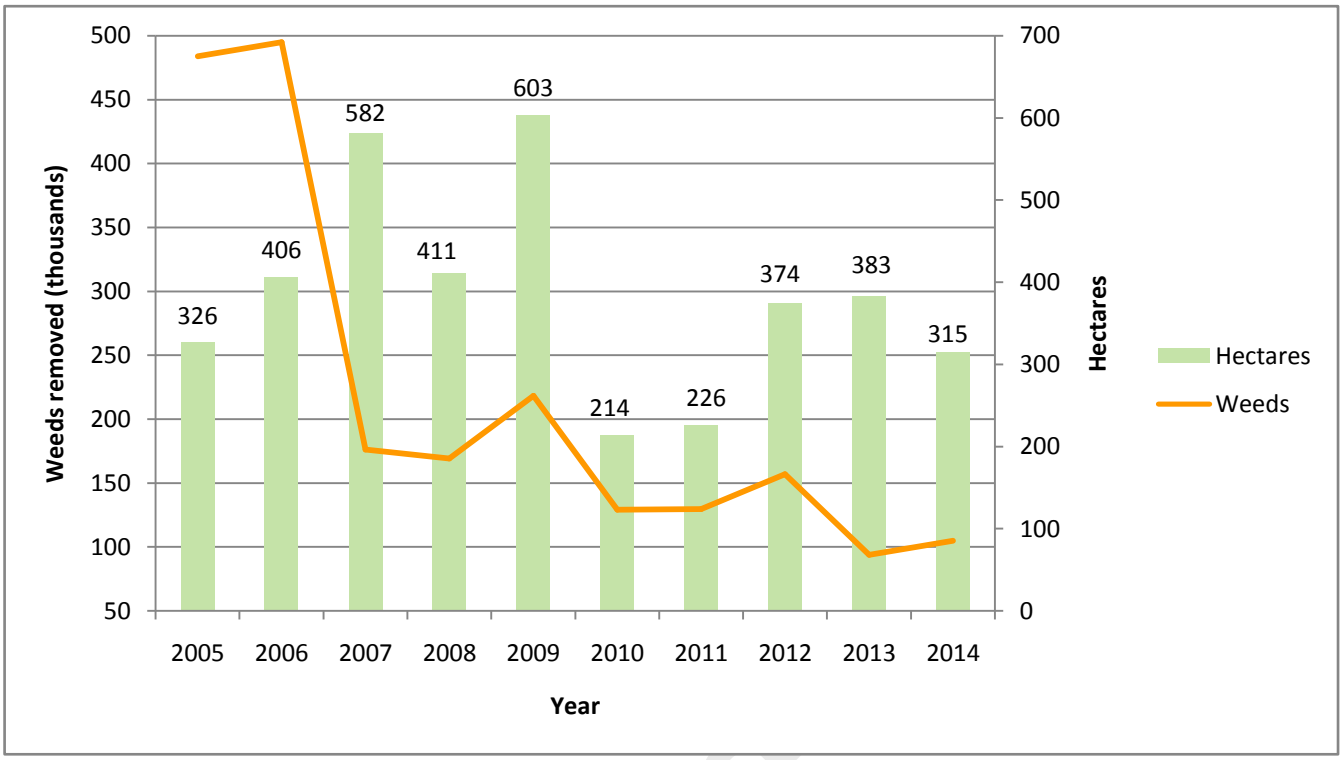


Figure 9 **Numbers of weeds removed and area treated (ha) across LHI, 2005–14.**

4.3 Repeat search effort

The 2006 Weed Management Strategy (LHIB 2006) recommended that, at a minimum, search effort for weed management blocks be repeated across the island within 24 months, to ensure blocks had follow-up treatment before emerging weeds could mature and set fruit again. By Year 10 of the program, all weed management blocks should have been visited five times, based on the 24-month treatment schedule. To date, only two landscape units (Lidgbird North and Intermediate Hill) have approached that target (Table 5).

Bringing the blocks up to speed

There are a number of factors that have contributed to not meeting the repeat search effort targets. At the start of the program not all target weeds were removed in initial treatments, often resulting in one weed being replaced with another. Further, some blocks were initially reported as complete, and the areas were thus assumed to be weed free even when they were not. Subsequent targeted treatment effort was then applied to remove remaining mature weeds and to adequately treat these blocks but it affected the number of complete visits attainable.

For example, in 2005–07 some blocks at Transit Hill were treated for woody weeds, but Ground Asparagus and Climbing Asparagus were left, allowing these species to proliferate with less competition. As a further example, weed-blocks in Malabar were reported complete when mature or dense infestations of Bridal Creeper were retained on the assumption that the Bridal Creeper Rust (*Puccinea myrsiphylli*) would control the plants, although it had little effect. Remote blocks in the southern mountains on Mt Gower were also initially reported and entered in the LHI WD as complete when they still held infestations of Cherry Guava below the cliff-lines.

Lastly, as with other parts of the program, inadequate funding at times during the first 10 years contributed to delays in search effort. Although there were shortfalls in substantial and committed funding for the program during some periods during the first 10 years, small-scale grants obtained at times enable targeted search effort of weed management blocks that were behind or contained outstanding hot spots of mature weeds, to bring infestations down to levels comparable with the remainder of the island.

Table 5 Area of each landscape unit, the number of weed management blocks in each, average number of visits to blocks in each landscape unit and the actual area treated over the 10 years of the program, 2004–14. Mean visits per block is the number of treatments for all weed management blocks divided by the number of blocks in the landscape unit.

Landscape Unit	Area of landscape unit (ha)	Number of blocks	Mean visits per block	Actual area treated 2004–14
Malabar	191	44[A]	3.4	758
Settlement North	186	196	2.25	449
Transit Hill	83	27	3.0	265
Settlement South	92	55	1.89	165
Intermediate Hill	170	18	4.6	826
Lidgbird North	129	21	4.0	532
Lidgbird Remote	155	5	1.0	795
Lidgbird South	309	19	2.6	94
Gower	255	9	2.6	58
Total	**1571**	**394**	**2.82**	**3941**

[A]Excludes 29 blocks with short benches of accessible terrain that end in steep, complex cliffs and narrow ledges, none of which has been treated as complete.

4.4 Meeting targets for area, effort and repeat treatments

Despite the conspicuous successes of the program over the first 10 years of its operation, the program has not met the expected annual area targets (500 ha per annum) nor achieved the maximum 24-month interval between repeat searches and treatments of landscape units and weed management blocks. The 2006 Weed Management Strategy also projected average resourcing, including volunteer hours, of 9.3 FTE per year on the ground and a total of 46.4 FTE over 5 years. The failure to meet these targets is a result of a range of factors, as discussed above; in summary, these include:

- Inconsistent funding over the first 10 years of the program. The program experienced significant shortfalls in funding, and subsequent reduction in area of search effort, in 2008, 2010 and 2011 (Figure 6).
- The assumption in the Weed Management Strategy that the effort (hours) to undertake repeat searches would decrease. Contrary to this assumption, the area and terrain of each

management block remains the same for repeat searches, even after most or all weeds have been removed, and the search effort needed can actually increase as weeds became less prevalent and less conspicuous. Nevertheless, a reduction in repeat search effort can be achieved, as recorded for the Transit Hill landscape unit. This reduction was most likely a result of the effort required to treat a widespread and dense infestation of Climbing and Ground Asparagus, and which was subsequently significantly reduced.

- Failure to complete search and control efforts in weed management blocks and landscape units, particularly in the early years of the program. For example, mature weeds (of all target weed species) were not removed in the first few searches and treatments across the island.
- Failure in control techniques. For example, broad-scale Cherry Guava treatments early in the program were ineffective, resulting in re-shooting and fruiting before blocks were revisited and having to control regrowth through debris piles, increasing work effort.
- The engagement of staff or volunteers was not necessarily aligned to the timing or goals of eradication and, in some instances, staff or volunteers were not suited to the work they were tasked to undertake.

Overall, the 2006 Weed Management Strategy did not forecast some of the complexities of the program and setbacks in determining the expected outcomes for the first 5 and 10 years of the program, and some of the assumptions of that strategy were incorrect. Nevertheless, the differences were not great and, despite program setbacks, lessons have been learnt and improvements to approach and techniques made. Further, the critical importance of adequate and consistent funding to the success of the program has been highlighted by the analysis of the reasons for failing to meet predicted targets. to enable the repeat treatment of blocks every 24 months across the island, and delivery of technical approaches for steep and remote terrain.

4.5 Differential treatments between landscape units

Figure 10 shows the total area treated in each landscape unit from 2004 to 2014, and the total number of weeds removed. The wide variation in treatment area and weeds removed in part reflects the size of the actual landscape unit, but mainly reflects the focus of search effort in areas with higher weed densities, such as Intermediate Hill, Lidgbird North and South, Malabar and Transit Hill; compared to the Gower landscape unit, where weed densities were assumed to be low and much of the area is inaccessible terrain requiring aerial surveillance and access. The small area treated for the Settlement North and South landscape units is in part due to the small size of the landscape units, in part because the areas also largely comprise modified habitats, such as the golf course and grazing land, and because weeding on leasehold land is undertaken by leaseholders as part of the Noxious Weed Inspection process.

Treatment times for landscape units

The treatment times for individual landscape units is related to variables within each landscape unit, such as the species of weed present, the density of infestations and accessibility of terrain. The 2006 Weed Management Strategy (LHIB 2006) assumed that the effort needed when revisiting blocks would decline after the first few treatments, following removal of mature plants, and that this would deliver a reduction of costs over time. Although dense weed infestations slow the pace of weeding, mature weeds are easier to detect. As weed population structure changes to increased numbers of juvenile and seedling plants, increased search effort is required to detect the smaller plants, which are readily missed without thorough searching.

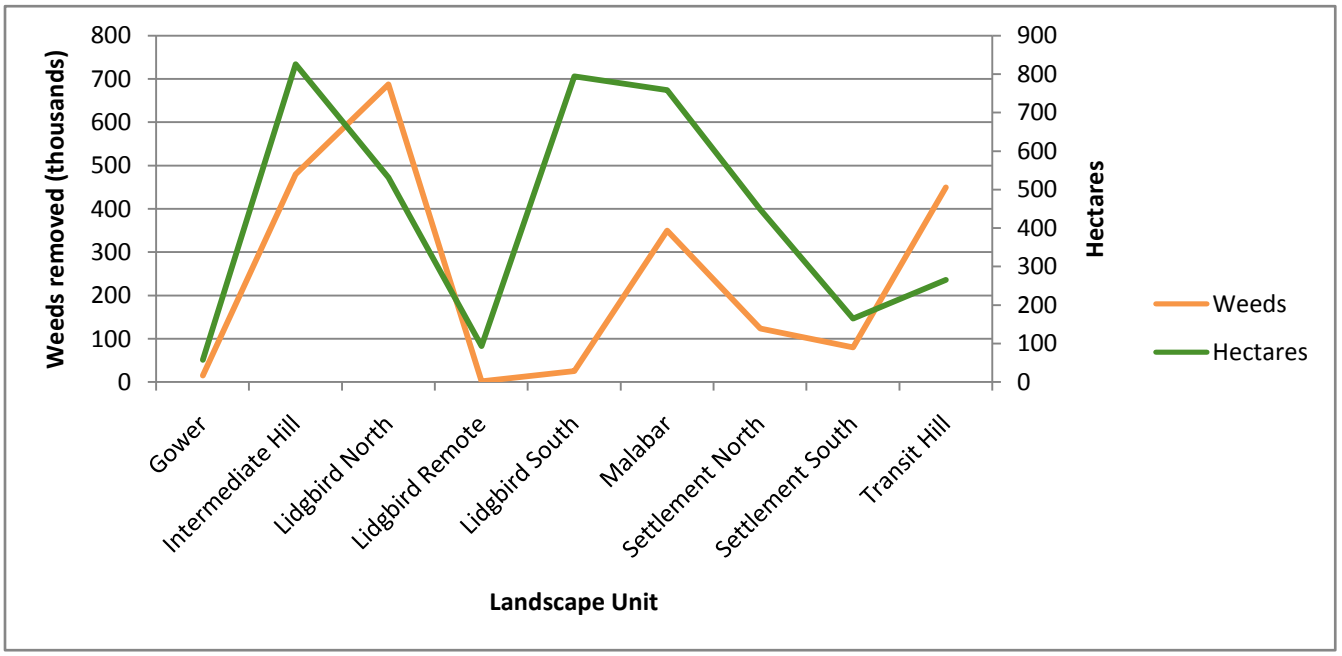


Figure 10 Total area treated (ha; green line) and numbers of weeds removed (orange line) for each landscape unit, 2004–15.

Owing to the varied terrain on LHI and the diversity of weeds being treated, intervals between repeat treatments vary between landscape units. Much terrain on LHI comprises dense, low, wind-sheared scrub that is difficult to move through regardless of whether weeds are present or not. Although it was forecast that, over time, repeat-treatment effort should reduce once weed seed-banks were depleted and juvenile and seedling plants removed. However, weed management blocks still need to be searched thoroughly and the assumption that lower numbers and density of weeds would translate into reduced search time has not been met.

To examine the assumption of a decrease in the effort needed for repeat surveys, the time taken to completely search and weed between the first and last treatments conducted, in the period 2004 and 2014–15, has been assessed using data for five landscape units: Malabar, Transit Hill, Intermediate Hill, Lidgbird North and Lidgbird South. Table 6 shows the change in effort (hours) expended to complete search and removal treatments between first and last treatments, and Figure 11 compares the numbers of weeds removed (of each weed life-stage) between first and last treatments and corresponding trends in treatment time for each landscape unit.

The change in effort required to complete treatments varied widely between landscape units, with some showing a reduction in effort (Transit Hill, Lidgbird North) to complete treatment of the unit, whereas others show an increase in effort (Malabar, Intermediate Hill, Lidgbird South). The variation ranged from a decrease of 42.6% (Transit Hill) to an increase of 20% (Lidgbird South).

Several factors have influenced the repeat treatment effort, including regrowth of Cherry Guava from failed treatments, difficulty in gaining access to weeds among dense regeneration of Crofton Weed and Bully Bush (*Cassinia tenuifolia*) or among fallen debris following removal of dense infestations of mature stands of Cherry Guava. Also, the initial method of control for Ochna (cut and paint) did not deliver satisfactory control, resulting in a significant number of re-shoots that required follow-up,

Table 6 Change in treatment effort (hours) between first and last visits for five landscape units.

Landscape Unit	Area of Landscape Unit (ha)	Average number of visits	Effort first visit (hours)	Effort last visit (hours)	Percentage change in effort
Malabar	191	3.4	8244	8620	+5%
Transit Hill	83	3.0	7497	4305	–42.6%
Intermediate Hill	170	4.6	5141	5243	+1.98%
Lidgbird North	129	4.0	5663	5290	–6.6%
Lidgbird South	309	2.6	2187	2646	+20%

reducing treatment success and increasing treatment time. Scrape-and-paint applications are now used to treat Ochna, which have proven successful and no longer require follow-up. An examination of factors influencing treatment times within each of these five landscape units reveals landscape-unit issues that affect effort time needed to treat weeds.

The **Malabar** landscape unit (Figure 11a) covers an area of 191 ha and has received an average 3.4 treatments over the first 10 years, compared with the predicted 5. The increase in treatment time for this landscape unit increased by 5% between first and last treatments (Table 6). Although the number of mature weeds removed has declined by 52%, the number of juvenile plants removed has increased by 71%. Malabar comprises areas with dense, low, wind-sheared vegetation on steep terrain that is difficult to access, particularly areas on Dawsons Point and the narrow benches above the cliff-lines to the north. Dominant weeds include Bridal Creeper and Ground Asparagus. A number of blocks within this landscape unit have missed the 24-month treatment schedule and seed-rain from dense infestations below the cliffs-lines has been ongoing.

Recent trial of the helicopter lance-spray program has provided a breakthrough in addressing complex weed infestations across 3 km of cliff-line. The Weed Eradication Program for this unit is currently incomplete. On-rope or working under restraint to access weeds at the interface between helicopter spray work and off-rope access will address residual weed issues.

Intermediate Hill (Figure 11b) covers 170 ha and has received an average 4.6 treatments, and effort between first and last visits are similar, with the treatment effort increasing by only 1.98% (Table 5). The total number of weeds removed has declined by 86.4% and number of mature plants by 94.8%. The dominant weeds are Ochna and Cherry Guava. Results suggest that the time to access and search for weeds as numbers reduces requires the same effort.

Lidgbird North (Figure 11c) covers 129 ha and has received an average 4.0 treatments (Table 5). Although some blocks within the unit are receiving their fifth treatment, remote blocks (e.g. LN005, LN021) have not received a third complete treatment. Treatment effort (hours) has reduced by 6.6% (Table 5) but remote blocks overdue for repeat treatments will affect the final average treatment time across the landscape unit. For this landscape unit, the total number of all weeds treated has declined by 83.6% and numbers of mature plants by 92.3%. With significant reduction in weed densities, treatment times between first and last visits are comparable.

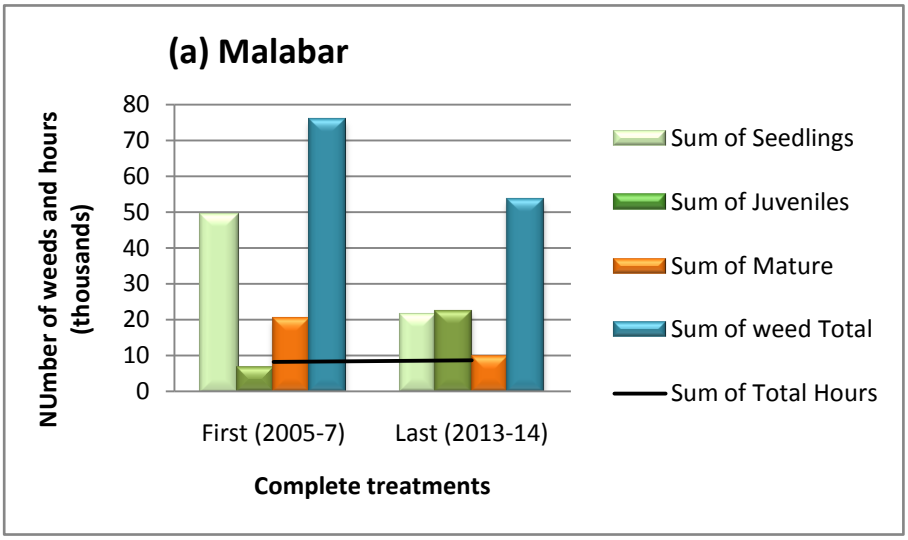
Lidgbird South (Figure 11d) covers 309 ha and has received an average 2.6 treatments (Table 5). This landscape unit comprises both readily accessible blocks and remote blocks that require a 10-km return walk. The calculations for this landscape unit (Table 5, Figure 11d) exclude some of the larger remote blocks on the eastern flanks of Mt Lidgbird as they were undergoing secondary search at the time of this report. Lidgbird South has experienced a 20% increase in hours of search effort between first and last visits. This difference is probably a result of lower quality search effort (undertaken too quickly) and reporting in the past. All search effort is now mapped on GPS units and should improve outcomes and understanding of future search effort needed in the landscape unit.

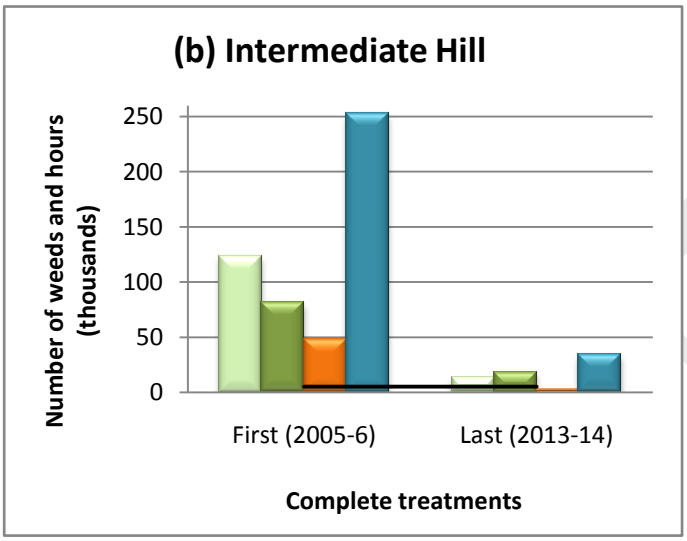
Transit Hill (Figure 11e) covers 83.2 ha and has received an average of 3.0 treatments. This landscape unit is one of the easier to access, at only 100 m above sea level. The treatment time for Transit Hill has declined by 42.6% (Table 5). During the preparation of this report blocks were receiving repeat treatments. Transit Hill has high numbers of Ground Asparagus, Pittosporum, Cherry Guava and Climbing Asparagus. The quality of reporting for this unit has varied, with blocks reported as complete after removal of woody weeds despite dense and widespread infestations of Ground Asparagus remaining. All weeds are now treated when grid-searching a block.

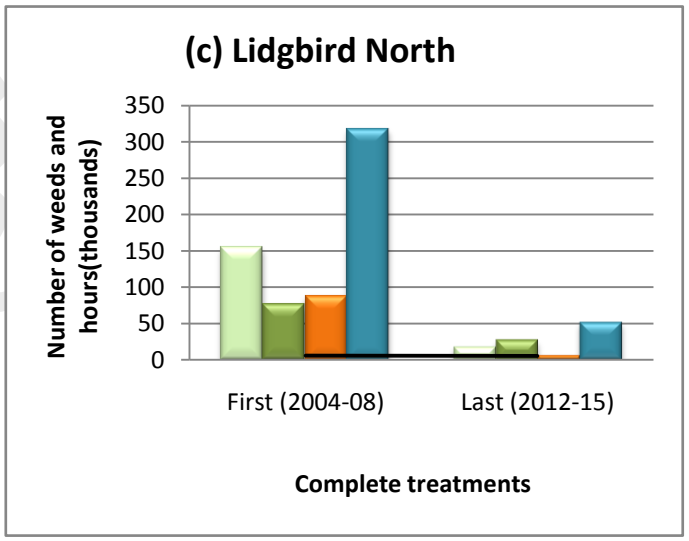
Early in the program, patches of Ground Asparagus, including seedlings, were removed by hand, which was very time-consuming. Since 2008, areas with dense Ground Asparagus infestations have been sprayed, which involved site preparation to protect native ground covers and limit non-target effects and to enable access to the site, followed by broad-scale spray application. This resulted in an almost doubling effort in the first repeat treatment. Volunteer input from the Friends of Lord Howe Island in removing dense Climbing Asparagus infestations has influenced the gains made on Transit Hill. For Transit Hill the total number of all weeds detected and removed has declined by 56.3% and of mature plants by 88.5%. Cliff-line infestations of Ground Asparagus have been reached by rope access and, more recently, treated by helicopter lance-spray.

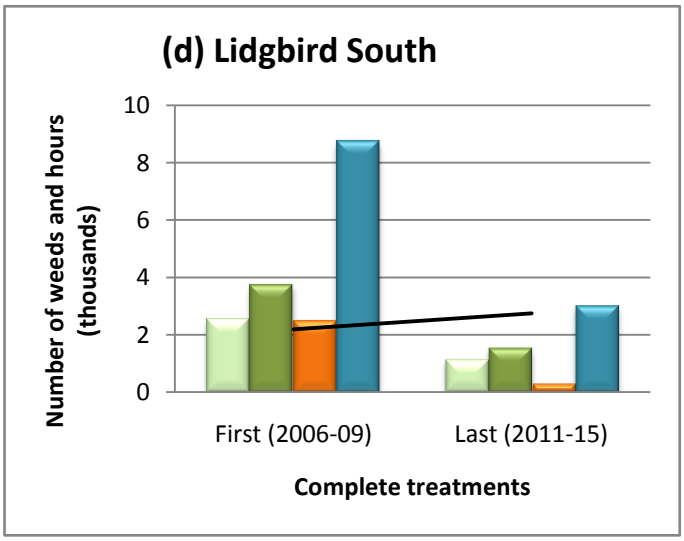
Overall, although there has been a 20% reduction in time for the complete treatment for the five landscape units analysed above (average of five landscape units), resourcing for on-ground search effort needs to be sustained, if not increased, to be able catch up on blocks that are behind in treatment schedules, to progress search effort in remote areas and on complex cliff-edges and to secure the investment to date. It is expected that with further depletion of juvenile weed populations over time, treatment times should reduce.

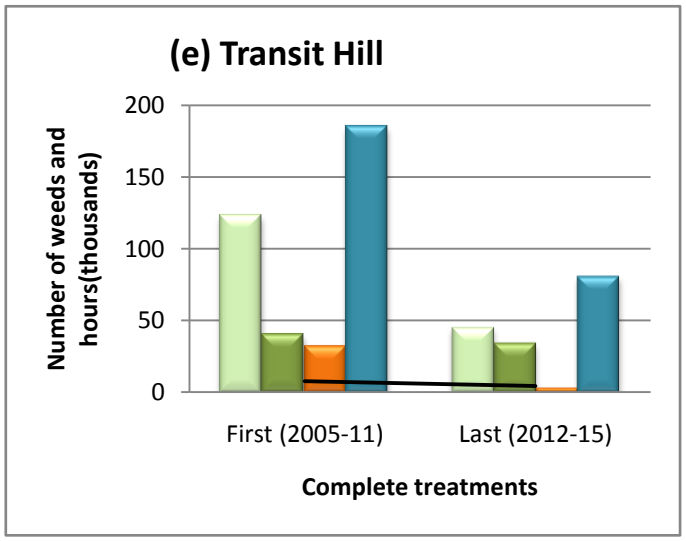
Figure 11 Change in number of weeds removed in first and last treatments with effort: (a) Malabar; (b) Intermediate Hill; (c) Lidgbird North; (d) Lidgbird South; (e) Transit Hill.











4.6 Change in density of common weeds

In this section, the results of search effort and treatment for some of the more common weeds are described, along with details of their treatment in specific landscape units.

Cherry Guava

Listed as one of the World's 100 Worst Invasive Alien Species, Cheery Guava has certainly demonstrated its invasive capacity on LHI. Cherry Guava is the most dominant and widespread weed in terms of numbers removed from the island, with a total of 704,000 individual plants, including 201,577 mature plants, removed between 2004 and 2014 (Figure 12). The number of Cherry Guava plants removed for each life-stage from all weed management blocks combined is shown in Figure 12. It demonstrates a solid downward trend in numbers removed from 2005 to 2014. (Search and removal in November–December 2004 of 25,716 plants, including 10,989 mature plants, has not been included in this graph. The equivalent data for each of the individual landscape units discussed below are also omitted.)

The Intermediate Hill and Lidgbird North landscape units were the main infestations and invasion front for Cherry Guava (Figure 12–Figure 14).

Intermediate Hill. This landscape unit supported very high densities of Cherry Guava and the numbers removed from 2005 to 2014 show a steady downward trend (Figure 13).

Lidgbird North. The Lidgbird North landscape, like Intermediate Hill, supported very high densities of Cherry Guava and similarly shows a solid downward trend in numbers removed since 2005 (Figure 14). This landscape unit had widespread stands of dense, mature Cherry Guava and large areas of treatments failed initially, which resulted in Cherry Guava then setting fruit. Cherry Guava was initially treated with triclopyr (Garlon) and ProTech oil; the oil sealed the cut surface of the stump and restricted access by the herbicide and resulted in widespread failure of treatment. The landscape unit also supports dense thickets of Crofton Weed that impair the detection of Cherry Guava re-shoots and seedlings. The upper areas of the landscape unit consist of steep terrain and cliff-lines, making access difficult. Cherry Guava has been detected and removed at 500 m elevation.

Mt Gower. The numbers of Cherry Guava removed from the Mt Gower landscape unit have not decreased over time (Figure 15). This is a result of incomplete search effort and delays in repeat search effort. The extent of search effort has been hindered over the duration of the program by a number of factors, such as difficulties of access owing to the rugged terrain, dense infestations of Crofton Weed, variable quality of reporting on apparent completion of search efforts, and delays and loss of helicopter services providing access. The Gower Plateau and cliffs to the south and west of the plateau are known, or assumed, to be weed free, based on incidental searches across the plateau during annual census of Lord Howe Woodhen (*Gallirallus sylvestris*), preliminary surveys of the Big Pocket and Big Slope, and periodic helicopter surveillance.

The Mt Gower landscape unit, specifically the north face of Mt Gower (81.2 ha, covering three weed management blocks), has not been completely treated. Cherry Guava is known to occur at Eddies Cave, close to the Mt Gower walking track, in the disturbance zone below the cliff, and has received repeated treatments, which requires searching through rocky rubble and dense Crofton Weed. The entirety of this block (60 ha) been previously reported as complete on a few occasions when it was not, in fact, complete, and funds or priorities have consequently been redirected. Surveys of threatened plants in 2010 detected mature Cherry Guava on both the eastern and western flanks of Mt Gower. Nodes or patches of mature Cherry Guava suggest prior dispersal by Pigs, which were eradicated from

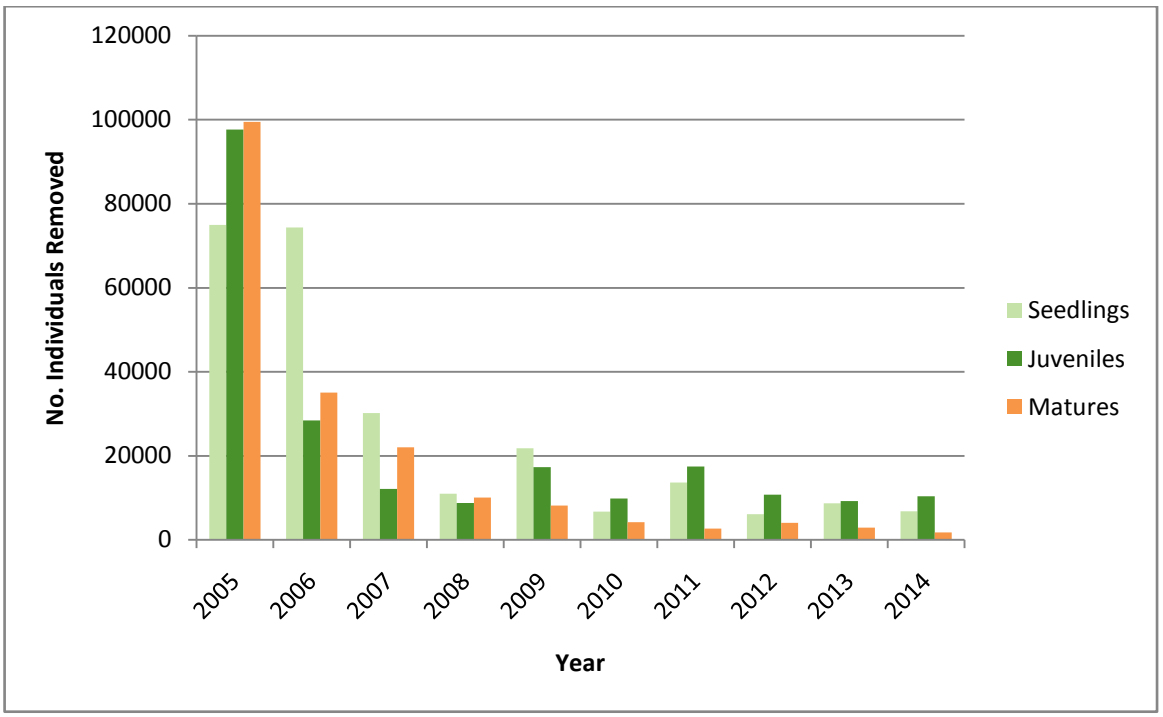


Figure 12 **Numbers of each life-stage of Cherry Guava removed from all treated areas combined, 2005–14.**

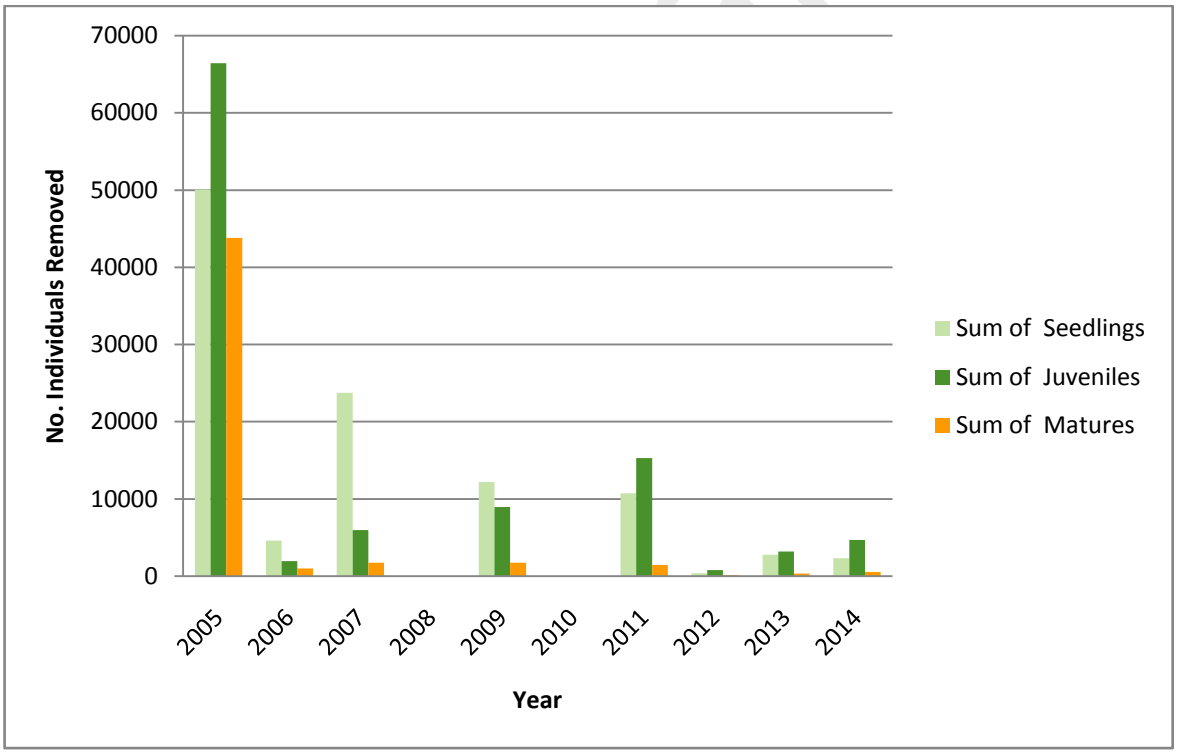


Figure 13 **Numbers of Cherry Guava removed from Intermediate Hill landscape unit, 2005–14.**

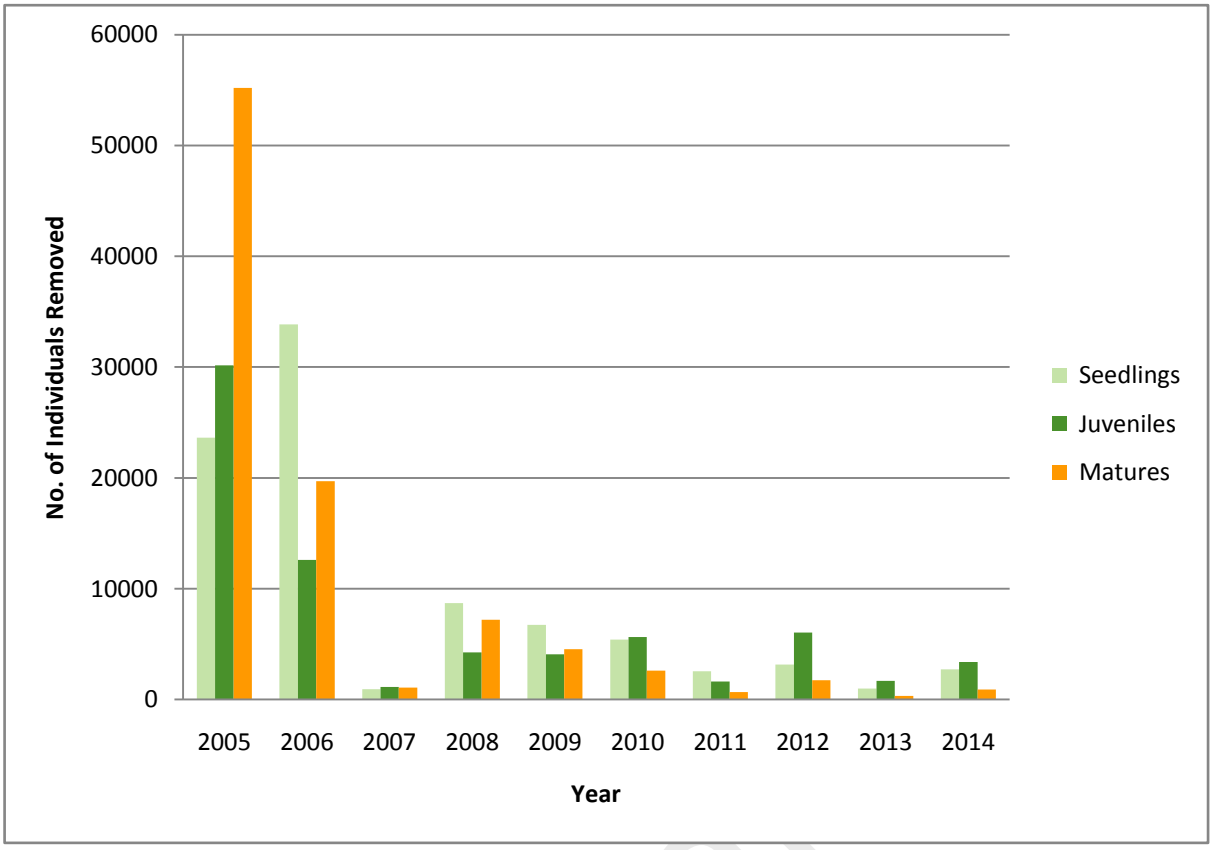


Figure 14 **Cherry Guava removed from Lidgbird North landscape unit, 2005–14.**

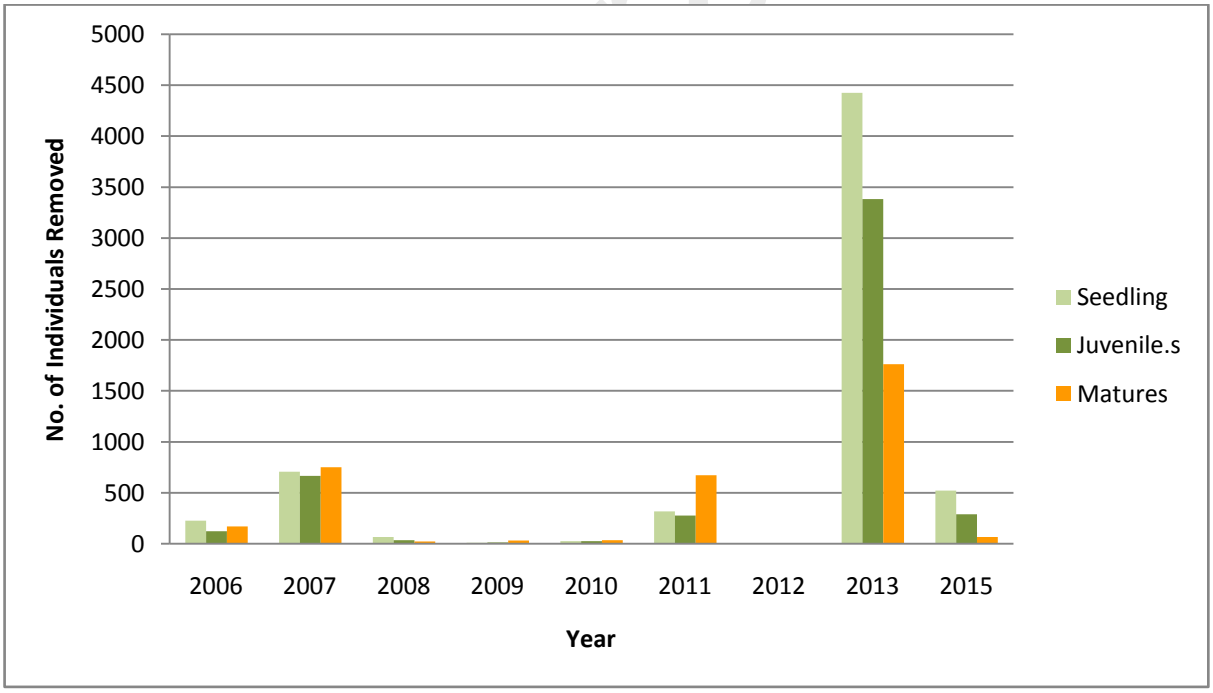


Figure 15 **Cherry Guava removed from Mt Gower landscape unit, 2005–14.**

the island by 1981. Pigs were unable to access the Gower Plateau, which may explain the current absence of Cherry Guava there.

Searches to date have not found extensive areas of Cherry Guava on the north face of Mt Gower, but have found scattered patches. Search effort is continuing in this landscape unit, and hot spots of Cherry Guava are being detected and treated.

Four helicopter winch operations have been undertaken to improve outcomes in this area and to increase search area in a short time (Figure 4, Figure 16). On the last of these operations, two teams were deployed in separate localities and, combined, they treated more than 20 ha of rugged terrain in 5 days. A team was also winched into the remote Big Pocket for a surveillance survey, and detected no Cherry Guava (but recorded extensive stands of mature Tobacco Bush *Solanum mauritianum*).

Isolated Cherry Guava plants have been detected on some cliffs that are inaccessible by foot. The helicopter lance-spray method is suitable for Bitou Bush and Ground Asparagus but not for Cherry Guava as it is not effectively controlled by spray applications. As discussed in Methods (above), the LHIB are investigating the benefits of Herbicide Ballistic Technology (HBT) to treat plants on steep terrain that is difficult to access, which is essential to prevent weeds establishing on cliff-lines and to achieve eradication.

Continued investment and search effort in the southern mountains is a high priority to reduce existing weed infestations to low numbers, as in the rest of the island.

Ground Asparagus

Ground Asparagus is the second most dominant weed removed on LHI. It has been recorded from 192 weed management blocks (compared with Cherry Guava recorded in 165 blocks). The number of mature Ground Asparagus plants removed over the 10-year period has not shown a strong downward trend owing to delays in completely treating some landscape units (Figure 17). Nevertheless, dense and widespread infestations of Ground Asparagus are no longer a feature on LHI. The raw numbers do not highlight the massive visual change in the landscape over the past 10 years through control of this weed, and the same can be said of Cherry Guava.

Ground Asparagus hotspots include Malabar and Transit Hill, with populations starting to establish in the Intermediate Hill landscape unit and on the northern flanks of Mt Lidgbird. Outlier plants, including mature plants, have been detected and removed from the saddle between Mt Gower and Mt Lidgbird and above The Lower Road and adjacent habitats. These records indicate an expansion into the southern mountains, which, if left unchecked, is predicted to expand throughout the southern mountains and associated cliff-lines. Reducing the numbers and seed-sources in accessible areas has been important to prevent dispersal of seed across the island. The challenge now is to prevent the expansion of populations into remote terrain.

Figure 16 Mt Gower (left), with arrow showing the location of the heli-winch site (see Figure 4) in proximity to a hot spot of Cherry Guava at 550m elevation, now reduced; and LHIB employee Jai Shick (right) removing Cherry Guava on Mt Gower in vicinity of the arrowed location in the left-hand image.

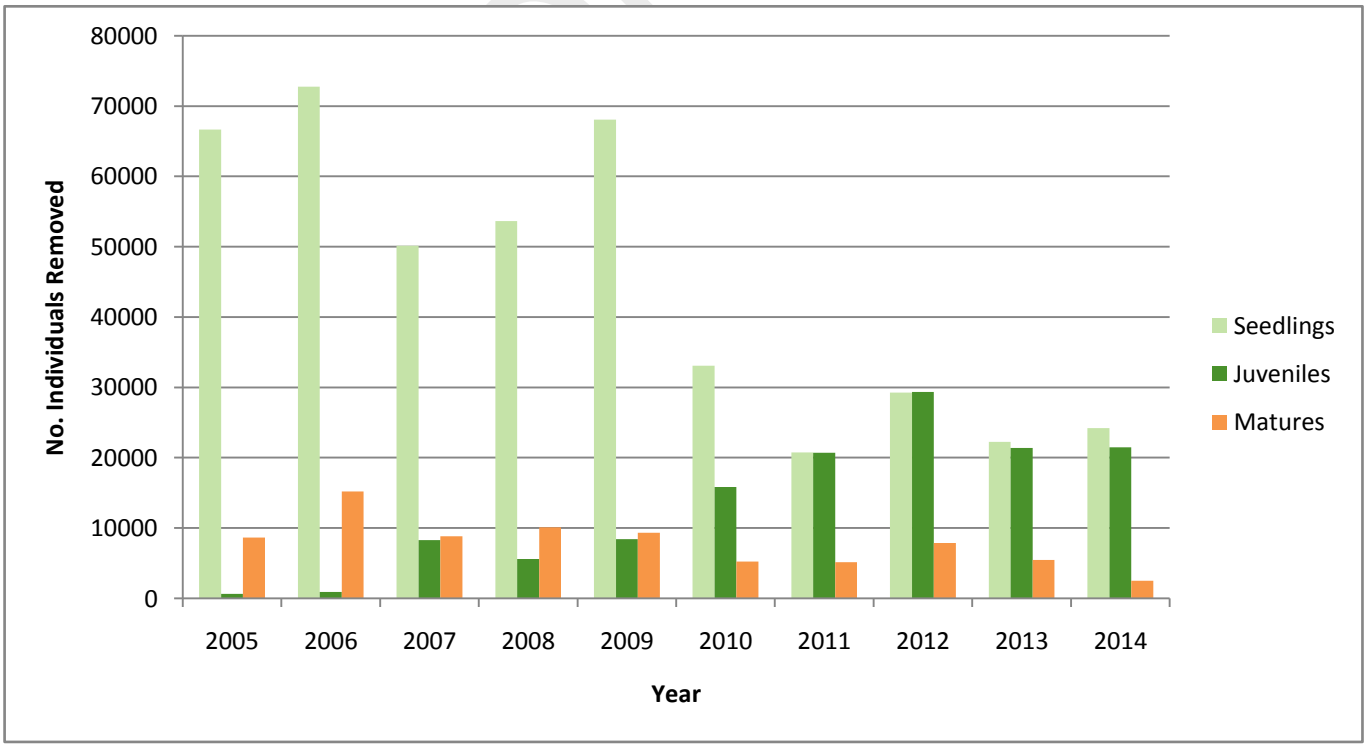


Figure 17 Numbers of Ground Asparagus of each life-stage removed from all areas, 2005–14.

Teams engaged through the recent NSW Environmental Trust Grant recorded an increase in mature Ground Asparagus in many blocks within the Intermediate Hill and Malabar landscape units. These particular blocks had a treatment interval of 48 months (4 years) owing to funding constraints. Applying a 24-month treatment schedule – as preferred targets – will ensure plants, particularly juvenile plants, which may have been overlooked, are prevented from maturing and fruiting. Lack of treatment of cliff-line infestations is likely to have aided dispersal of seed into previously treated blocks.

Recent use of the helicopter access and lance-spraying has provided a breakthrough in undertaking search and treatment of Asparagus weeds, Bitou Bush and Boxthorn on cliffs, with 10 km of cliff-line treated over 2 days. Mature Ground Asparagus were detected on the northern face of Mt Lidgbird and treated along with dense infestations on Malabar cliffs. This project work was undertaken outside of this formal reporting period. Further investment is required to complete the cliff-based program.

The combined ecological risk and impact of Ground Asparagus and Cherry Guava has been significantly reduced but the presence of outliers in the southern mountains must be targeted and treated.

Bitou Bush

Bitou Bush has been detected in 48 weed management blocks. It is largely associated with cliffs and cliff-edges at Malabar, Transit Hill, Lower Road, Blinky Beach and Scab Point, with outliers having been removed from the Nobbin on Mt Lidgbird. Only low numbers of Bitou Bush have been recorded (total of 3459 plants). Figure 18 indicates that current search and removal efforts have not been effective in reducing the numbers of mature plants.

Accessibility has been a primary issue. Helicopter-based spraying operations began in 2005 and re-started in 2009. Two helicopter long-line cone-spray operations were undertaken 4 years apart, which is too long an interval between treatments. Funding to build a purpose designed lance-sprayer was received in 2011 and the equipment finally trialled in 2015. The lance-spray unit has proven safe

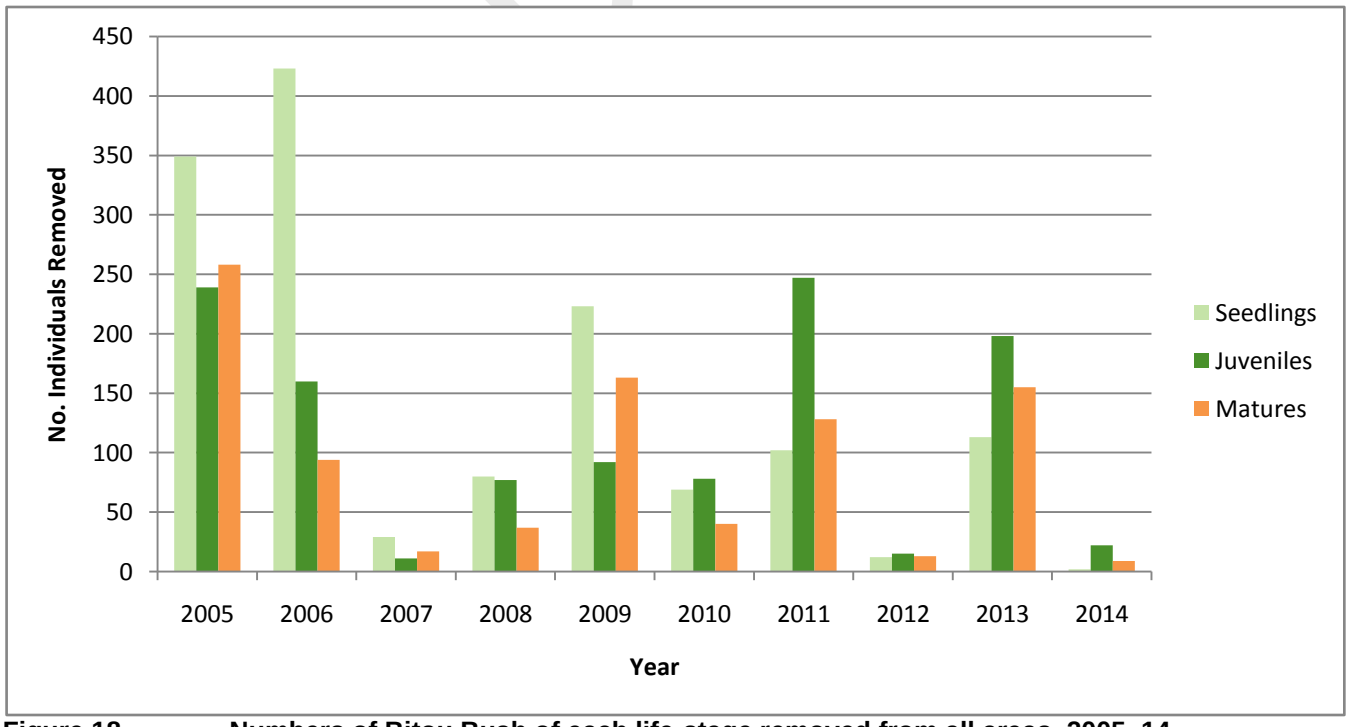


Figure 18 **Numbers of Bitou Bush of each life-stage removed from all areas, 2005–14.**

and effective in treating cliff-line weeds and is more cost-effective than rope access for treating large areas. Figure 19 shows the track of helicopter lance-spraying search and control efforts for Bitou Bush and Ground Asparagus undertaken with McDermott Aviation in 2015. Search and treatment of Bitou Bush across their full extent on cliffs has been delayed, however, allowing populations to build up. On-rope access was undertaken on the Lower Road in 2013. Continuation of the helicopter lance-spray program annually for the next 5 years will help to reduce Bitou Bush populations on cliffs.

Six other common weeds

Figure 20 shows the number of plants removed across the island over the 10 years 2004–14 for five common species of weed: Pittosporum, Ochna, Cotoneaster, Bridal Creeper and Glory Lily, and the weight of Madeira Vine removed from the Settlement area (except one outlier from Lidgbird North).

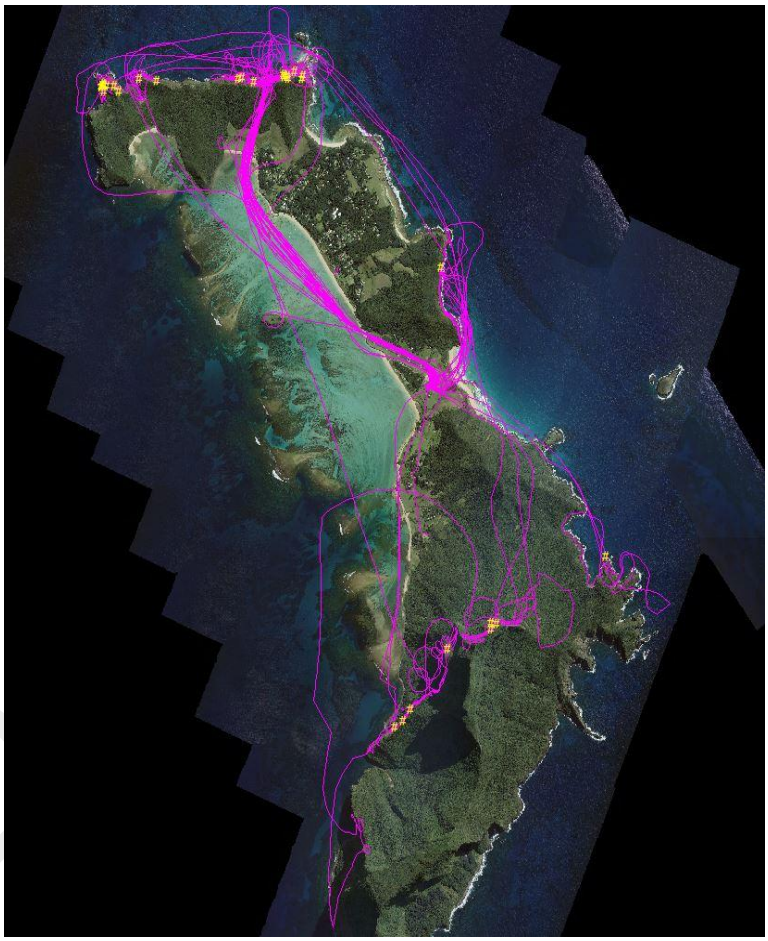


Figure 19 GPS track-log of helicopter lance-spray program, 2015.

Pittosporum (Figure 20a) is most prevelant in the Transit Hill landscape unit. A spike in the number of mature plants removed in 2008 probably correlates with increased effort at that time. Weed-density mapping over the 10 years indicates significant reductions in density of this species (see following section).

Ochna (Figure 20b) is common in the Intermediate Hill and Lidgbird North landscape units. This is the third most abundant weed on LHI, with over 485,000 individuals removed, including more than 19,000 mature plants. Two juvenile Ochna plants have been detected, and removed, at 400 m elevation in the Gower landscape unit. The significant reduction in the abundance of Ochna achieved over the 10 years, in habitats in proximity to the southern mountains has aided the protection of these important environments. The species is bird-dispersed and the presence of outliers on Mt Gower identifies its potential expansion range.

Cotoneaster (Figure 20c) has been recorded in 52 blocks across the island and is more commonly found in the Intermediate Hill landscape unit and on the lower flanks of Mt Lidgbird than elsewhere, and is less common in the Malabar landscape unit and in the Settlement. Like Ochna, Cotoneaster is also dispersed by birds and, as with most weeds targeted, reductions in populations through grid-search effort has reduced the extent of its spread southwards.

Bridal Creeper (Figure 20d) is generally restricted to the Malabar landscape unit (northern hills) where it is common. It is also present, but at lower density, at Middle Beach in the Settlement area, and the eastern fringe of Transit Hill. Outliers have been detected from Intermediate Hill, where they are being

monitored, and a single plant was recently recorded from Lidgbird South, indicating its potential increase in range on the island.

An increase in mature plants removed in 2012 (Figure 20d) was a result of targeted effort to reduce infestations to a level achieved with other target weeds on LHI. Bridal Creeper rust was introduced in an attempt to decrease the vigour and fruiting of Bridal Creeper but it had variable and limited effect. Plants are now sprayed or completely removed. The habitat occupied by Bridal Creeper is generally difficult to access. Repeated investment under Northern Rivers Catchment management Authority grants to hotspots of Bridal Creeper has paid off. Follow-up is scheduled for winter when the plant is actively growing and before the fruiting period in October.

Glory Lily (Figure 20e) is recorded from 14 weed management blocks, generally in small discreet patches in gardens in the Settlement area and on the lower north-western flanks of Mt Lidgbird adjacent to Soldiers Creek, and on the lagoon foreshore in the south. The highest densities of this species are found in the southern infestations, with up to 2000 plants removed in 2 ha. Small outlying patches have been detected in adjacent bushland upslope of the main infestation. All sites are mapped and repeated seasonal treatments applied during its active growth period between December and April to further drive downward trends.

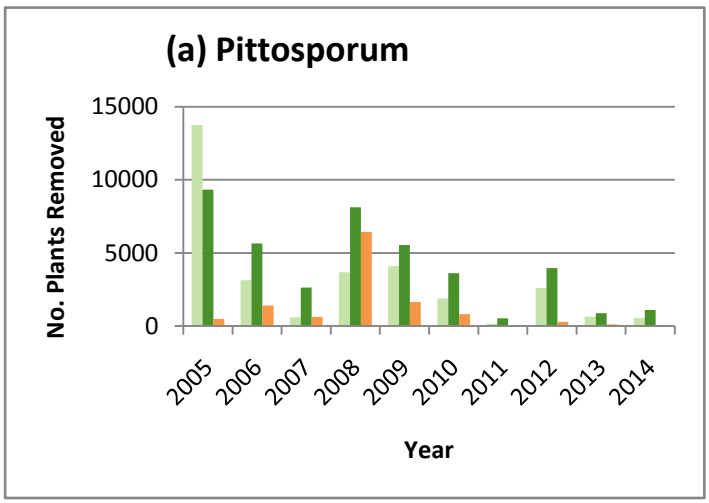
Madeira Vine (Figure 20f) is recorded from 49 sites, mostly in the Settlement North landscape unit. An outlier occurs adjacent to the Little Island track on the lower flanks of Mt Lidgbird, which is likely to have been brought to the site as vegetative material on a weeder's bag or boot. Sites are repeatedly visited as part of the program's wet-weather work schedule, when weather conditions prove unsafe for work in the PPP. To increase a downward trend in Madeira Vine sites should be visited no less than three times a year.

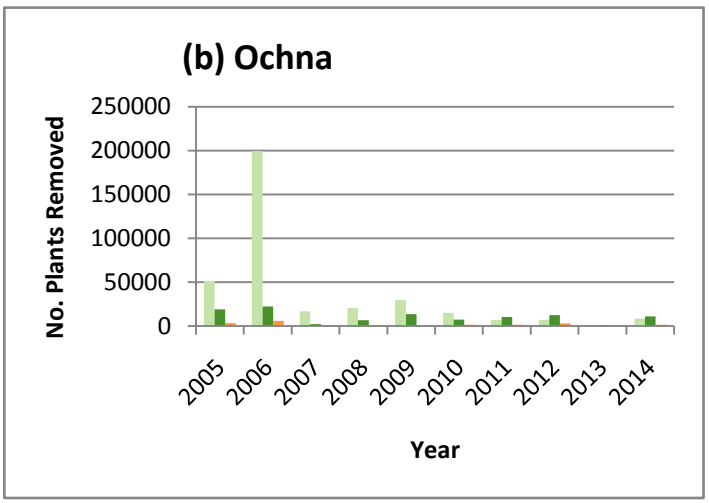
Eradicated weeds

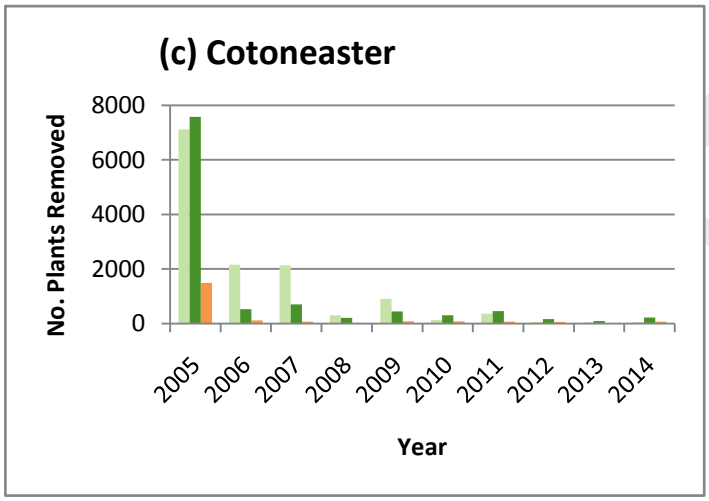
Six species of weed have been completely eradicated from LHI, all of which were originally limited in extent (see Appendix 1: Table A1 and Table A3):

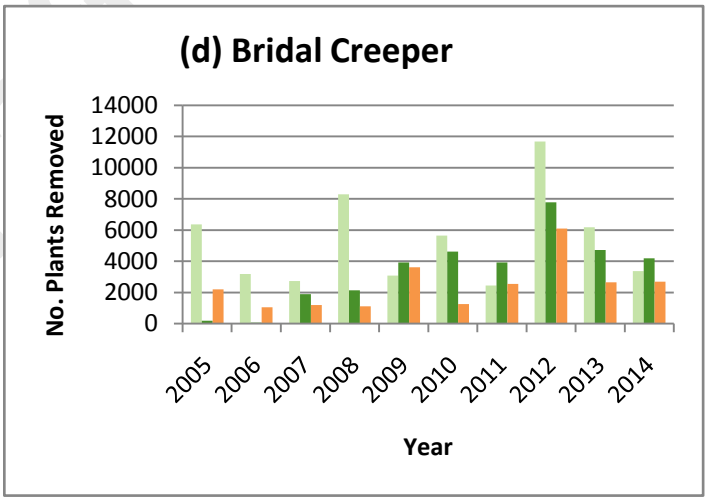
- Cat's Claw Creeper (*Dolichandra unguis-cati*) – 25 plants
- Cocos Palm (*Syagrus romanzoffiana*) – 3 plants
- Tipuana (*Tipuana tipu*) – 1 mature plant
- Turkey Rhubarb (*Acetosa sagittata*) – 1 plant
- French Broom (*Genista monspessulana*) – 1 plant
- Potato Vine (not Madeira Vine) (*Solanum wendlandii*) – 1 plant

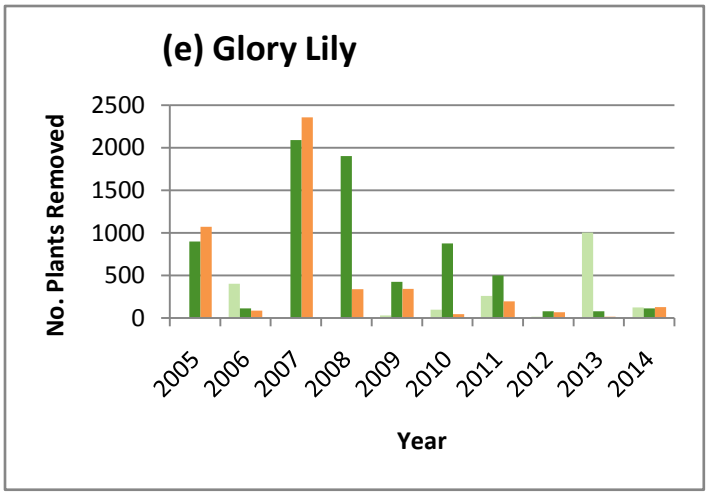
Figure 20 **Numbers of plants removed for six weed species on LHI: (a) Pittosporum, all areas; (b) Ochna, all areas; (c) Cotoneaster, all areas; (d) Bridal Creeper, all areas; (e) Glory Lily, all areas; (f) Madeira Vine, Settlement landscape unit only. For graphs (a) to (e), pale green bars are seedlings, dark green bars are juveniles, and orange bars mature plants.**

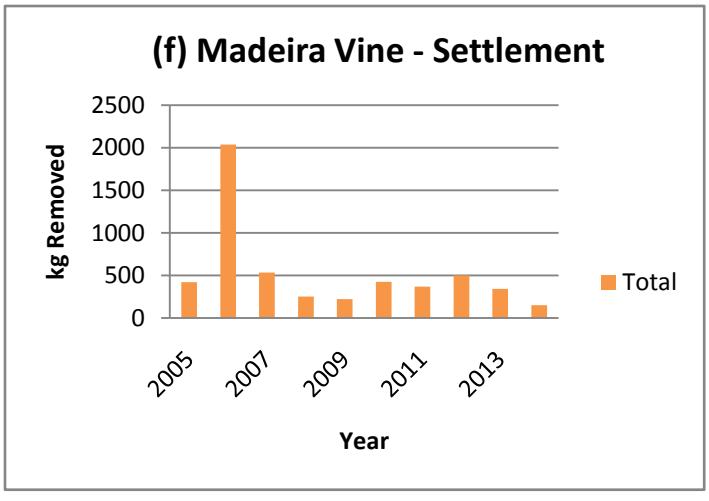












5 Weed density distribution monitoring and mapping

To quantify the extent of the weed threat on LHI, baseline mapping of weed distribution and density was undertaken in 2002–03 (February to August) over four main landscape units: Malabar, Transit Hill, Lidgbird North and Intermediate Hill (Figure 21).

Repeat surveys were undertaken in the same landscape units in 2013–14 (December to September) to measure changes in weed populations after 10 years of the Weed Eradication Program, grid-search and weed treatment effort. The repeat surveys were done with the assistance of Jenni Le Cussan applying the earlier survey methodology (Le Cussan 2002a, 2002b, 2003a, 2003b).

The repeat mapping shows a significant reduction in weed density over the survey area. The following section discusses examples of the weed-density mapping for the four landscape units surveyed.

Figure 21 The four landscape units in which weed density was mapped 2002–03 and 2013–14. Units (from north to south): Malabar, Transit Hill, Intermediate Hill and Lidgbird North.

5.1 Weed density and distribution mapping methodology

For each of the study landscape units, parallel transects were run either north–south or east–west (using a compass bearing) across the unit. Transects were spaced as close to 100 m apart as practical. At 20-m intervals along each transect a circular sample plot 4 m in diameter (12.566 m^2) was surveyed for weeds. The 20-m spacing was determined by GPS (rather than with a hip-chain counter and string line, to avoid confusion with any current weed-search effort) and a GPS waypoint entered at the centre point of each sample plot. GPS waypoints were downloaded into the GIS package ArcView 3.3 (ESRI, Redlands, CA). Repeat survey effort essentially replicated the same survey pattern and effort of the initial work.

Table 7 Summary of weed survey mapping effort, and weeding effort between first and last weeding treatments of the Weed Eradication Program.

Landscape Unit	Number of sample plots		Size of survey area (ha)	Total survey area 2013–14[A] (ha)	Total weeding effort (hours)	First visit weeding effort (hours)	Last visit weeding effort (hours)
	2002–03	2013–14					
Malabar	240	512	60 ha	0.64 ha	36,947	8,244	8,620
Transit Hill	355	456	88 ha	0.57 ha	21,701	74,97	4,305
Intermediate Hill	965	830	176 ha	1.04 ha	21,844	5,142	5,243.5
Lidgbird North	701	768	136 ha	0.96 ha	21,750	5,663	5,290

[A]Total area of survey plots calculated for 2013–14 surveys only.

In the initial and latter surveys, all weeds (excluding common exotic annuals and grasses) were surveyed and categorised for each sample plot. Crofton Weed and Tiger Lily were assigned density categories (Category 1: 1–5 individuals; Category 2: several plants 5–10 individuals; Category 3: common >10 individuals). Woody weeds were categorised as: juvenile (ground to knee height), shrubs (knee to head height) and mature (above head height). Bridal Creeper and Ground Asparagus were recorded as juvenile or mature. The counts of all plant species of each life-stage within a sample plot were then summed. Weeds detected during surveys were flagged for future control or isolated weeds treated or removed as they were encountered.

Field survey data were entered into ArcView and maps of distribution and density were generated using an Independent Distance Weighted (IDW) surface interpolation method in the ArcMap Spatial Analyst (ESRI).

It became apparent as the second surveys were being conducted that the density and life-stage categories were not adequate for categorising Cherry Guava and Ochna and the reproductive and life-stage status of these two species. The failure of the previous categorisation may be a result of changes in the population structure of the species following control efforts in the intervening years. Before treatment, dense canopies of head-high mature plants probably overshadowed the shrub class. In the repeat surveys it was evident that both species were capable of being at maturity while in the shrub category, so were assigned to the shrub class to represent a size-class rather than a reproductive age-class. Very few mature woody weeds (of any size-class) were detected in the repeat surveys.

Table 7 summarises the survey effort in terms of number of survey plots, and area of those plots, for each of the four landscape units, as well as the total weeding effort (hours) and the weeding effort of first and last weeding treatments. The survey effort on Malabar was substantially greater in the second surveys than the initial mapping (more than doubled; Table 7) and were slightly increased in the Lidgbird North and Transit Hill landscape units. Survey effort was lower on Intermediate Hill (14% decrease in number of sample plots; Table 7).

5.2 Weed density within the surveyed landscape units

The following sections provide paired maps for each landscape unit – for the initial weed-density mapping in 2002–03 (left-hand image) and the repeat surveys in 2013–14 (right-hand image) – showing

the survey effort (mapped transects and survey plots) and then the weed density for relevant weeds, and their life-stages.

Intermediate Hill

Figure 22 shows the survey points surveyed in the initial and second weed-mapping surveys. Mapping shows widespread decreases in the distribution and density of Cherry Guava (**Error! Reference ource not found.**) and Ochna (Figure 24) across this landscape unit between 2002–03 and 2013–14.

Cherry Guava showed a reduction of 94.3% (all life-stages combined; **Error! Reference source not ound.**a) between 2002–03 and 2013–14. Residual plants in 2013–14 were mostly juvenile plants. The reduction shown by this mapping compares well with weed-removal data from the LHI WD, indicating a 90.42% reduction in total counts of plants detected and removed between first and last treatments (see section 4.6 above). Comparing first and repeat surveys: only one mature Cherry Guava was recorded in 2013–14 compared with 874 in 2002–03 (**Error! Reference source not found.**b); only 12 shrubs ere recorded in 2013–14 compared with 920 in the initial survey (**Error! Reference source not found.**c); and 104 juveniles were recorded in 2013–14 compared with 256 in the initial surveys (59.4% reduction) (**Error! Reference source not found.**d). The latter shows the need for follow-up treatment.

The **Ochna** (Figure 24) detected in this landscape unit in 2013–14 were mostly juvenile plants.

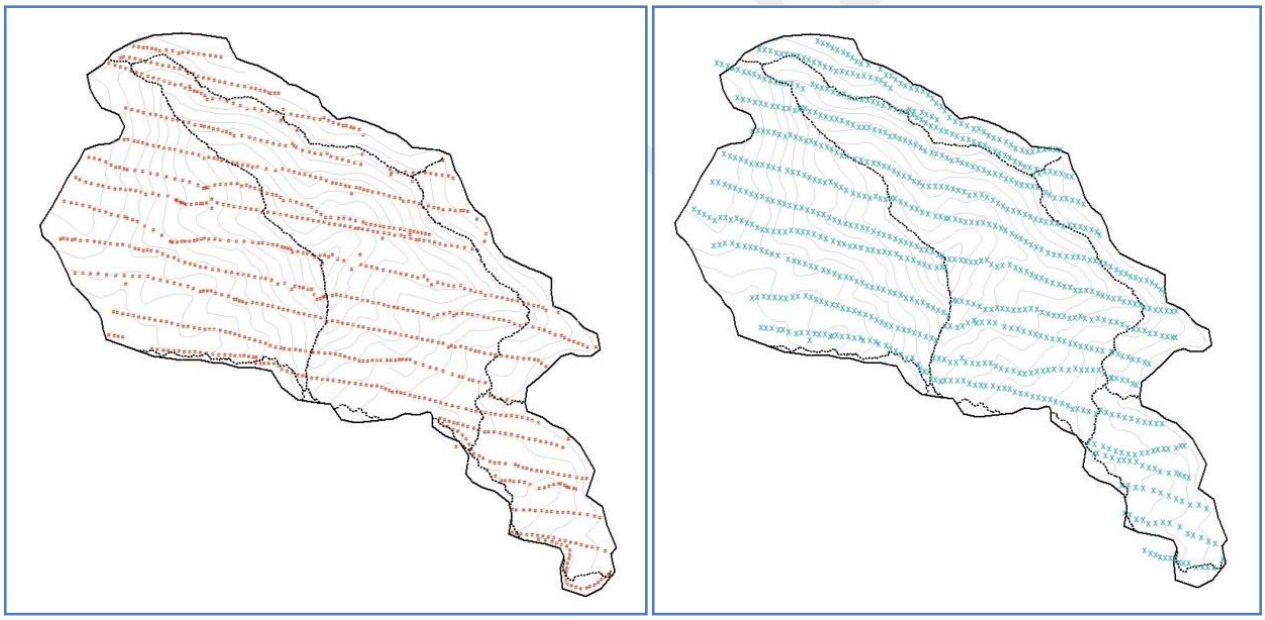


Figure 22 Intermediate Hill weed mapping survey effort in 2002–03 (965 survey points; left) and 2013–14 (830 survey points; right).

Intermediate Hill – Cherry Guava

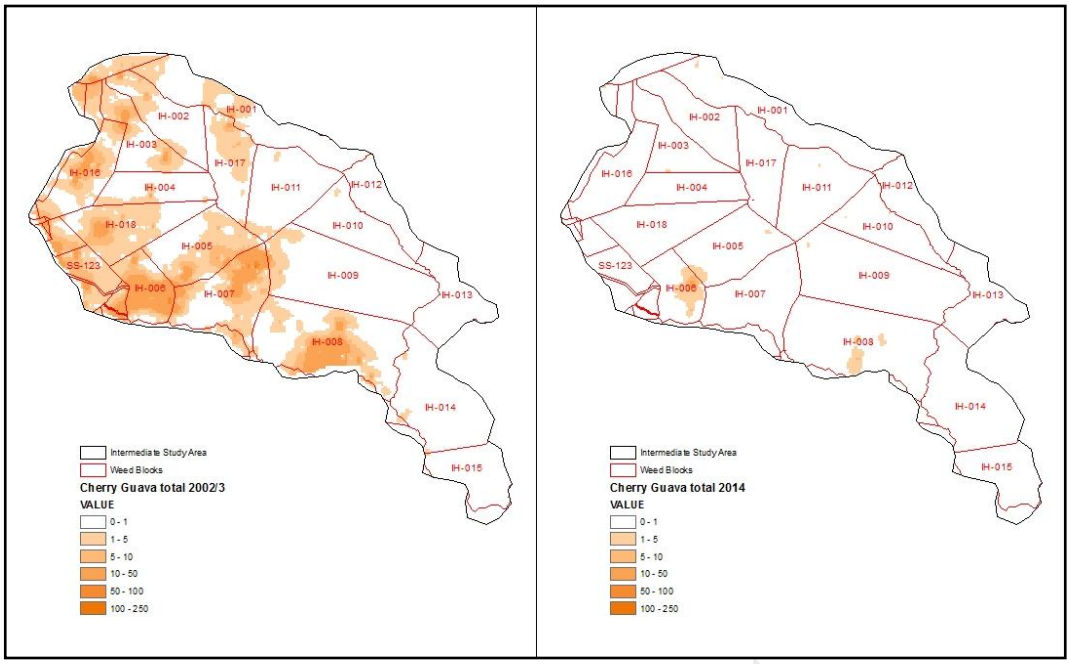


Figure 23a Intermediate Hill – Cherry Guava 2002–03 (left) and 2013–14 (right): total count all plants.

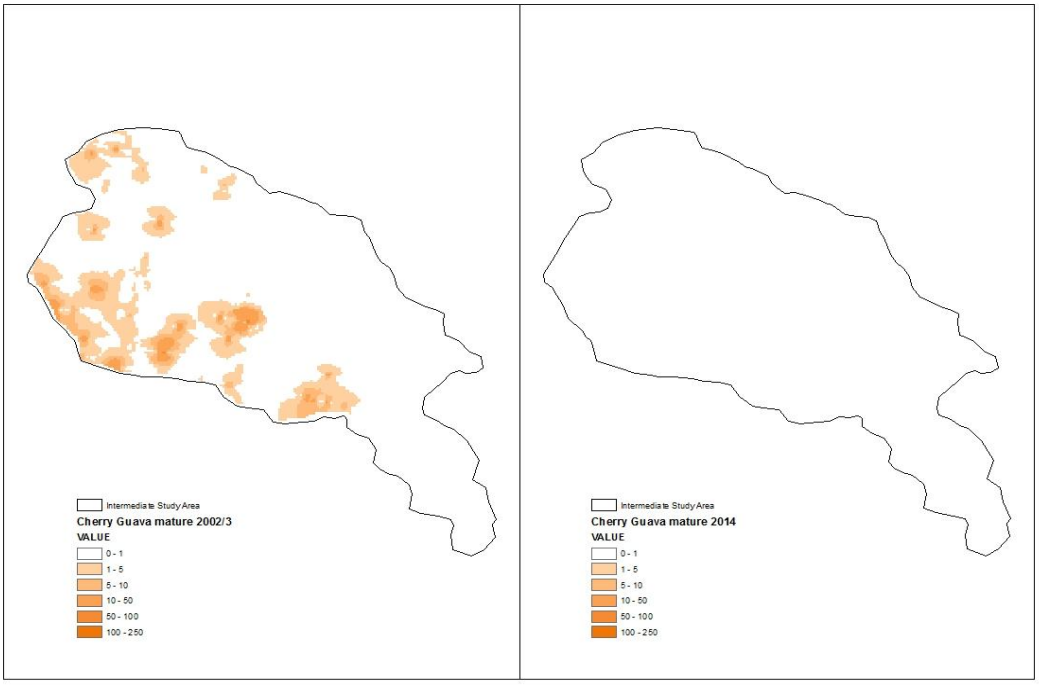


Figure 23b Intermediate Hill – Cherry Guava 2002–03 (left) and 2013–14 (right): mature plants.

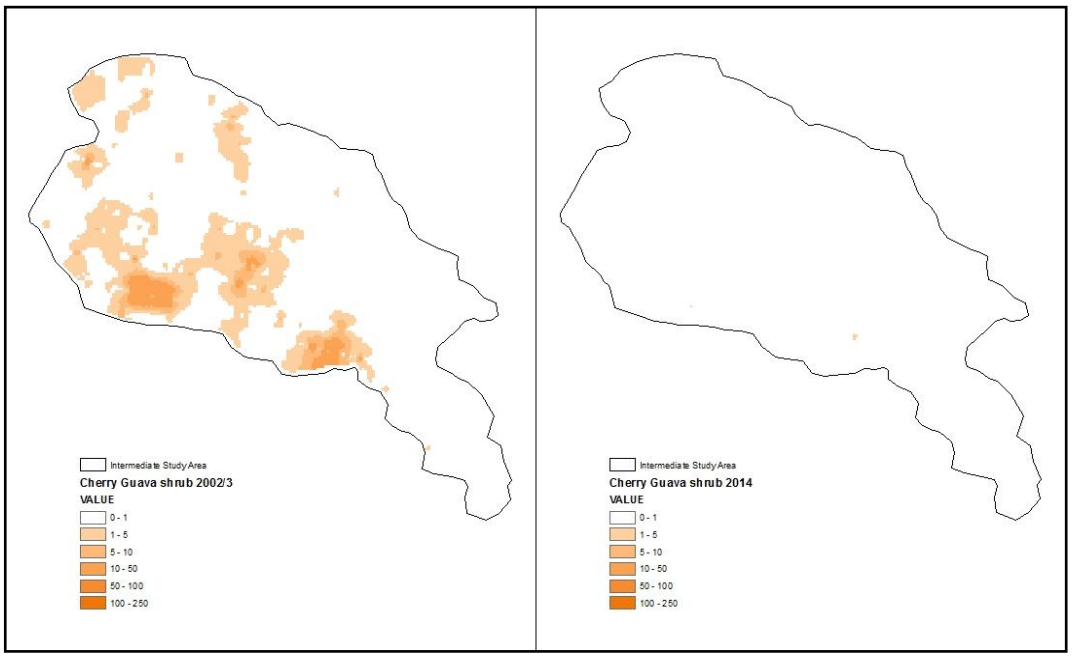


Figure 23c Intermediate Hill – Cherry Guava 2002–03 (left) and 2013–14 (right): shrubs.

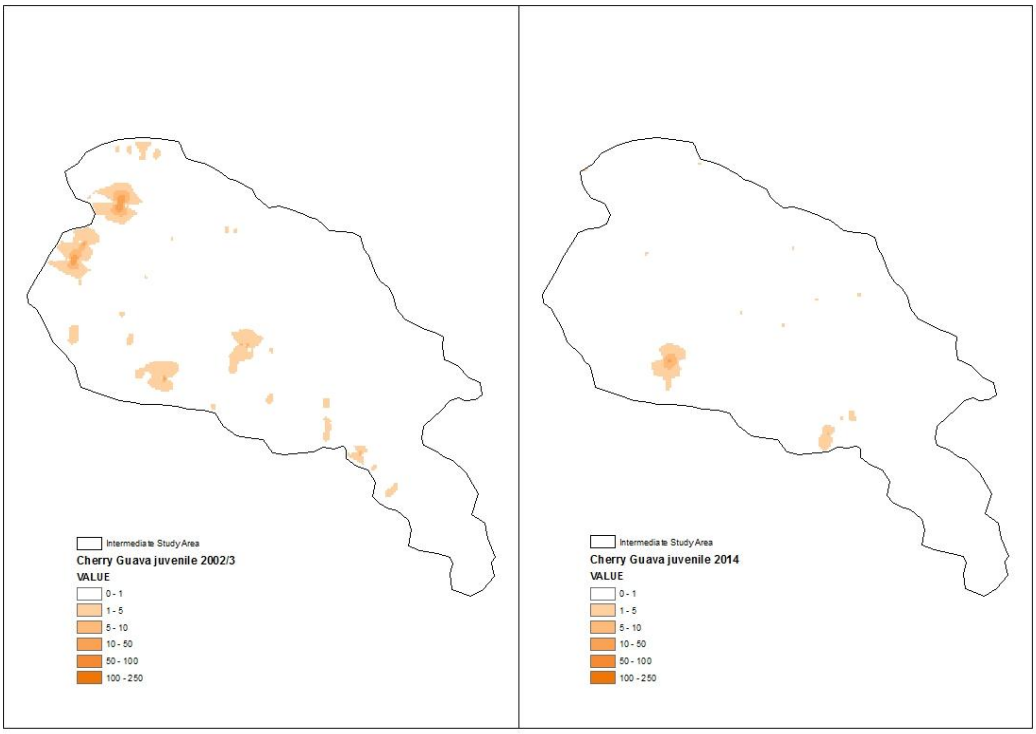


Figure 23d Intermediate Hill – Cherry Guava 2002–03 (left) and 2013–14 (right): juveniles.

Intermediate Hill – Ochna

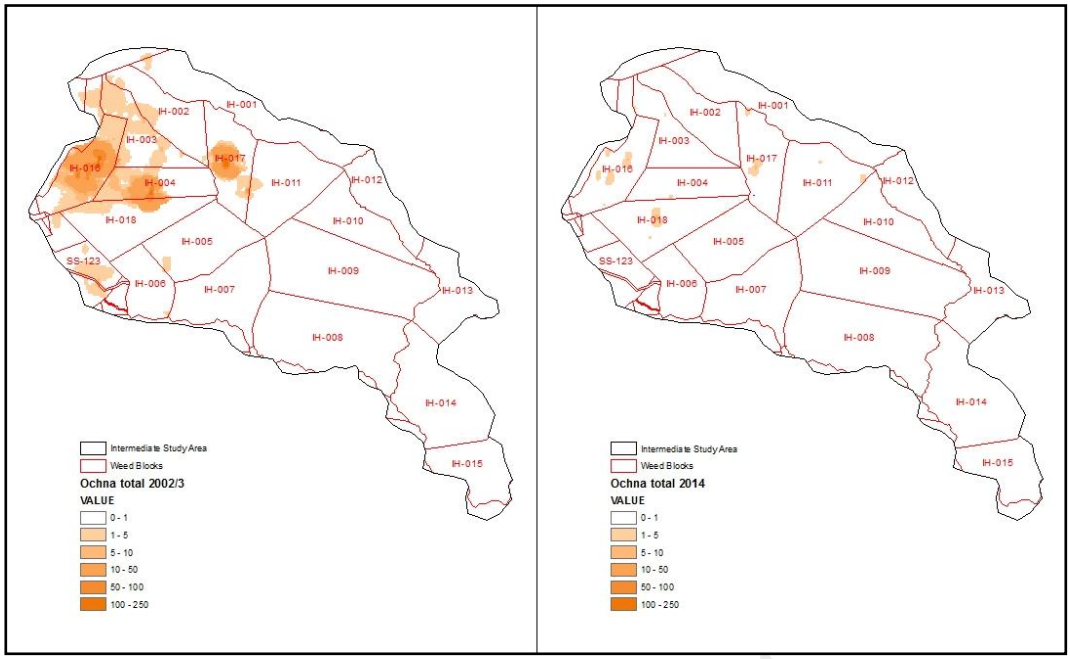


Figure 24 Intermediate Hill – Ochna 2002–03 (left) and 2013–14 (right): total count of all plants.

Lidgbird North

Figure 25 shows the survey points surveyed in the initial and second weed-mapping surveys for Lidgbird North landscape unit. The weed mapping shows a marked decrease in the distribution and density of Cherry Guava (Figure 26) between 2002–03 and 2013–14, and a decrease in Ochna (Figure 27). The Cherry Guava detected in 2013–14 (Figure 26) are largely juvenile plants and in the northern portion of the landscape unit. This residual infestation occurs among dense Crofton Weed, which makes access and ability to detect Cherry Guava more difficult. A biological control for Crofton Weed has recently been released on mainland Australia and it is being investigated for possible release on LHI (see http://www.csiro.au/en/Biological-control/Crofton-weed).

The Cherry Guava detected in the south-west of the site are located close to rock shelves or cliffs-lines and close to a weed management block that has had limited repeat visitations. Most of the Ochna plants recorded in 2013–14 (Figure 27) are juvenile plants.

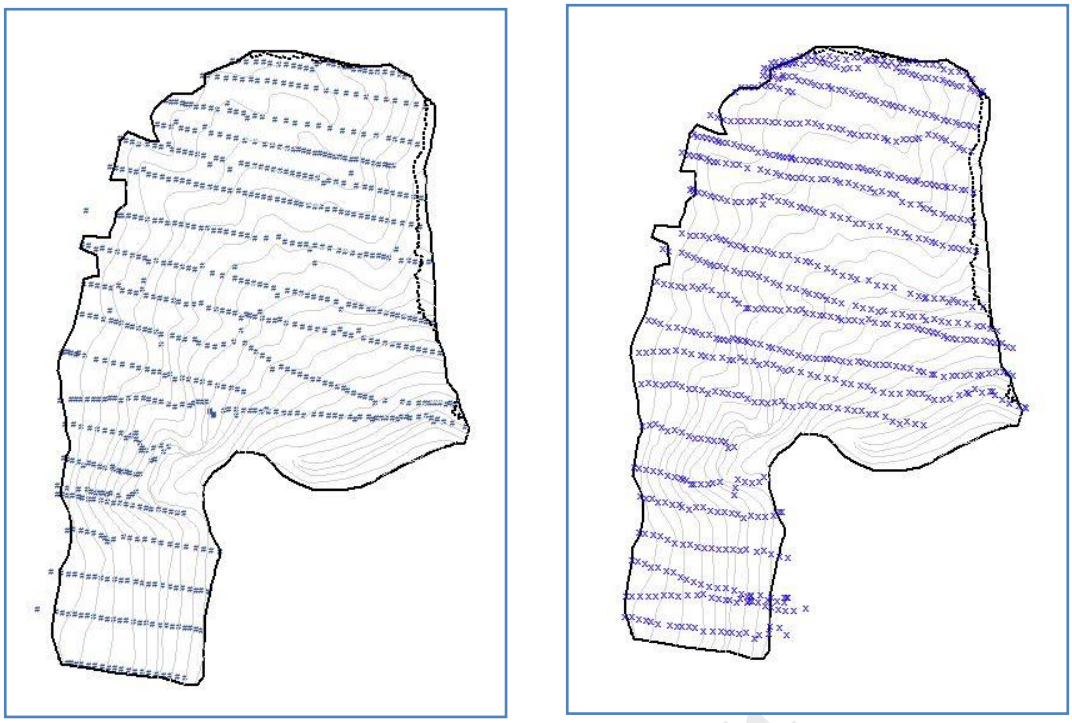


Figure 25 Lidgbird North weed mapping survey effort in 2002–03 (701 survey points; left) and 2013–14 (760 survey points; right).

Lidgbird North – Cherry Guava

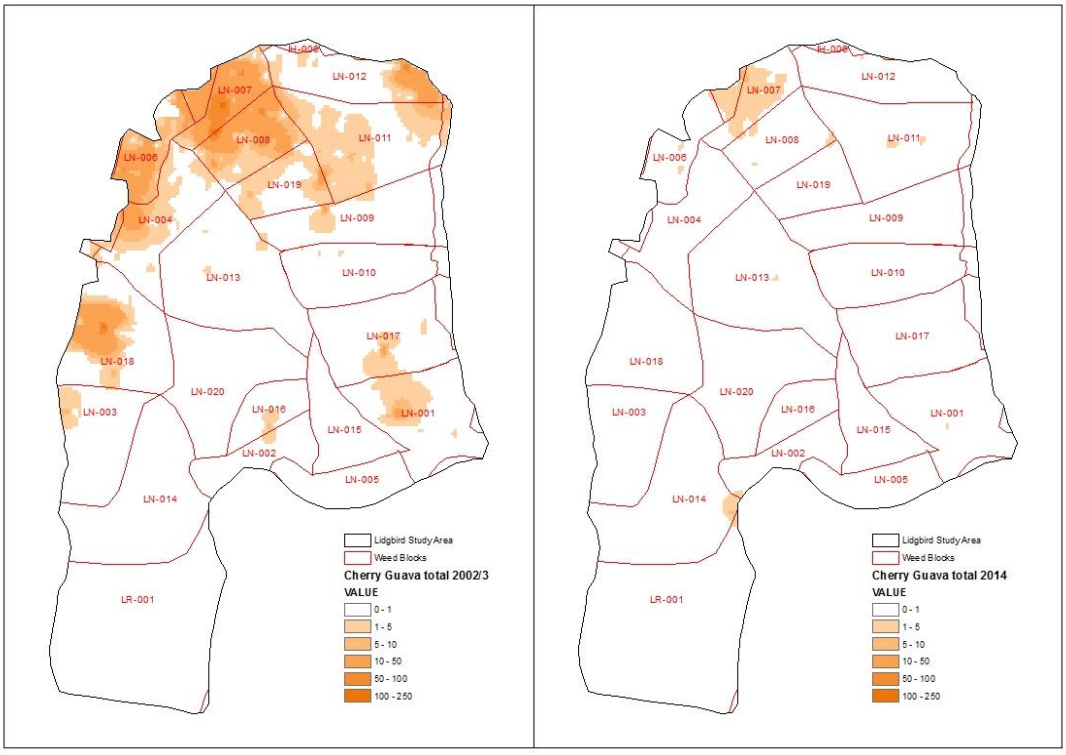


Figure 26 Lidgbird North – Cherry Guava 2002–03 (left) and 2013–14 (right): total count of all plants (life-stages combined).

Lidgbird North – Ochna

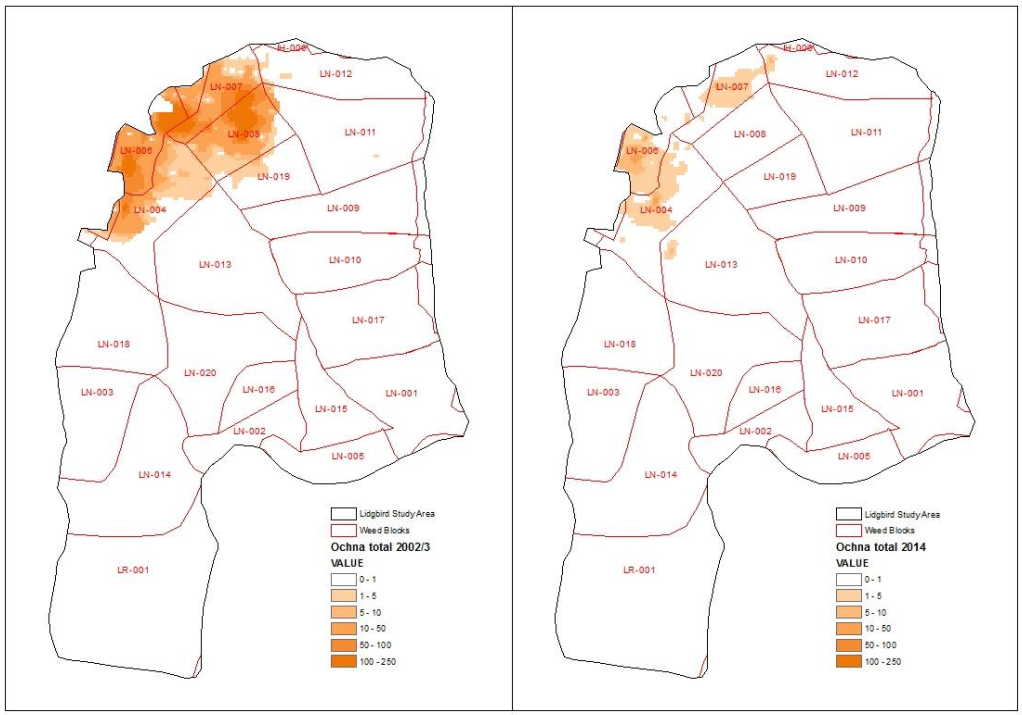


Figure 27 Lidgbird North – Ochna 2002–03 (left) and 2013–14 (right): total count of all plants (life-stages combined).

Malabar

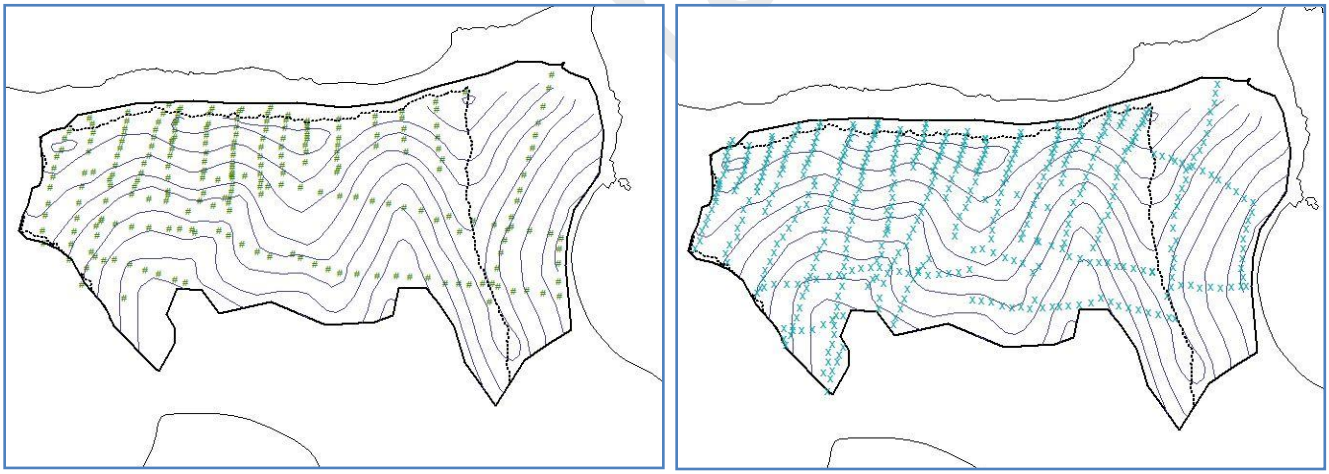


Figure 28 Malabar weed mapping survey effort in 2002–03 (240 survey points; left) and 2013–14 (512 survey points; right). Survey effort in repeat survey more than double that of initial surveys.

Figure 28 shows the survey points surveyed in the initial and second weed-mapping surveys for the Malabar landscape unit. The weed mapping shows a decrease in the distribution and density of Ground Asparagus (Figure 29) between 2002–03 and 2013–14, and a marked decrease in Bridal Creeper (Figure 30). The weed-mapping surveys located a block of **Ground Asparagus** in the north-east of the landscape unit that has had inadequate follow-up treatments, which is reflected in the increase in mapped weed presence in the area, although that may also be a result of increased survey effort.

Ground Asparagus infestations on the cliffs below Malabar have provided an ongoing seed source for adjacent weed blocks in the area. Recent helicopter lance-spray programs have provided a breakthrough in rapid access to, and treatment of, these areas. Most of the **Bridal Creeper** (Figure 30) recorded in 2013–14 were juveniles.

Malabar – Ground Asparagus

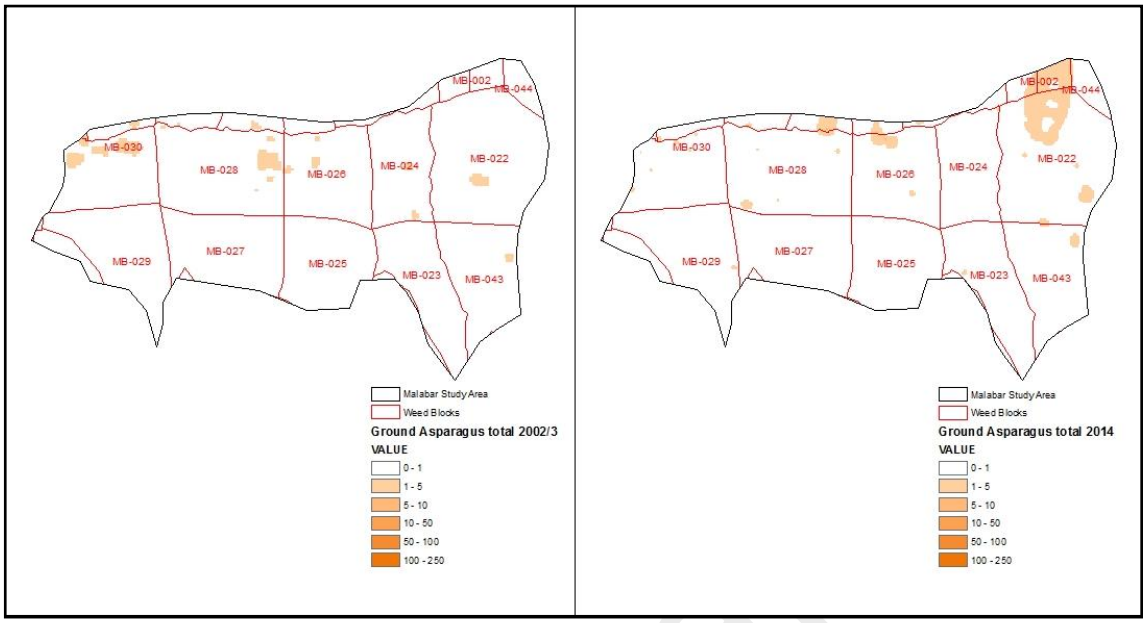


Figure 29 Malabar – Ground Asparagus 2002–03 (left) and 2013–14 (right): total count of all plants (life-stages combined).

Malabar – Bridal Creeper

Figure 30 Malabar – Bridal Creeper 2002–03 (left) and 2013–14 (right): total count of all plants (life-stages combined).

Transit Hill

Figure 31 shows the survey points surveyed in the initial (2002–03) and repeat (2013–14) weed-mapping surveys for the Transit Hill landscape unit. The weed mapping shows a decrease between 2002–03 and 2013–14 in the distribution and density of Ground Asparagus (**Error! Reference source ot found.**), Climbing Asparagus (**Error! Reference source not found.**) and Pittosporum (Figure 34). The occurrence of mature **Ground Asparagus** (**Error! Reference source not found.**a) has been ignificantly reduced across the Transit Hill landscape unit. Recent helicopter lance-spraying of Ground Asparagus on cliff-lines in the east of the site has helped to protect the gains and investment made in the transformation of Transit Hill. Although the sample area for the surveys in this landscape unit is small (0.57 ha), the mapping does show a significant reduction in the numbers of mature plants detected. The extent of juvenile Ground Asparagus mapped for 2013–14 (**Error! Reference source ot found.**b) has received complete repeat treatment since the mapping surveys. Repeat surveys will show further reduction in juvenile plants.

Dense mature infestations of **Climbing Asparagus** (**Error! Reference source not found.**a, b) were revalent at Transit Hill as well as in the Settlement area, with residual patches at Neds Beach and Middle Beach. The Friends of Lord Howe Island removed the last dense infestations of mature Climbing Asparagus from the Transit Hill landscape unit in 2011. All areas are now in a follow-up phase. Outliers of Climbing Asparagus have been detected and removed from Intermediate Hill (a total of 25 plants total, including two mature plants) and Malabar (a total of 95 plants, including 19 mature plants). The remaining population surveyed in 2013–14 mostly comprised juvenile plants; these areas have since received repeat visitation and treatment.

The **Pittosporum** detected in the 2013–14 surveys (Figure 34) were largely juvenile plants.

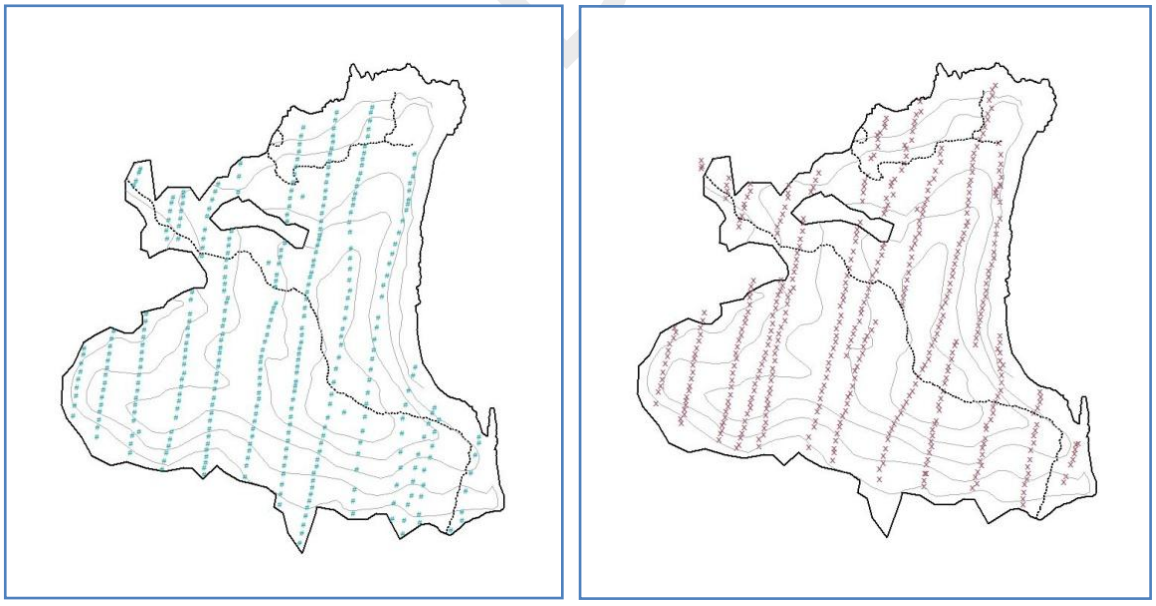


Figure 31 **Transit Hill survey effort 2002–03 (355 sample points) to 2013–14 (456 sample points).**

Transit Hill – Ground Asparagus

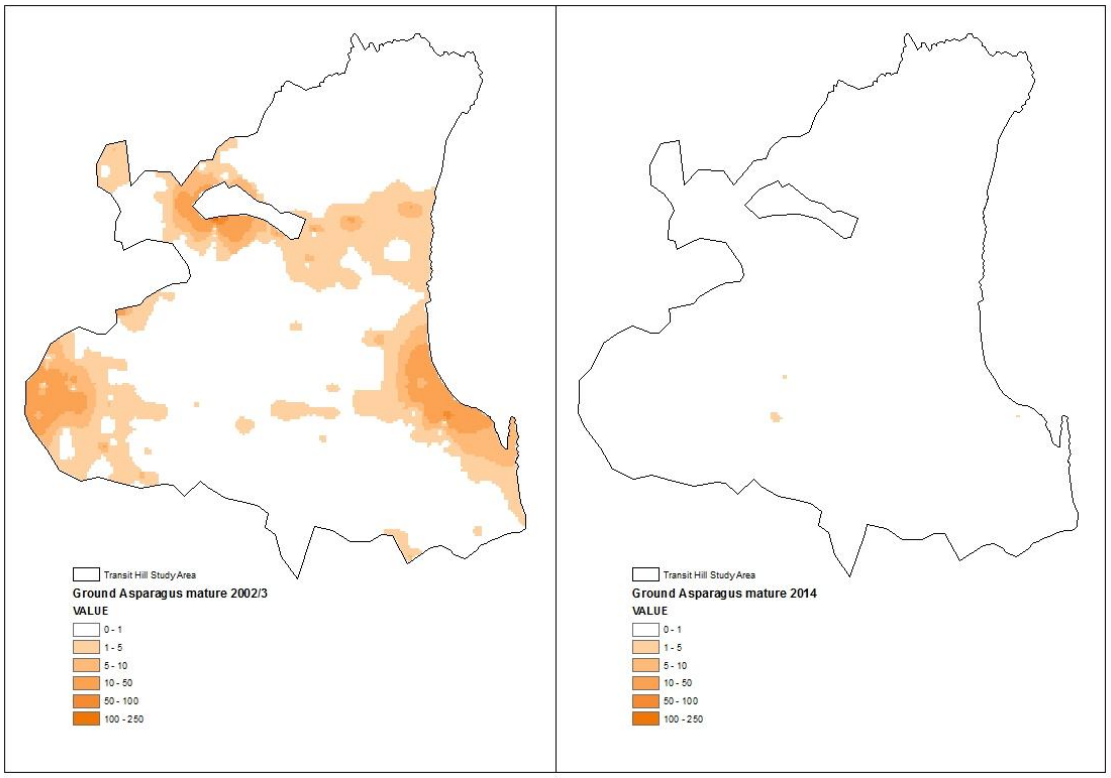


Figure 32a Transit Hill – Ground Asparagus 2002–03 (left) and 2013–14 (right): mature plants.

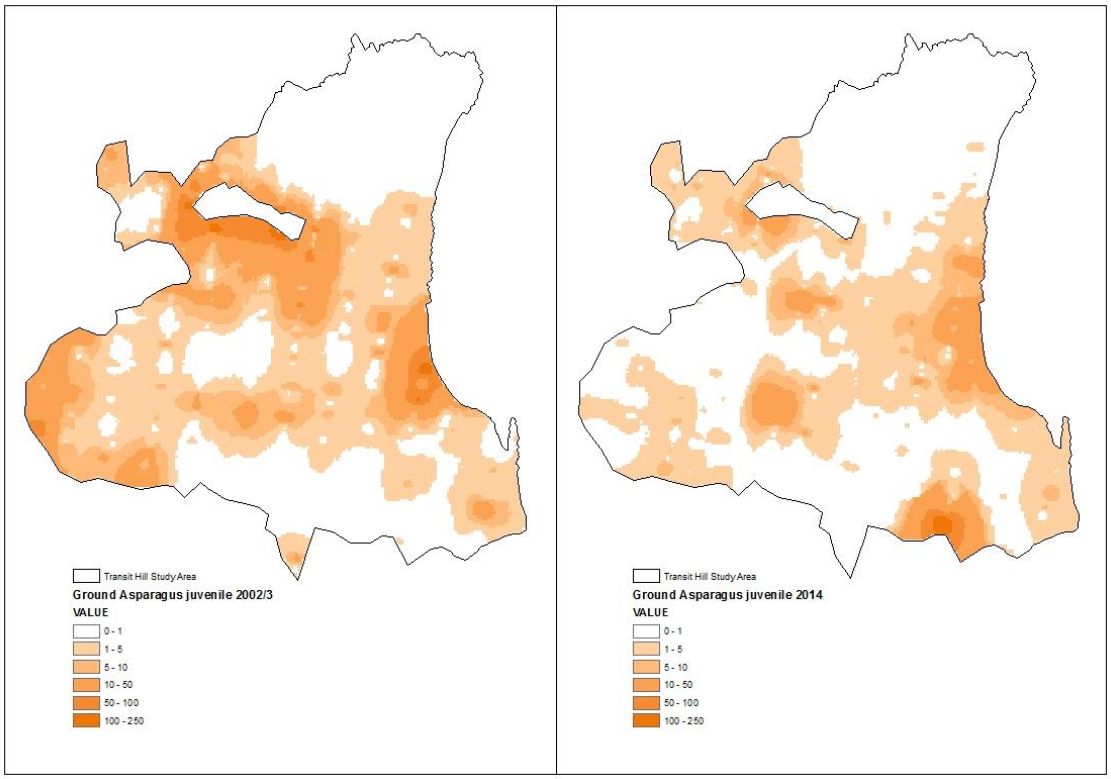


Figure 32b Transit Hill – Ground Asparagus 2002–03 (left) and 2013–14 (right): juveniles.

Transit Hill – Climbing Asparagus

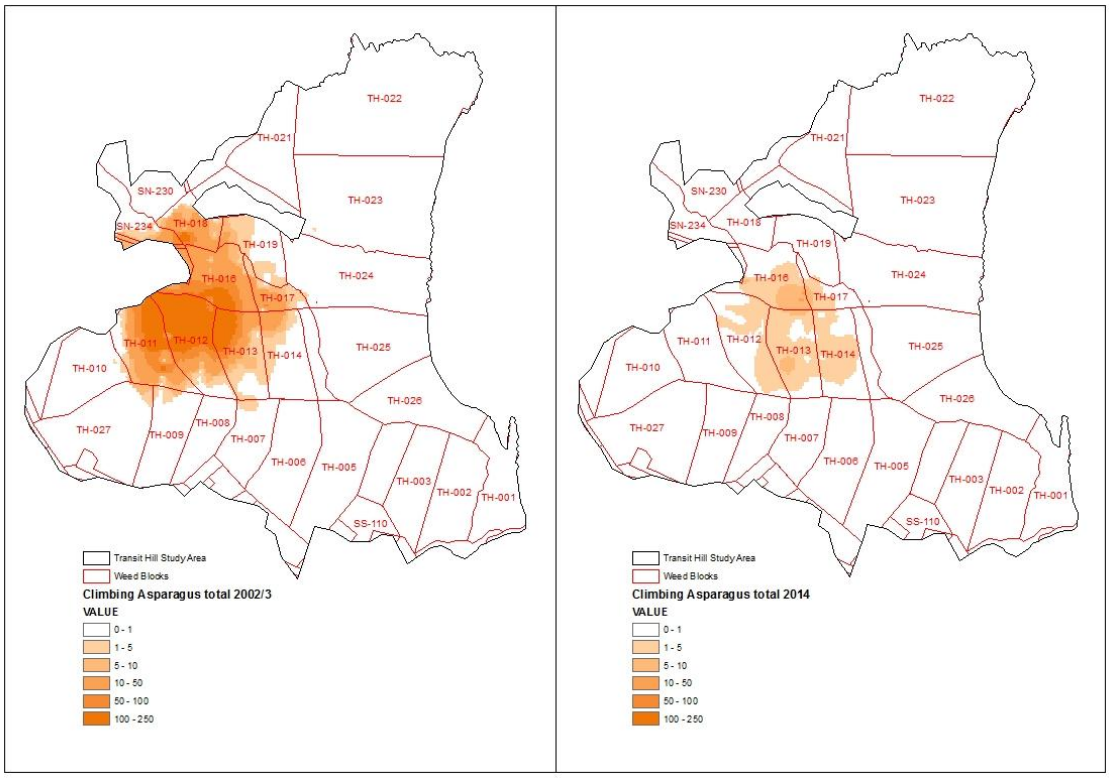


Figure 33a Transit Hill – Climbing Asparagus 2002–03 (left) and 2013–14 (right): total count of all plants (life-stages combined).

Figure 33b Transit Hill – Climbing Asparagus 2002–03 (left) and 2013–14 (right): mature plants.

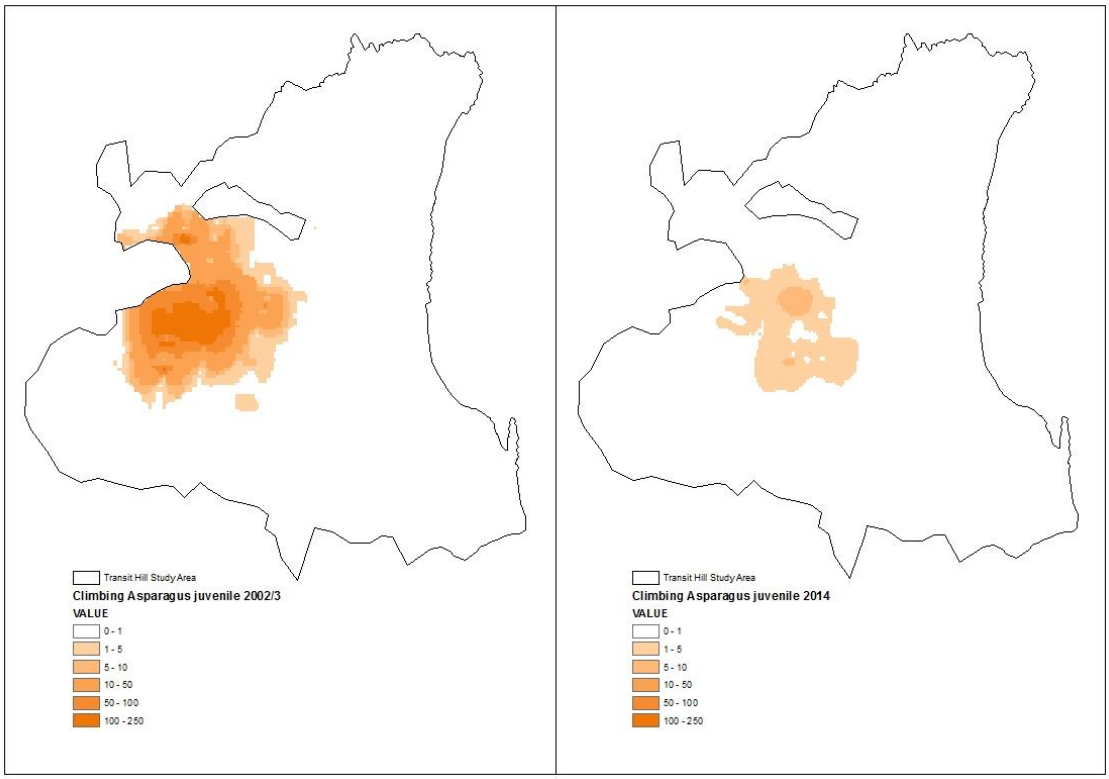


Figure 33c Transit Hill – Climbing Asparagus 2002–03 (left) and 2013–14 (right): juvenile plants.

Transit Hill – Pittosporum

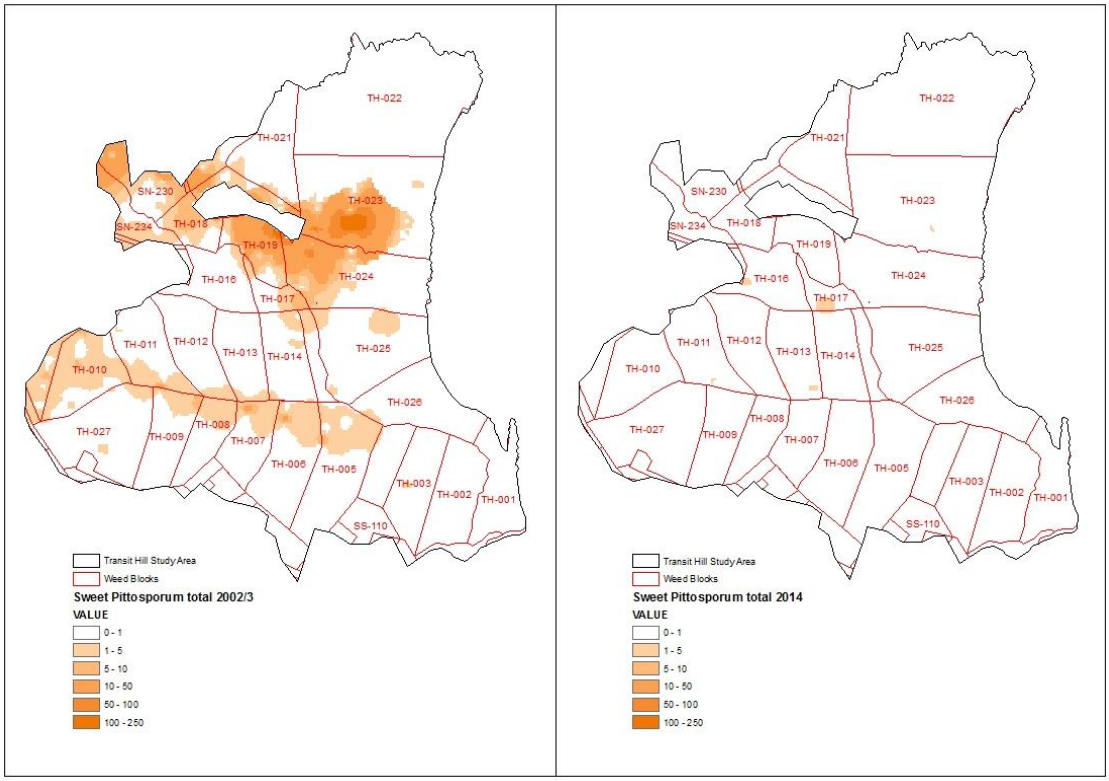


Figure 34 Transit Hill – Pittosporum 2002–03 (left) and 2013–14 (right): total count of all plants (life-stages combined).

5.3 Results and recommendations

The weed-density maps above are self-explanatory in demonstrating the overwhelming extent of the weed threat at the start of the program and the significant reduction in the numbers of weeds and the threat posed across most areas. However, ongoing seed-rain from dense infestations on adjacent cliff-lines could threaten gains made to date, and ongoing 24-month treatment of accessible blocks, application of helicopter lance-spray operations for cliff-lines and winch access to remote southern mountain blocks is recommended to continue reducing weed density and secure investments made to date.

The survey methodology provides an adequate random sampling across a range of habitats, aspects and niches, despite the proportion of each landscape directly surveyed ranging from 0.57% and 14%. Further, the percentage reductions in weed abundance from the mapping surveys and from total counts of weeds removed between first and last treatments (LHI WD) are comparable, indicating the survey method is adequate and representative.

The mapping surveys revealed patterns of weed presence that highlighted both the importance of quality search effort, and also that, as the abundance of weeds are reduced through management, the effort required to detect sparsely distributed or isolated juvenile or sub-mature plants needs to be thorough and carefully timed. The results of the surveys have also been used to provided feedback and training to staff to improve search outcomes.

Sites where residual weeds were mapped, and that need careful consideration in search and detection, include:

- In dense vine thickets;
- Near track edges;
- Near the boundaries of weed management blocks (marked with tape);
- Edges of gullies or creek banks and the base of cliff-lines;
- In weed management blocks among dense infestations of Crofton Weed, Bully Bush or Hop Wood (*Dodonaea viscosa* subsp. *burmanniana*), or generally dense low vegetation;
- On small cliffs or terrain that requires some scrambling to access;
- Where infestations of Ground Asparagus and Bitou Bush on cliff-lines have remained untreated (e.g. Malabar), owing to delays in accessing the helicopter lance-spray apparatus;
- In weed management blocks that have exceeded the 24-month treatment cycle.

A number of new weed species were identified during the repeat survey that were not recorded in the initial surveys, including White Cedar (*Melia azedarach*; a seedling detected at 200 m elevation), outlier populations of Pittosporum and Glory Lily from Lidgbird North, and Pittosporum, Small-leaved Privet and Umbrella Tree from Malabar.

It is recommended that weed density and distribution mapping should be repeated in another 5 years (2019–20), which will mark the halfway point of the 30-year Weed Eradication Program and will provide a useful assessment of progress and assist in determining priorities for the last 15 years of the program. It is also recommended that all surveys and assessment of Cherry Guava should use juvenile and mature as age-classes to reflect the reproductive stage when they are recorded rather than size-ranges used above. Cherry Guava can set fruit at various sizes, depending on environmental conditions and plant age. The shrub class used in this survey was more suited for a reproductively mature classification.

The significant and obvious reduction in weeds demonstrated through the initial and repeated weed density and distribution survey and mapping suggests that the program methodology outlined in the 2006 Weed Management Strategy (see section 3 above) is effective and should be retained as the basis to drive an eradication trajectory, although maintaining adaptive management principles need to be implemented to evaluate the program on an ongoing basis and to trial new and improved techniques as they are developed. As already stated, continued adequate and reliable funding is a necessary requirement for the continued success of the program.

6 Summary of outcomes and recommendations

1. Species eradicated and future eradication targets

Six species of weed are considered to have been **eradicated** from LHI since the Weed Eradication Program began. They are Cat's Claw Creeper, Cocos Palm, French Broom, Potato Vine, Tipuana and Turkey Rhubarb. All six species were limited in number and distribution.

Forty invasive species of weeds that are limited in population size and distribution are targeted for eradication to prevent their spread and future impacts. Owing to their restricted abundance their eradication should be readily achieved. These are species that are either rarely found in the PPP, are known from isolated locations in the Settlement, or have not been detected for some time but may still be present.

2. The 24-month repeat treatment schedule of blocks will improve eradication trajectories

An area search target of 500 ha per year is needed to achieve the minimum 24-month repeat treatment effort across priority landscapes. This level of search area aims to prevent the fruiting and spread of weeds and to deplete seed-banks to progress towards weed eradication. The target enables the removal of seedlings, re-shoots and any missed mature plants and to ensure that soil seed-banks are fully depleted. This time-frame is particularly relevant for species such as Ground Asparagus, Bitou Bush and Bridal Creeper, that if missed at a juvenile stage may reach reproductive maturity if search left to a 36-month interval rather than the targeted 24 months.

The NZ Department of Conservation weed program on Raoul Island has reported searching 1000 ha per year, with weed densities lower than those on LHI (Le Cussan 2004b; J. Le Cussan unpublished data). The current reduction of weed infestations on LHI indicates that the 500 ha and 24-month interval targets are feasible.

3. Weeds requiring shorter search intervals

- **Bitou Bush:** Requires annual search effort and no less than a minimum 2-year search effort.
- **Madeira Vine:** Known infestations require at least two control treatments per year, although four would prevent regrowth. Repeated treatment is required until all tubers are exhausted. Madeira Vine is periodically treated by the LHIB or by leaseholders in the Settlement and populations there are being reduced.
- **Glory Lily:** Requires repeat treatment twice a year in summer when it is actively growing.
- **Palm Grass:** Requires annual treatment prior to seed-set.

4. Improving outcomes in the southern mountains and other steep and inaccessible terrain

Rugged terrain and cliff-lines require specific investment to ensure they receive adequate treatment. Outbreaks of target weeds in rugged terrain need to be made priorities for eradication treatments. Successful weed control in such areas requires a range of increasingly technical means of access, including heli-winching, and helicopter search and treatment (such as lance-spraying). Staff have been provided preliminary training in remote-area access using lightweight rope-access systems (e.g. TRACE rope systems, see http://ctoms.ca/Mission-Essential-/Rope-Access-Equipment/) to enable

teams to safely undertake progressive search effort in rugged terrain that would otherwise remain inaccessible.

The continuation of the helicopter lance-spraying program is a high priority. Annual operations over the next 4–5 years will deplete Asparagus weeds and Bitou Bush on cliffs. Helicopter winch-access programs are required to complete search effort on Mt Gower and to gain access to other remote areas. Investigation into Herbicide Ballistic Technology (HBT) and other technologies, such as drones (UAV), to undertake search and control in steep and remote terrain will only benefit the program.

5. Dispersal of target weeds

The main target weeds are mostly fleshy fruited and spread by birds (e.g. Cherry Guava, Ginger Lily) or are dispersed by wind (e.g. Silky Oak, Pampas Grass *Cortaderia* spp.), which can allow wide dispersal on the island and confirms the importance of continued island-wide search and control treatments. The main avian vectors of fleshy fruited plants on LHI currently are the Lord Howe Silvereye (*Zosterops lateralis tephropleurus*), Lord Howe Pied Currawong (*Strepera graculina crissalis*) and the introduced Common Blackbird (*Turdus merula*). Cherry Guava was formerly dispersed by Pigs but these were removed from the landscape by 1981.

6. Noxious Weed Inspections and early intervention to weeds risks from the Settlement

Early intervention to prevent the spread of new weed incursions will save time, money and environmental impact. New species of weeds that are identified as a risk on the island will be declared noxious to allow their complete removal or will be removed after discussion with leaseholders. Annual Noxious Weed Inspections, as required under the *Noxious Weeds Act*, are essential in assisting with identification of any new or emerging weed threats and to ensure treatment of known declared invasive weeds has been undertaken.

7. Seasonal weed treatment to mitigate impacts to migratory seabirds

Two helicopter spray programs are needed, in part to deal with differing weed management targets but largely to mitigate effects on breeding of migratory breeding seabirds. Helicopter lance-spray programs are required in winter to access the northern hills to avoid nesting Sooty Terns (*Onychoprion fuscata*) and Red-tailed Tropicbirds (*Phaethon rubricauda*). Winch access to the southern mountains is required in summer to avoid the winter nesting season of Providence Petrels (*Pterodroma solandri*).

Similarly, the treatment of Bridal Creeper, which is mainly restricted to the northern hills, requires working around seabird breeding periods These areas are targeted for treatment in winter to avoid Sooty Tern nesting, which coincides with the plants active growth-phase, with treatments needing to be completed before October when the plant starts to fruit.

8. Release of a new biological control agent for Crofton Weed

A new biological control for Crofton Weed has been released on the mainland following extensive trials by the CSIRO (see http://www.csiro.au/en/Biological-control/Crofton-weed). This rust has been tested against all of LHI's native Asteraceae species and found not to affect them. Reduction in the vigour and spread of Crofton Weed will improve the detection and control of other priority weeds.

9. GPS recording

GPS units are now routinely used to record search effort and the locations of weeds and weed infestations and other geographically based data. This improves accuracy of treatments, of reporting, and will allow accurate identification of gaps in treatments or areas that have been missed or that require technical approaches. Over time these areas can be quantified and costed for treatment. GPS data informs program managers of the true extent of the search effort and will assist in identifying future priorities.

10. Increased knowledge base of current and future weed threats for staff

On-ground staff need to be able to recognise all target weed species in all life-stages and to be aware of, and be able to identify, newly emerging or potential weeds, considering there are likely to be up to 1000 introduced species of plants on the island. Ongoing training in plant identification and weed recognition is required, including refreshing identification skills on weeds that are sparsely distributed, or nearing eradication, or potential new weeds.

11. Labour resources and abating eradication fatigue

Based on past search effort and areas covered, an average staffing of 9 FTE is required to deliver search effort over 500 ha per year. It is important that the program maintain competent, motivated and skilled staff and other labour that are fit for work in the terrain so as to drive eradication outcomes on the ground. The repeated task of weeding can get monotonous, a monotony that may increase as the abundance of weeds decreases over time.

Retention of experience helps to improve efficiency and outcomes, as experienced staff are familiar with program methodology, capable of self managing, and have demonstrated eradication ethic and ability. Prior staff, volunteers and contractors with experience and demonstrated good performance on LHI should be supported to continue involvement in the program. A combination of local staff and periodic contractor and volunteer input helps to build a good team dynamic and increase enthusiasm.

12. Training – improving local capacity to address weeds

It is important that knowledge of program methodology, techniques and investment in skills is sustained on the island. Although staff receive on-the-job training in program methodology and plant identification they are also trained in remote first aid, use of chemicals, working safely at heights, working safely around helicopters and winch and hover access. Staff training is also offered to members of the local community who may assist in special operations in remote terrain or wish to seek future employment on the program.

13. Staff accommodation

The program has experienced a high level of itinerant staff, particularly during the winter season. The program needs to continue to support volunteers and contractors to assist resident staff. Limited housing and the high cost of lodge accommodation is not financially viable and continued access to reasonably priced rental accommodation and the research facility managed by the LHIB is required.

14. Eradication ethic and alignment to program goals

To achieve eradication of target weed species, all stakeholders, including funding agencies and the LHIB and its managers and elected Board members, need to be aligned to program goals or outcomes will be compromised. Staff engaged on the program must be committed to applying thorough grid-search effort to 'get the last weed' to achieve eradication and must also be aware of the obligations and difficulties of their position.

15. Volunteers

Over 150 volunteers supported by the LHIB or by external grants have been engaged through the Weed Eradication Program. Increasingly, LHI residents are volunteering on the program to gain experience of the program and to improve their employment opportunities.

The Friends of Lord Howe Island continue to provide invaluable volunteer assistance to the program, building networks and raising awareness of the Weed Eradication Program, island ecology and threat of invasive weeds.

Volunteers supported by the LHIB are selected through an expression of interest. They must demonstrate needed skills and, importantly, a high level of bush fitness. Weed infestations have reduced significantly, which increases the difficulty of weed detection and search effort. Increased screening of volunteer applications is needed.

16. Plant Importation Strategy

The adoption of the Lord Howe Island Regulations 2014 and Plant Importation Policy 2014 (LHIB 2014) early in the program is instrumental in regulating the importation of invasive plants onto the island. The Plant Importation Policy also addresses the risk of Myrtle Rust, by prohibiting the import of species of Myrtaceae.

17. Garden Plant Inventory

A Garden Plant Inventory was established early in the program and is ongoing. It is generally collated during Noxious Weed Inspections. The Settlement remains a source of latent and novel weed threats. Although the importation of new ornamental or agricultural plants requires approval, a number of illegal or unapproved imports have been intercepted, and the movement of plant material through the postal service is not controlled and its extent is not known. Ongoing community education is required to mitigate this risk. The rate at which some weeds have spread since the time of their introduction to the island is alarming and should raise concern about the vulnerability of the island's ecosystem to the threat posed by the introduction of new plants. The garden plant inventory needs to be continued.

18. Support the propagation of non-invasive ornamental and horticultural plants on the island

The LHI nursery is now leased and is propagating native and non-invasive ornamental plant species. This will help to reduce the risk of unapproved importation of new pests and pathogens.

19. Weed-detector dog

The NZ Department of Conservation has shown that weed-detector dogs can be trained to detect multiple species (see http://blog.doc.govt.nz/2015/03/30/raoul-weed-dog/). As populations of weeds on LHI are increasingly reduced a weed-detector dog trained for Cherry Guava, Ground Asparagus and

Ochna should be introduced to the program. Some landscape units on the island, particularly the southern mountains, may already provide low-level weed densities suitable for application of detector dogs.

20. Trialling weed-control techniques before their application at a broad scale

Past failures of weed control have confirmed the need to trial new techniques on LHI, on a small scale, for 2 years before their application at a broad scale. Early in the program, large patches of dense Cherry Guava were treated with triclopyr and ProTech oil. This technique resulted in the wound of the cut stump being sealed by the ProTech oil and the herbicide intake being compartmentalised, resulting in a poor rate of kill, large numbers of re-shooting plants and much subsequent fruiting by the second or third year of the program. Owing to the high density of plants initially cut and felled, teams also needed to pick through large piles of Guava debris to access the new shoots.

The application of neat triclopyr was adopted in 2006, which improved the kill rate. However, the recommended treatment method (by visiting teams and in the absence of a Flora Management Officer) at that time suggested that herbicide be only applied to the plants outer cambium (the 'fairy ring'), which also resulted in low kill rates. These ineffective techniques have set the program back by several years. However, lessons have been learnt and improvements made. The program now uses a cut, scrape and paint method using a 50:50 mix of glyphosate and water with 1 g of metsulfuron-methyl per litre. Staff are required to demonstrate their approach to ensure everyone is applying the same and correct method. Monitoring of how staff apply control techniques and seeking improvements to efficiency and effectiveness will improve outcomes.

21. Funding the next decade of weed-eradication work

The Weed Eradication Program can report an 80% reduction in target weeds of all life-stages and a 90% reduction in mature plants across the landscape in the PPP, despite program setbacks and inconsistent resourcing. To improve eradication trajectories, the program needs to seek funding to apply the repeat treatment of weed blocks every 24 months with a minimum areal target of 500 ha per year. These goals will require nine full-time equivalent (FTE) staff dedicated to on-ground grid-search effort (over the targeted 500 ha per annum), two helicopter-assisted programs (lance-spray and winch access), and additional staff dedicated to treatment of weeds on cliff-edges, crest-lines and other remote and difficult terrain (on rope or under restraint) and in the Settlement area. New technical methods may also be developed for future use, for example, drones (UAV) may be used as an alternative to helicopter operations when Asparagus infestations are further reduced,.

The program needs to seek dedicated funding for the next decade. An annual project investment of $983,900 from external sources (excluding LHIB inputs) is recommended for the next 5 years to continue to improve eradication outcomes (see section 7, following).

It is suggested that an interim program of 4 years of high-level funding is applied to enable two complete treatments of the island and the helicopter programs, followed by program review and repeat monitoring by Year 15 – the halfway point of the planned 30-year program.

7 Program funding 2016–2021

Consistent high-level funding is required for the next 10 years to improve weed eradication trajectories on LHI. However, a funding program for the next 5 years 2016–21 is presented here (Table 8), a program that will allow for continued weed search and control effort as well as monitoring and review midway through the next 10-year period, including a repeat of the landscape-scale mapping and further detailed analysis of the LHI WD to define and assess the program to identify areas for improvement and future priorities and investment needs.

The Weed Eradication Program and the LHI Weed Management Strategy 2006 require resourcing of four main elements:

- Ongoing grid-search and control of weeds in accessible terrain, with a target area of 500 ha per year.
- Technical applications on cliff-lines and other rugged or otherwise inaccessible terrain using helicopter winch access and lance-spray programs, on-rope terrestrial access, drones (UAV) and Herbicide Ballistic Technology (HBT).
- Working with the local community in addressing current and future weed risks in the Settlement.
- Monitoring and review of the program and the progress of weed eradication.

None of these individual program elements should be undertaken at the expense of another – they integrate to achieve the goal of weed eradication on LHI.

Based on results achieved to date and recommendations from the 2006 Weed Management Strategy, a minimum target of 500 ha per year should be maintained to deliver repeat search effort of weed management blocks at intervals of no more than 24 months. Based on an average of 30 hours per hectare (over the 10-year period) this will require labour resources equivalent to 9 FTE positions for on-ground search and control. Additional personnel are also required to undertake on-rope or other technical search effort in complex terrain on cliff-edges and crests (3 FTE) and for dedicated search-effort in the Settlement (0.4 FTE), and funding is required for helicopter operations to treat steep and remote terrain. The project also has costs associated with project management, materials and administration, and development and trialling of new methods of control.

The LHIB has put in a bid to NSW Treasury for funding to assist with the effective management of the PPP and World Heritage Values, and has been investigating avenues for philanthropic sponsorship and negotiating with external funding bodies. The 2006 Strategy suggested that the LHIB underwrite the program in the absence of funding. With a small rate base and a tourism levy, LHIB resources for environmental project work are limited and not always available when they might be needed. In 2008, the LHIB underwrote the program knowing that external funding was imminent. However, most grant programs prohibit back payment of expenditure, which is limiting for a program that requires consistent resourcing.

A clear understanding and commitment to the eradication targets and methodology of the program by all stakeholders is important to ensure the project is adequately resourced and the methodology is effectively applied to continue to drive eradiation targets and protect investment to date. Failing to secure adequate resources to achieve these targets won't compromise program success in the short term, but in the long term will enable weed populations to rebound. Ongoing, reliable and adequate funding will enable further search effort and drive stronger eradication trends.

Table 8 Estimated annual program inputs 2016–21: (A) external funding sought; and (B) LHIB inputs.

(A) Activity – external funding sought	Cost
On-ground grid-search effort – 6 FTE positions	$443,500
Settlement weeding – estimated 0.4 FTE position	$30,000
Weeding cliff-edges and other remote terrain – estimated 3 FTE positions	$230,400
Helicopter lance-spray program (July – August)	$140,000
Helicopter winch access (October – February)	$100,000
Herbicide Ballistic Technology	TBD
Materials	$20,000
Administration	$20,000
Total external funding	**$983,900**

(B) Activity – LHIB inputs	Cost
3 FTE positions	$221,999
Project management	$95,938
Materials	$10,000
Total LHIB funding	**$327,937**

8 Conclusion

The LHI Weed Eradication Program has demonstrated that the eradication methodology and investment to date is delivering a highly significant reduction in invasive weeds and has effectively protected the World Heritage listed ecosystems of the island from the immediate threat of dense and widespread weed infestations. Program setbacks have meant that the eradication time-frame may have increased in the first 10 years of the program. However, valuable lessons have been learnt from these setbacks and methods modified or new methods adopted to improve future outcomes and which may be of benefit for other island restoration programs.

The results achieved over the past 10 years have reduced weed infestations to a level where eradication is considered feasible for many species, given adequate funding for grid-search effort of an area of 500 ha per year and the increasing adoption of technical methods such as helicopter lance-spray and heli-winch access to remote or difficult sites.

The Weed Eradication Program still requires reliable, dedicated and consistent funding to deliver the target of no more than 24-months between repeat treatments of all weed management blocks, the increased treatment for Bitou Bush, and investment into search effort on cliffs and the complex edges of cliff-lines with rope and aerial access programs. Although the program may have some level of robustness with the gains made to date, resourcing and effort cannot be eased or reduced as this will increase the overall eradication time-frame and compromise the investment and the ecological benefits that have already been made.

Significantly, the Weed Eradication Program has built much community capacity and involvement through training, volunteering opportunities and employment on the program. Ongoing community education and capacity building is essential to increase knowledge and understanding of the threat to the island posed by weeds and to sustain support for the program.

To deliver weed eradication on LHI requires resourcing, commitment and a strong eradication ethic by the teams on ground, the LHIB administration and elected Board, State and Federal agencies and the LHI community.

All of the people involved and the agencies that have supported the program should be commended for embarking on and continued support of what may have seemed an impossible task at the outset. Their collective commitment and vision to invest in protecting the island's unique environment and World Heritage values has been well worth the effort. The challenge for the future is to take the program into the next decade with a focus to achieving zero density of weeds – ERADICATION. This is what is required to deliver long-term protection of the island and its biodiversity.

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Appendix 1 Weed species treated 2004–14

Table A1 All 68 species of declared noxious weeds ***targeted for eradication*** on LHI through the Weed Eradication Program, and the total number of plants removed over the 10 years 2004–14. **Species highlighted in bold have been eradicated.** 'Control class' is the Control Class under the NSW *Noxious Weeds Act 1963* (see Table A4); under Control class, * indicates a plant that must not be sold, propagated or knowingly distributed. 'Other class' identifies other categorisations of these weeds: WoNS = Weeds of National Significance; IUCN = World's 100 Worst Invasive Alien Species; Alert = National Environmental Alert List; NRC, extreme (NRCx) to very high (NRCv) priority invasive species that pose a threat to biodiversity in NSW; AUS = Australian species introduced to LHI (see section 2 for details of these listings). Where the number of sites is given in parentheses, this is indicative of weeds with fairly high abundance but localised distribution. Rows highlighted in grey indicate species that were identified as eradication targets in the 2006 LHI Weed Management Strategy (LHIB 2006).

Common name (and alternate common names)	Scientific name	Control class	Other class	Total number of plants removed 2004–14
***TOP 10:* Common and widespread noxious weeds (>13,000 – 700,000 plants removed) or species with localised occurrence – PPP + Settlement**				
Ground Asparagus	*Asparagus aethiopicus*	3*	WoNS, NRCv	665,831
Bridal Creeper	*Asparagus asparagoides*	3*	WoNS, NRCv	110,794
Climbing Asparagus	*Asparagus plumosus*	3*	WoNS	53,840
Lady-of-the-night	*Cestrum nocturnum*	4*		13,380
Bitou Bush	*Chrysanthemoides monilifera* subsp. *rotundata*	2	WoNS, NRCx	3,459
Cotoneaster (Large-leaf Cotoneaster)	*Cotoneaster glaucophyllus*	3*		26,211
Glory Lily	*Gloriosa superba*	3*	Alert	13,655 (14 sites)
Ochna	*Ochna serrulata*	3*	NRCv	485,168
Sweet Pittosporum	*Pittosporum undulatum*	3*	AUS	84,729
Cherry Guava	*Psidium cattleyanum* var. *cattleyanum*	3*	IUCN	704,266
18 Occasional to Uncommon (widespread to localised) noxious weed species (>1000 – <2000 individuals) — PPP + Settlement				
Flame Tree	*Brachychiton acerifolius*	3*	AUS	120
Camphor Laurel	*Cinnamomum camphora*	3*		81

Common name (and alternate common names)	Scientific name	Control class	Other class	Total number of plants removed 2004–14
Pampas Grass	*Cortaderia* spp.	3*		13
Holly Fern	*Cyrtomium falcatum*	4		13
Silky Oak	*Grevillia robusta*	3*	AUS	271
Ginger Lily (Kahili Ginger)	*Hedychium gardnerianum*	2	IUCN	123
Lantana (all forms)	*Lantana camara*	2	WoNS, NRCx	451
Broad-leaf Privet (Large-leafed Privet)	*Ligustrum lucidium*	2	NRCv	3
Narrow-leaf Privet (Small-leafed Privet)	*Ligustrum sinense*	2	NRCv	897
African Boxthorn	*Lycium ferocissimum*	3*	WoNS	460
Siratro	*Macroptilium atropurpureum*	3*		51
White Cedar (Chinaberry)	*Melia azedarach*	4	AUS	292
Blue Passionflower	*Passiflora caerulea*	3*		256 (4 sites)
Umbrella Tree	*Schefflera actinophylla*	3*	AUS	702
Palm Grass	*Setaria palmifolia*	3*		1,071
Brush Cherry (Magenta Cherry)	*Syzygium paniculatum*	3*	AUS	2
Rice Paper Plant	*Tetrapanax papyrifer*	3*		824
Rhus Tree	*Toxicodendron succedaneum*	4*		36
40 Uncommon (localised) noxious weed species (<1000 individuals or <50 sites) — Settlement only				
Lilly Pilly (Small-leaved Lilly Pilly)	*Acmena smithii*	3*	AUS	0
Madeira Vine	*Anredera cordifolia*	3*	WoNS, NRCx	5,245 kg (49 sites)
Arundinaria Reed (Simon Bamboo)	*Arundinaria* spp.	3*		556 (2 sites)
Giant Reed (Elephant Grass)	*Arundo donax*	3*		93
Ming Fern (Ming Asparagus Fern)	*Asparagus macowanii* var. *zuluensis*	2*		0

Common name (and alternate common names)	Scientific name	Control class	Other class	Total number of plants removed 2004–14
Mother-of-millions	*Bryophyllum delagoense*	4*		0
Resurrection Plant (Mother-of-millions)	*Bryophyllum pinnatum*	4*	NRCv	160
Mirror Bush (Coprosma)	*Coprosma repens*	2		0
Common Thornapple	*Datura stramonium*	3*		1
Cape Ivy	*Delairea odorata*	3*	NRCv	35
King Orchid	*Dendrobium speciosum*	3*	AUS	1
Cat's Claw Creeper	***Dolichandra unguis-cati***	**2**	**WoNS, NRCv**	**25 (Eradicated)**
Water Hyacinth	*Eichhornia crassipes*	2	WoNS	0
French Broom (Montpellier Broom, Cape Broom)	***Genista monspessulana***	**2***	**WoNS**	**1 (Eradicated)**
Native Frangipani	*Hymenosporum flavum*	3*	AUS	1
Freckleface	*Hypoestes phyllostachya*	3*		40
Blue Morning Glory (Purple Morning Glory)	*Ipomoea indica*	3*	NRCv	1,845 (3 sites)
Coastal Tea-tree	*Leptospermum laevigatum*	3*	AUS	10
Japanese Honeysuckle	*Lonicera japonica*	3*	NRCv	0
Murraya (Orange Jessamine)	*Murraya paniculata*	3*		1
African Olive	*Olea europaea* subsp. *cuspidata*	4*		2
Bower Vine	*Pandorea jasminoides*	3*	AUS	0
Leaf Cactus (Satan Plant)	*Pereskia aculeata*	2	Alert	5
Rhizomatous Bamboo	*Phyllostachys* spp.	3*		0
Water Lettuce	*Pistia stratiotes*	1		0
Staghorn Fern	*Platycerium superbum*	3*	AUS	0
Castor Oil Plant	*Riccinus communis*	3*		930 (6 sites)
Black Locust	*Robinia pseudoacacia*	3*		0
Salvinia	*Salvinia molesta*	2	WoNS	0
Cassia (Senna, Winter Senna, Easter Cassia)	*Senna pendula* var.*glabrata*	3*		15

Common name (and alternate common names)	Scientific name	Control class	Other class	Total number of plants removed 2004–14
Winter Senna (Arsenic Bush, Brazilian Buttercup)	*Senna septemtrionalis*	3*		186 (3sites)
Climbing Nightshade (Brazilian Nightshade)	*Solanum seaforthianum*	2		1
Singapore Daisy	*Sphagneticola trilobata*	2	IUCN	94 (1 site)
Cocos Palm	***Syagrus romanzoffiana***	**3***		**3 (Eradicated)**
Broad-leaved Lilly Pilly	*Syzygium hemilampra*	3	AUS	0
Blue Lilly Pilly	*Syzygium oleosum*	3	AUS	0
Spanish Moss (Old Man's Beard)	*Tillandsia usneoides*	2		0
Red Cedar	*Toona ciliata*	3	AUS	0
Blue Periwinkle (Greater Periwinkle)	*Vinca major*	3*		110
Arum Lily	*Zantedeschia aethiopica*	4*		0

Table A2 Introduced plant species on LHI ***targeted for containment*** (control only) through the Weed Eradication Program and the total number of plants removed over the 10 years 2004–14. None of these species is a declared noxious weed. Other declared noxious weeds that occur on LHI and sleeper weeds will eventually be targeted for eradication or containment. The alternate common names given are not exhaustive but include the first name (at least) given in PlantNET – New South Wales Flora Online (http://plantnet.rbgsyd.nsw.gov.au/floraonline.htm) where it differs from the name adopted here. See Table A1 for legend to columns. Rows highlighted in grey indicate species identified as eradication targets in the LHI Weed Management Strategy of 2006, although, of those, Mauritian Hemp is not listed as it is not a declared noxious weed and none has been removed.

Common name (and alternate common names)	Scientific name	Control class	Other class	Total number of plants removed 2004–14
Bushman's Poison (Wintersweet)	*Acokanthera oblongifolia*	–	–	373
Agapanthus (African Lily)	*Agapanthus praecox*	–	–	584
Crofton Weed	*Ageratina adenophora*	–	–	20
Peruvian Lily (Parrot Alstroemeria, Christmas Lily)	*Alstroemeria pulchella*	–	–	54
Bunya Pine	*Araucaria bidwillii*	–	–	6
Hoop Pine	*Araucaria cunninghamii*	–	–	140
Norflolk Island Pine	*Araucaria heterophylla*	–	–	3,882
Begonia	*Begonia* spp.	–	–	42
Buddlejai (Butterfly Bush)	*Buddleja madagascariensis*	–	–	10
Canna Lily	*Canna indica*	–	–	2
Paw Paw	*Carica papaya*	–	–	17
Swamp Oak (She-oak)	*Casuarina glauca*	–	–	12
Lemon	*Citrus x taitensis*	–	–	22
Coffee	*Coffea arabica*	–	–	331
Panic Veldt Grass	*Ehrharta erecta*	–	–	10
Loquat	*Eriobotrya japonica*	–	–	66
Coral Tree	*Erythrina x sykesii*	–	–	9
Brazil Cherry	*Eugenia uniflora*	–	–	137
Sea Spurge	*Euphorbia paralias*	–	–	23
Rubber Tree	*Ficus elastica*	–	–	1
African Plum	*Harpyphyllum caffrum*	–	–	146
Coastal Morning Glory	*Ipomoea cairica*	–	–	153

Common name (and alternate common names)	Scientific name	Control class	Other class	Total number of plants removed 2004–14
Sweetpea (Perennial Pea, Everlasting Pea or Sweetpea)	*Lathyrus latifolius*	–	–	275
Formosan Lily	*Lilium formosanum*	–	–	10
New Zealand Christmas Bush	*Metrosideros kermadecensis*[A]	–	–	36
Fruit Salad Plant (Monstera)	*Monstera deliciosa*	–	–	8
Mulberry	*Morus* spp.	–	–	21
Oleander	*Nerium oleander*	–	–	1
Broadleaf Paspalum	*Paspalum mandiocanum*	–	–	54
Black Passionfruit (Common Passionfruit)	*Passiflora edulis*	–	–	187
Avocado	*Persea americana*	–	–	2
Philodendron	*Philodendron* spp.	–	–	34
Peach, Nectarine	*Prunus persica*	–	–	108
Yellow Guava (Common Guava)	*Psidium guajava*	–	–	6,931
Pomegranate	*Punica granatum*	–	–	1
Hawthorn	*Rhaphiolepis umbellata*	–	–	140
Roldana	*Roldana petasitis*	–	–	113
Cup of Gold Vine	*Solandra maxima*	–	–	6
Tobacco Bush (Wild Tobacco Bush)	*Solanum mauritianum*	–	–	27,809
Wild Sorghum	*Sorghum bicolor* subsp. *arundinaceum*	–	–	260
Railroad Daisy (Mexican Sunflower)	*Tithonia diversifolia*	–	–	1
Wandering Jew	*Tradescantia fluminensis*	–	–	30
Striped Trad (Silvery Inch Plant)	*Tradescantia zebrina*	–	–	50
Chinese Elm	*Ulmus parvifolia*	–	–	1
Tung Oil Tree	*Vernicia fordii*	–	–	32
Spanish Bayonet (Dagger Plant)	*Yucca aloifolia*	–	–	35
Total				**42,185**

[A]Plants that appear to be hybrids between *M. kermadecensis* and the endemic *M.sclerocarpa* have also been removed from the PPP.

Table A3 Weed species not declared as noxious weeds but ***eradicated*** through the Weed Eradication Program, with total number of plants removed. See Table A1 for legend to columns.

Common name	Scientific name	Control class	Other class	Total number of plants removed 2004–14
Turkey Rhubarb (Rambling Dock)	***Acetosa sagittata***	**–**	**NRCv**	**1 (Eradicated)**
Potato Vine	***Solanum wendlandii***	**–**		**1 (Eradicated)**
Tipuana (African Rosewood)	***Tipuana tipu***	**–**	**Alert**	**1 (Eradicated)**

Table A4 Weed control classes and control measures as defined under the *Noxious Weeds Act* (from NSW DPI http://www.dpi.nsw.gov.au/aboutus/about/legislation-acts/noxious-weeds). Under Example control requirements, * indicates that in some cases a plant may not be sold, propagated or knowingly distributed (see Table A1).

Control class	Weed type	Example control requirements
1	Plants that pose a potentially serious threat to primary production or the environment and are not present in the State or are present only to a limited extent	The plant must be eradicated from the land and the land must be kept free of the plant The weeds are also "notifiable" and a range of restrictions on their sale and movement exist
2	Plants that pose a potentially serious threat to primary production or the environment of a region to which the order applies and are not present in the region or are present only to a limited extent	The plant must be eradicated from the land and the land must be kept free of the plant The weeds are also "notifiable" and a range of restrictions on their sale and movement exist
3	Plants that pose a potentially serious threat to primary production or the environment of a region to which the order applies, are not widely distributed in the area and are likely to spread in the area or to another area	The plant must be fully and continuously suppressed and destroyed.*
4	Plants that pose a potentially serious threat to primary production, the environment or human health, are widely distributed in an area to which the order applies and are likely to spread in the area or to another area	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread*
5	Plants that are likely, by their sale or the sale of their seeds or movement within the State or an area of the State, to spread in the State or outside the State	There are no requirements to control existing plants of Class 5 weeds However, the weeds are "notifiable" and a range of restrictions on their sale and movement exists

Appendix 2 Sources of funding for the Lord Howe Island Weed Eradication Program 2004–14

Agency	Year	Funding ($)
NSW Environmental Trust		
Intergrated Environmental Project	2004	1,227,911
Battle for Transit Hill (North East)	2009	99,012
Battle for Transit Hill – Saving the Little Muttonbird Grounds	2010	98,346
Progressing the Eradication of Weeds (Year 1)	2012–13	416,962
Progressing the Eradication of Weeds (Year 2)	2013–14	475,193
Progressing the Eradication of Weeds (Year 3)[A]	2014–15	540,550
Sub-total – NSW Environmental Trust[B]		**2,857,974**
Northern Rivers Catchment Management Authority / Natural Heritage Trust – War on Weeds	2006	600,000
Northern Rivers Catchment Management Authority (NRCMA)		
Biodiversity Grants	2009	80,000
Biodiversity Grants	2010	20,000
Incentive Program	2010	75,000
Biodiversity Program	2012	55,000
Weeds to Glory	2011	75,000
North Coast Local Land Service (NCLLS) – Eradication of priority weeds	2014–15	30,710
Sub-total – NRCMA / NCLLS / NSW Environmental Trust		**935,710**
Caring for our Country (Australian Government)		
Saving Island Ecology	2008–09	360,000
Abating the threat of weeds on LHI (Remote Guava)	2010–11	50,000
Eradication is the key	2011–12	400,000
Managing World Heritage Areas – Directional sprayer	2011–12	15,000
Sub-total Caring for our Country		**825,000**

Agency	Year	Funding ($)
Foundation for National Parks and Wildlife – Directional sprayer	2011–12	2,700
NSW Department of Primary Industries – noxious weed inspections	2004–15	32,273
Overall external funding subtotal		**4,653,657**
Lord Howe Island Board Project Management, Staff, Materials	2004–15	1,835,937
Total		**6,489,594**

[A]The total Progressing the Eradication of Weeds (Year 3) grant was split between 2014–15 and 2015–16.

[B]In addition to the 2004–14 funding, the NSW Environmental Trust provided a total of $139,640 funds for two other weed management projects in 2001 and 2003.

[C]Local Land Services replaced Catchment Management Authorities.

Appendix 3 Implementation progress of the 2006 Weed Management Strategy

The following table summarises progress against the stated objectives of the 2006 *Weed Management Strategy for Lord Howe Island* (LHIB 2006).

Primary objective Objective unit	2006 Weed Management Strategy Recommendation, target, outcome	Progress	Comment
Objective 1 Eradication of Category 1, 2 and 3 weeds (as listed in Appendix 1), with continued searching for any new recruits and new invaders			
1	PPP and Crown Land (80% of the island) to be repeatedly searched and weeds controlled for 25 target weed species (Category 1–3 weeds) by applying a grid-search and control methodology originally developed by the NZ Department of Conservation.	Achieved and ongoing	Methodology implemented (depending on funding) since 2004 for 1024-ha priority area. By Year 5, the target of 90% of treatment area met. By Year 10, 78% of treatment area target met. The priority area excludes 271 ha of remote or inaccessible terrain that was assumed to be either weed free or requires alternative methods for access or treatment, and 160.2 ha of the Settlement. Six species of weed eradicated and a further 36 are nearing eradication (known from Settlement).
2	Apply a 24-month repeat treatment schedule to systematically treat (search and control) priority blocks and remove all target weeds in the PPP and on Crown Land. Over a 10-year period a weed management block should have received five visits.	Not achieved – partially achieved	On average, across all blocks (1024 ha) 3.9 visits have been made. An average of 788 ha searched and weeded every 24 months (compared with the target of 1024 ha). The projected treatment time did not forecast program setbacks (e.g. the impact of selective weeding that removed woody weeds but left scrambling lower strata Asparagus weeds; failure in initial broad-scale treatment of Cherry Guava; varied quality of search effort and reporting; and, significantly, fluctuations in funding.

Primary objective Objective unit	2006 Weed Management Strategy Recommendation, target, outcome	Progress	Comment
3	Remote or rugged areas to be searched and treated by helicopter, aerial spray or winch-access for on-ground crews.	Partially achieved and ongoing	The program has trialled several methods including rope access (staff and contractors), winching staff into remote areas by helicopter, and helicopter spray programs firstly with a cone sprayer and recently using a helicopter with a forward-mounted lance-spray apparatus. Repeat investment needed to continue operations in rugged terrain and cliffs to prevent the build up of weed populations in hard-to-access terrain.
4	That during the first treatment of blocks all observed mature plants and sub-mature plants likely to reach reproductive maturity (within 2 years) are removed.	Not achieved	The projected treatment time did not forecast program setbacks (as point 2 above).
5	That within 4–5 years from commencement of the program, populations of mature plants will be greatly reduced, requiring much less time for search and treatment and so greatly reducing costs.	Partially achieved and ongoing	90% reduction in mature weeds removed in Year 10 compared to Year 1. Results show that treatment time has not reduced in all areas after removal of mature weeds, primarily because the search for smaller plants requires careful and time-consuming effort but still over the same area. Transit Hill is the only landscape unit that has achieved a reduction in treatment time. Search effort is expected to reduce after juvenile populations are depleted. The program is not at a stage where resourcing of search effort can be reduced.
6	Based on initial 1.5 years of effort, projected that a high level of investment will be required until 2010, with estimated average annual expenditure of $450,000–$550,000.	Achieved	Funding of $6.48 million invested over 10 years has been achieved but the annual level of investment has been inconsistent. Further analysis of funding cycles is required.

Primary objective / Objective unit	2006 Weed Management Strategy Recommendation, target, outcome	Progress	Comment
7	New invaders to be detected and removed and added to the eradication list. Expected new threats to arise over the next 10–30 years noting that up to 1000 introduced plants are likely to occur on island.	Achieved and ongoing	In 2014, 68 weed species were declared noxious for LHI under the NSW *Noxious Weed Act 1993* to enforce their control on all-tenure basis across the island; 62 species are now targeted for eradication. Systematic grid-search and annual Noxious Weeds Inspections enable detection of new invaders.
8	Through adopting this strategy, infestations of hundreds and thousands of target weeds will no longer occur.	Achieved	90% reduction in mature weeds removed and 80% reduction in all weeds (from the PPP).
Objective 2(a)	**Prevent new weed threats arising through removal of latent invasive alien plants from Settlement gardens identified after completion of a garden plant inventory**		
9	A fully curated garden plant inventory is undertaken for the island and eradicate potentially serious invasive species.	Partially achieved and ongoing	A garden plant inventory was established early in the program and is generally updated following Noxious Weed Inspections. Further work required to update and maintain the LHI herbarium.
Objective 2(b)	**Prevent new weed threats arising through plant importation controls**		
10	Adopt a plant importation policy.	Achieved	Lord Howe Island Plant Importation Policy and Strategy updated in May 2014.
Objective 2(c)	**Prevent new weed threats arising through eradication of non-native dispersers of weed seeds**		
11	To eradicate exotic rodents.	Ongoing	Planning and approvals phase of the Rodent Eradication Program has commenced.

Primary objective / Objective unit	2006 Weed Management Strategy Recommendation, target, outcome	Progress	Comment
Objective 3	**Engender community support and introduce sustainable land-use planning**		
Objective 4	**Explain the significance of the alien invasive plant problem to the LHI community**		
12	Disseminate community education and awareness programs to promote the importance of the program for tourism.	Ongoing	Various community education initiatives have taken place and are continuing, including articles in newspaper and online, community market displays, information sessions and newsletters, ipad user guide and conference presentations.
13	Establish a local Landcare group.	Achieved	Community based *Friends of Lord Howe Island* volunteer bush-regeneration group has 108 members, conducted 77 week-long trips and contributed over 24,000 hours of weeding. Locally, short-term and long-term residents periodically volunteer on the program to improve employment opportunities.
14	Develop a native plant retail nursery.	Partially achieved	In 2014, a commercial operator began the initial phase of re-establishing a nursery on LHI.
15	Develop property management plans, including inspection, planning mapping, garden inventory and follow-up inspections for all perpetual leases. To be completed by Year 4.	Ongoing	Property management plans have been prepared for special leases and annual Noxious Weed Inspections are undertaken in the Settlement.
16	Undertake yearly Noxious Weed Inspections.	Achieved	Periodic Noxious Weeds Inspections have been undertaken since the program started. Annual inspections aiming to cover 50% of leases began in 2014.
17	Elected Board members and LHIB staff to lead by example in managing weeds on leases.	Ongoing	Noxious weeds inspections have been undertaken since the start of the program. Annual inspections

Primary objective / Objective unit	2006 Weed Management Strategy Recommendation, target, outcome	Progress	Comment
			aiming to cover 50% of leases began in 2014.
Objective 5	**Continue research and monitoring to ensure best weed-management practices**		
18	Research and monitoring for best practice (Tiger Lily control, Crofton Weed biological control, Bridal Creeper rust, herbicide effectiveness, regenerating the edge of the PPP).	Ongoing	Bridal Creeper is now completely hand removed or sprayed. A new biological control for Crofton Weed has been released on the mainland following extensive trials by the CSIRO. This rust has been tested against all of LHI's native Asteraceae plants and found not to affect them. The program no longer uses triclopyr for treatment of woody weeds. Glyphosate and metsulfuron-methyl now used for all woody weeds. For aerial spraying, a forward-mounted lance-spray apparatus specifically designed and successfully tested on island in winter 2015. Spraying the edge of the PPP is undertaken gradually as forest edges expand.
19	Maintain the LHI Weed Database and INF (infestation) mapping systems.	Achieved and ongoing	GPS units introduced in 2014 are now used to record the search effort and infestation sites. This information is downloaded into GIS for mapping and analysis.
20	LHIB to underwrite the program in the event that finances are not available in the 5th year. Continue to seek funding.	Ongoing	$6.48 million invested in the program over 10 years to 2014–15, with $1.83 million from the LHIB and $4.65 million from external agencies, primarily Commonwealth and NSW State Government grants.

Primary objective Objective unit	2006 Weed Management Strategy Recommendation, target, outcome	Progress	Comment
			The LHIB initially underwrote the program in its early years, but most grants expressly prohibit reimbursement of prior expenditure. The program experienced a lull in funding with only three on-ground staff at times during the first 10 years. The LHIB is seeking additional program investment and project partners through marketing the program.