Australian Government
Department of Agriculture, Fisheries and Forestry



Weeds of National Significance

African boxthorn

National best practice management manual for African boxthorn (*Lycium ferocissimum*)

Second edition

Weeds of National Significance

African boxthorn

National best practice manual for African boxthorn (*Lycium ferocissimum*)

Second edition

M. Noble, M. Rose, J.G. Virtue and M.R. Sheehan

Originally produced and published by the Tasmanian Department of Primary Industries, Parks, Water and Environment with funding from the Australian Government Caring for Our Country program.

This second edition manual produced by Wild Matters Pty Ltd with funding from the Australian Government Department of Agriculture, Fisheries and Forestry.

Australian Government
Department of Agriculture, Fisheries and Forestry

Tasmanian Government

© Commonwealth of Australia 2022

Ownership of intellectual property rights

Unless otherwise noted, copyright (and any other intellectual property rights) in this publication is owned by the Commonwealth of Australia.

Creative Commons licence

All material in this publication is licensed under a Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License except content supplied by third parties, logos and the Commonwealth Coat of Arms.

Inquiries about the licence and any use of this document should be emailed to copyright@agriculture.gov.au.

Cataloguing data

This publication (and any material sourced from it should be attributed as:

Noble, M., Rose, M., Virtue J.G. and Sheehan, M.R. (2022). African boxthorn: National best practice manual for African boxthorn (*Lycium ferocissimum*) Second edition, Department of Agriculture, Fisheries and Forestry, Canberra. CC BY-NC-ND 4.0.

ISBN 978-0-6456718-0-3 (pdf)
ISBN 978-0-6456718-1-0 (print)

This publication is available at **www.weeds.org.au**

Wild Matters Pty Ltd, 11 Templeton Street, Castlemaine Vic 3450

Acknowledgements

First edition published in 2013 by Department of Natural Resources and Environment, Tasmania (formally Department of Primary Industries, Parks, Water and Environment).

This second edition produced by Wild Matters Pty Ltd and published in 2022 by the Department of Agriculture, Fisheries and Forestry.

Illustration by: Dennis Morris
Cover images (clockwise from top left) by: Matt Rose, NSW NPWS, FOBSI and Greg Stewart
Maps prepared by: Farzin Shabani, Macquarie University.
Editing: Elite Editing
Design: R.G. & F.J. Richardson, based on first edition elements by Nova Design and Print, Devonport, Tasmania

Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past, present and emerging.

Disclaimer

The views and opinions expressed in this publication do not necessarily represent the views of the Australian Government or the portfolio ministers for the Department of Agriculture, Fisheries and Forestry.

The content of this publication does not constitute advice to any third party. Although due care and skill has been applied in the preparation and compilation of the information and data in this publication, no reliance may be placed on it by any other party. No representation expressed or implied is made as to the currency, accuracy, reliability, completeness or fitness for purpose of the information contained in this publication. The reader should rely on its own inquiries to independently confirm any information and comment on which they may intend to act.

The Commonwealth of Australia, its officers, employees, agents and the other parties involved in creating this publication disclaim, to the maximum extent permitted by law, responsibility to any other party for any liability, including liability for negligence and for any loss, damage, injury, expense or cost incurred by any person as a result of accessing, using or relying upon any of the information or data in the publication.

AUTHORS AND CONTRIBUTORS

Authors

Michael Noble (formerly Weeds of National Significance African Boxthorn National Coordinator), Matt Rose (Natural State), John Virtue (for Wild Matters Pty Ltd) and Matt Sheehan (Wild Matters Pty Ltd).

Contributors

Jim Balnaves, Department of Primary Industries, Parks, Water and Environment (DPIPWE), Tasmania

Ross Gardiner, Glenn Currie and Michael Murphy, NSW National Parks and Wildlife Service (NSW NPWS), New South Wales

Ben Gooden and Michelle Rafter, CSIRO

Matthew Kennewell, former South Coast Natural Resource Management (NRM) Inc., Western Australia

Liz McIntyre, Eyre Peninsula Landscape Board, South Australia

Shauna Potter, Wild Matters Pty Ltd, South Australia

Graeme Simpson, former South Coast NRM Inc., Western Australia

Karen Stewart, Department of Natural Resources and Environment, Tasmania

Greg Taylor, Tasmania

Jarvis Weston, Jon Fallaw and Ben Thomas, Phillip Island Nature Parks, Victoria

Karen Ziegler and Katriona Hopkins, Friends of Bass Strait Islands, Tasmania

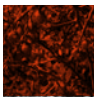
ACKNOWLEDGEMENTS

Contributors and photographers shared their time, information and photos generously. Their contribution to the manual is gratefully acknowledged.

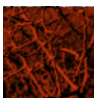
First edition: Thanks go to Michael Askey-Doran for feedback and advice, the Australian Government for Caring for Our Country funding, Janice Bird for editing, Margaret Quill and Angela Loveless (DPIPWE) for research assistance, Ashlee Griffiths from Nova Design and Print for design and layout, Chris Auricht for developing maps and Brett Littleton (DPIPWE) for use of his illustrations. Craig Magnussen developed the African Boxthorn Weed Management Guide and has provided ongoing advice and information.

Additional for second edition: Dr Robin Adair, Michael Noble and Dr Kylie Ireland published a scientific review of the biology and management of African boxthorn in 2021, from which information has been drawn for this manual update. Dr Farzin Shabani of Macquarie University developed revised maps. Andrew Storrie provided information on state and territory regulation of herbicide use.

CONTENTS



INTRODUCTION



CHAPTER 1

Biology, distribution and impacts of African boxthorn

CHAPTER 2

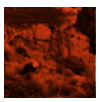
Managing African boxthorn

CHAPTER 3

Controlling African boxthorn

CHAPTER 4
Case studies

CHAPTER 5
Further information



REFERENCES

Greg Stewart NRM North

INTRODUCTION

African boxthorn — a Weed of National Significance

African boxthorn (*Lycium ferocissimum*) is endemic to southern Africa. It has been declared a Weed of National Significance (WoNS) in Australia because of its invasiveness, impacts, potential for spread and effects on socioeconomic and environmental values.

Introduced to Australia in the mid-1800s, African boxthorn was used as a hedge plant and windbreak. It has been recorded in all Australian jurisdictions. It infests natural and production lands through much of coastal and inland temperate and subtropical Australia.

African boxthorn is legally recognised (declared) as a weed under legislation in all Australian jurisdictions except Western Australia. It displaces native vegetation and degrades fauna habitat, as well as harbouring pest fauna including rabbits, foxes, feral pigs and starlings.

On production lands, African boxthorn can reduce access to grazing and water for livestock; animals are also at risk of injury from its large thorns, particularly in times of lean feed when they are browsing near boxthorn shrubs. Boxthorn fruit can host insect pests such as Queensland fruit fly and tomato potato psyllid.

Being so widespread in Australia, African boxthorn is sometimes used by some native animals for habitat or food, particularly in cleared or degraded landscapes. Such use needs to be taken into account when planning a control program. Similarly, African boxthorn growing at Aboriginal cultural sites needs to be controlled in a way that does not cause site damage (e.g. disturbance to middens).

In Australia, management of African boxthorn is focused primarily on areas where significant environmental and economic assets are under threat. This manual has case studies for the nationally recognised Fitzgerald River Ravensthorpe biodiversity hotspot in Western Australia's south coast region, Victoria's Phillip Island Nature Parks, conservation islands off the coasts of Tasmania and South Australia and the Oolambeyan National Park on the south-west plains of New South Wales.

Various chemical and mechanical control methods are effective for managing African boxthorn. As the plant has a remarkably resilient rootstock and will readily shed its leaves when under stress, foliar spraying does not produce such reliable results as it does for some other weed species. Intensive methods such as cut stump and mechanical plucking/pulling of plants, followed up with foliar spraying or cut stump of regenerating or newly establishing plants, seem to be the most effective formulae. As with most weeds, though, it is essential to follow-up initial control work—and experience with African boxthorn around the country indicates a need to do it several times.

With this plant's declaration as a WoNS in 2012, a National African Boxthorn Strategic Plan (2012–2017) was produced. The plan established the following three broad goals for management of African boxthorn in Australia, underpinned by strategic actions:

1. prevent new infestations from establishing
2. ensure existing infestations are under strategic management
3. increase stakeholder capability and willingness to manage African boxthorn.

One of the high-priority actions that the strategic plan identified was the need for development of information on best practice, to promote efficient, effective long-term control of African boxthorn. This manual is an important means of providing such information.

CHAPTER 1

Biology, distribution and impacts of African boxthorn

Colin Wilson

CHAPTER 1

Biology, distribution and impacts of African boxthorn

1.1 Name, origin and description

African boxthorn (*Lycium ferocissimum*) is a member of the Solanaceae plant family. Other members of this family include potatoes, tomatoes and tobacco.

The name 'boxthorn' is thought to be derived from *boksdorn*, the name given to the plant by Dutch settlers in South Africa. The genus name *Lycium* comes from Lycia, the name of an ancient country in Asia Minor (where a similar spiny shrub was found), and *ferocissimum* comes from the Latin *ferox*, meaning 'bold' or 'fearless', referring to the very spiny nature of the shrub (Parsons and Cuthbertson, 2004).

African boxthorn is a native of southern Africa, specifically the Western Cape and Eastern Cape provinces of South Africa, and Lesotho. It has not been distributed to many parts of the world but has been recorded in the United States of America (USA) and the western Mediterranean (including Morocco, Tunisia, south-west Spain, Cyprus, Sardinia and coastal France) (Parsons and Cuthbertson, 2004; Kriticos et al., 2010; Noble et al., 2021) as well as Australia and New Zealand.

Though it is recognised and legislated as a weed in other countries, including the USA (DiTomaso and Healy, 2007), it is most troublesome in Australia and New Zealand, where it was deliberately introduced and is extensively distributed. African boxthorn is legally recognised (declared) as a weed in all jurisdictions in Australia except Western Australia (Noble et al., 2021). A summary of the legal status of African boxthorn in each Australian jurisdiction is provided in Chapter 5 (Section 5.1).

African boxthorn is a densely branched, often multi-stemmed perennial shrub that can grow up to 5 m high (but more often is 2–3 m) and 5 m across (more commonly, up to 3 m). On windswept coasts, the plant's growth habit is often quite different. In these situations, boxthorn is wind-pruned, very dense and often relatively short, with its shape determined by the predominant wind direction (Parsons and Cuthbertson, 2004).

Stems are smooth and silver-grey when young, becoming brown and fissured as they mature. Branches and stems end in sturdy thorns 20–150 mm long.

African boxthorn shrub

Leaves are slightly fleshy and oblong, up to 40 mm long, growing in clusters.

Flowers are approximately 10–12 mm in diameter and hang from the leaf axils on stalks, singly or in pairs. Their colour ranges from white to lilac and the five petal lobes often have a lilac base.

Fruit is 5–12 mm long, starting with a smooth green appearance and ripening to an orange-red berry, and with a prominent calyx. There are 20–70 seeds per fruit (Blood, 2001; Muyt, 2001).

1.2 Biology and ecology

African boxthorn has become widely established throughout temperate Australia, having been deliberately introduced as a hedge plant during the nineteenth century.

In its native situation in southern Africa, the plant grows both in areas that receive winter rainfall and those with non-seasonal rainfall. It is drought deciduous. In winter rainfall–summer dry situations it sheds leaves at the beginning of summer. In areas of non-seasonal rainfall, it is evergreen (Cowling et al., 1995). In Australia the species seems to respond in a similar way to its location and climate (Parsons and Cuthbertson, 2004; Kriticos et al., 2010; Noble et al., 2021).

African boxthorn readily grows in a broad range of soil types, often establishing best on light soils. It thrives on low productivity and unmanaged lands, and along dry creek beds. It is considered a halophyte (a plant tolerant of high concentrations of salt in the soil and air) and is found on the margins of salt lakes and clay pans, as well as in coastal situations (Muyt, 2001; Parsons and Cuthbertson, 2004; Adair, 2013; Noble et al., 2021).

Wind-pruned African boxthorn

African boxthorn stems and leaves

African boxthorn flower

Ripe African boxthorn berry

African boxthorn in use as an evergreen hedgerow, north-west Tasmania

African boxthorn plants do not flower and fruit until at least two years of age (Parsons and Cuthbertson, 2004).

1.2.1 Dispersal

African boxthorn is almost always spread via seed but has also been known to spread by vegetative reproduction, growing from dislodged roots or stem fragments that come into contact with moist soil (fragments can remain viable for several months before taking root) (Muyt, 2001; Parsons and Cuthbertson, 2004).

Flowering and setting of seeds usually occur in summer, but can happen at any time of year.

Fruits are consumed by fauna, including the red fox (*Vulpes vulpes*) and birds, and seeds remain viable when they have been excreted. The greater the range of birds that eat the fruit, the broader the foraging and movement patterns involved, and so seeds are dispersed to different microhabitats (Stanley and Lill, 2002). As African boxthorn seed is distributed by a range of native and non-native birds, even localised eradication and containment of the species is hard to achieve. A list of fauna species known to consume African boxthorn fruit is provided in Chapter 2 (Section 2.2).

Seed can also be dispersed by movement in water, on machinery and in soil (Muyt, 2001).

In Western Australia it was observed that sole African boxthorn plants that were remote from others of their species did not multiply or spread (Walker, 2013). Research has shown African boxthorn to be strongly self-incompatible. In field experiments in South Africa 75% of cross-pollinated flowers produced fruit, compared to only 8% for self-pollinated flowers (Miller et al., 2008).

1.2.2 Germination

Flowering and seeding can begin when plants are two years old. Seeds germinate at any time of the year. In laboratory studies, African boxthorn was found to germinate at temperatures of 5–25°C, and light encouraged germination. Peak germination occurred at 10–20°C in combination with exposure to a period of 12 hours of light each day (Podda et al., 2015).

There is little documented information available about how long the seeds might remain viable in the soil. Long-term experience in controlling infestations on islands off north-east Tasmania suggests that some seed can germinate from the soil seed bank over 20 years after control (refer Furneaux Group case study) (Ziegler and Hopkins, 2022).

1.2.3 Response to disturbance

Established African boxthorn plants have long, deep root systems. If the above-ground plant is destroyed and the soil is disturbed, the root system sends up shoots or suckers. Mass germination has been observed after soil disturbance.

In response to fire, African boxthorn re-sprouts from its rootstock. It has been found that 100% leaf scorch from fire will kill less than 30% of plants (Choate, 1997).

1.3 Preferred climate and habitat

From the mid-1800s, African boxthorn appeared in Australian nursery catalogues, was grown in botanical gardens and was recommended as a hedge plant.

African boxthorn has been recorded in all states and territories in Australia and is one of the nation's most widespread weeds. It is also widely distributed in New Zealand. (Kriticos et al., 2010; Invasive Species Compendium, 2013).

Having evolved under climatic extremes in the South African environment, African boxthorn thrives in Australia's many similar and suitable environments. Its distribution in Australia ranges from islands and coasts through to semi-arid areas, and from temperate to subtropical climates (Atlas of Living Australia, 2022).

Climatic factors that limit the distribution of African boxthorn in Australia appear to include a tropical climate, very low rainfall (below 200 mm/annum) and harsh winter temperatures at higher altitudes (such as alpine areas of New South Wales, Victoria and Tasmania). In semi-arid environments, infestations occur along ephemeral stream beds.

The species will readily grow in a range of positions from partial shade to full sun, although it has been reported in New Zealand as being intolerant of full shade (Timmins and Mackenzie, 1995). It occurs on a wide range of soil types, including low-fertility sands, fertile clays, saline and alkaline soils (Noble et al., 2021).

1.4 Current and potential distribution in Australia

African boxthorn is common across all but tropical and arid parts of central and northern Australia (Figure 1.1) (Atlas of Living Australia, 2022; Shabani, 2022). Because it is spread by birds, it often grows under trees, poles and fences, and is found on relatively remote islands (e.g. Houtman Abrolhos islands, islands in Bass Strait; and Lord Howe and Norfolk islands). It displaces local native vegetation on islands and coasts in most states of Australia and is widespread through inland areas, including much of temperate and semi-arid coastal and inland New South Wales, Victoria and South Australia. It has previously occurred in and around Alice Springs in the Northern Territory but these isolated infestations have been removed (Jobson, 2022).

1.4.1 Climate change and future African boxthorn distribution in Australia

Figure 1.2a predicts suitable areas for African boxthorn in Australia under present climatic conditions, as modelled by Macquarie University (Shabani, 2022). This indicates high suitability for it across south-west Western Australia, the southern agricultural zone of South Australia, central and eastern Tasmania, much of lower elevation Victoria and New South Wales, southern inland Queensland and parts of central Australia. This broadly aligns with other modelling done by CSIRO (Kriticos et al., 2021).

Modelling the effects of further climate change (SSP2-4.5 intermediate greenhouse gas emissions scenario, Figure 1.2b) indicates that, at a national level, the area of favourable climate for African boxthorn is predicted to contract south away from more arid areas (Shabani, 2022).

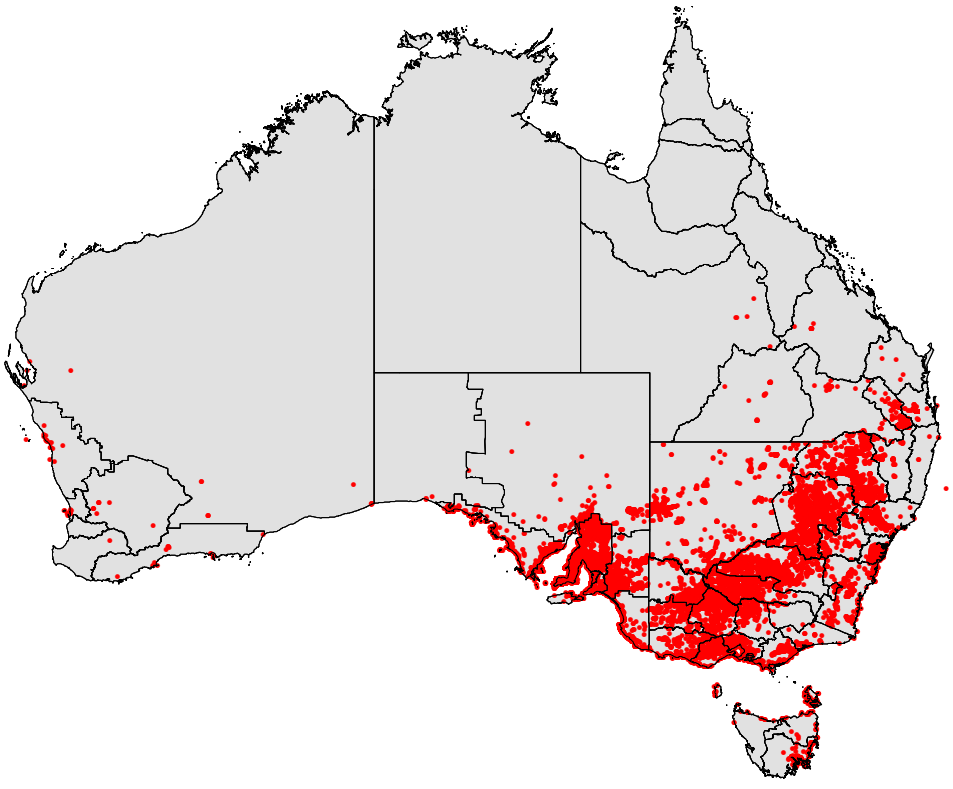


Figure 1.1 *The current distribution of African boxthorn in Australia (Atlas of Living Australia, 2022)*

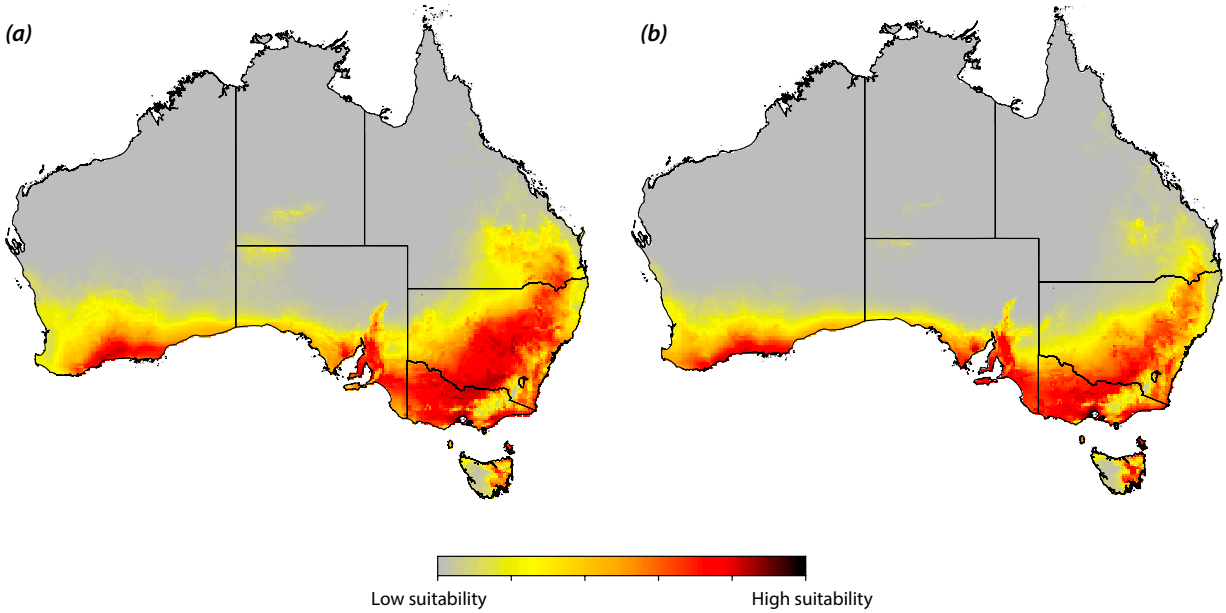


Figure 1.2 *The potential distribution of African boxthorn in Australia under (a) present and (b) projected 2050 climatic conditions as per the SSP2-4.5 intermediate greenhouse gas emissions scenario (Shabani, 2022)*

1.5 Impacts of African boxthorn in Australia

African boxthorn is recognised as a WoNS because of its major ecological and economic impacts across Australia, with potential for further spread and damage. African boxthorn affects a broad range of environments across Australia and is of concern because of its current and potential impacts on:

- the natural environment, by displacing native vegetation, degrading fauna habitat and harbouring pest animals (e.g. foxes, European rabbits *Oryctolagus cunniculus*, European starlings *Sturnus vulgaris*)
- grazing lands, by reducing access to pasture and water, injuring stock and harbouring pest animals
- cropping and horticulture, by causing machinery tyre punctures and hosting pests (e.g. fruit fly, tomato potato psyllid) (Parsons and Cuthbertson, 2004; Yen, 2013; Ireland et al., 2019).

African boxthorn can also be difficult and expensive to control, particularly in remote or sensitive environments (Cousens et al., 2013; Ireland et al., 2019).

In 2000, African boxthorn was estimated to cost primary industries in Australia approximately $700 000 per annum (Thorp and Lynch, 2000). A 2013 research report on coastal weeds found that African boxthorn was the species most often cited by natural resource managers as the worst coastal weed in southern Australia (as well as the most commonly managed). The report's authors estimated that coastal weed management in southern Australia costs around $30 million annually (Cousens et al., 2013).

Research in New South Wales found African boxthorn was the weed most frequently cited by catchment management authorities as impacting on that state's biodiversity (Turner, 2012). African boxthorn is considered a biodiversity threat in at least two rangeland biodiversity hotspots: Brigalow North and Brigalow South in Queensland, and the Carnarvon Basin in Western Australia (Martin et al., 2006).

Where African boxthorn infests coastal areas and offshore islands it can significantly alter and interfere with native fauna habitats. In some small island and coastal sand-dune environments, including Bass Strait islands and coastal New Zealand, it is a woody invader, changing the vegetation structure. This can make a place less suitable for native fauna and more hospitable to shrub-dependent pest animals such as starlings (Timmins and Mackenzie, 1995; Ziegler and Hopkins, 2011).

On islands off South Australia and Western Australia, African boxthorn displaces the native shrub nitre bush (*Nitraria billardierei*), which is used by seals (*Arctocephalus* spp.) to shelter their pups. African boxthorn does not provide an equivalent nursery habitat, leaving pups more vulnerable to predation (Moritz and Kikkawa, 1994).

On islands inhabited by Australian sea lions (*Neophoca cinerea*), such as East Beagle Island off the coast of Western Australia, African boxthorn grows down to the beach and is known to impede the sea lions' access to the island for pupping.

African boxthorn root systems are thought to make burrowing more difficult for short-tailed shearwaters (*Puffinus tenuirostris*). On Althorpe Island off the coast of South Australia, the fine, dense root systems of boxthorn have been observed to impede the bird's burrowing efforts (Lawley et al., 2005; CRC for Australian Weed Management, 2007). In Bass Strait, the ongoing spread of boxthorn on islands is considered to have the potential to destroy burrowing seabirds' breeding habitat (Brothers et al., 2001).

The large thorns on boxthorn can be hazardous for native fauna such as seabirds and shorebirds, which can become fatally ensnared. On Bass Strait islands, short-tailed shearwaters become ensnared, and in New Zealand, fairy prions (*Pachypptilla turtur*) and white-faced storm petrels (*Pelagodroma marina*) are known to become ensnared (Taylor, 1968; Priddel et al., 2000; Ziegler and Hopkins, 2011).

Even long after the plant is dead, the thorns can injure people, livestock and wildlife. The eyes of livestock are particularly at risk when feed is limited and stock are grazing in and around boxthorn plants. The thorns can also puncture tyres of vehicles and machinery.

Controlling boxthorn by hand on Beagle Islands, Western Australia

A short-tailed shearwater ensnared in African boxthorn

Once established, the plant can harbour pest animals including rabbits, foxes, feral pigs (*Sus scrofa*) and starlings. Impenetrable thickets exclude desirable vegetation (native vegetation and pasture), impede stock trying to access grazing and watering points (thus reducing the production potential of rangelands) and hinder mustering activities.

In horticulture, African boxthorn poses a risk as an alternative host for pests and diseases, including Queensland fruit fly (*Bactrocera tryoni*) and tomato potato psyllid (*Bactericera cockerelli*). The psyllid is known to overwinter on African boxthorn and then colonise commercial solanaceous crops in spring (Vereijssen et al., 2018).

African boxthorn plants (fruit, leaves, stem and roots) are toxic to people and livestock. Leaves may be toxic to poultry (Parsons and Cuthbertson, 2004; Shepherd, 2004; McKenzie, 2012). Tropane alkaloids are the suspected toxin and can affect all animal species, although the level of risk is believed to be low.

African boxthorn is also known to hamper revegetation efforts. Revegetation provides habitat and roosting points for birds; however, if these birds also visit African boxthorn, they will spread seed into revegetation sites, increasing the amount of work and money needed to maintain the revegetated area.

1.6 Native look-alikes

Several Australian native plant species could be mistaken for African boxthorn. This section describes these species and their general distribution.

The plants listed opposite and overleaf are valuable ecological contributors in their endemic locations.

Australian boxthorn (*Lycium australe*) is endemic to southern mainland Australia, mainly in drier areas west of the Great Dividing Range, in New South Wales, Victoria, South Australia and Western Australia (Atlas of Living Australia, 2013a; Magnussen 2011). It is quite similar in appearance to African boxthorn, but has shorter, narrower leaves, smaller berries (2–5 mm in diameter) with only 5–20 seeds and typically grows to only 1.5 m in height (CRC Australian Weed Management, 2007).

Australian boxthorn (Lycium australe)

Prickly box (*Bursaria spinosa*) is found mainly in eastern Australia (including Tasmania), and in South Australia. It is also known as sweet bursaria, Australian boxthorn and Christmas bush (Atlas of Living Australia, 2013b). It differs from African boxthorn by not having fleshy leaves or berry fruits (CRC Australian Weed Management, 2007).

Prickly box (Bursaria spinosa)

Tree violet (*Melicytus dentatus*—formerly *Hymenanthera dentata*) has a natural range from the Queensland–New South Wales border southward, including Victoria, Tasmania and South Australia (Atlas of Living Australia, 2013c). Its leaf margins are often slightly toothed and its fruit is a purple-black berry (CRC Australian Weed Management, 2007).

Tree violet (Melicytus dentatus)

Currant bush (*Scaevola spinescens*) is found across mainland Australia (in Western Australia, South Australia, the Northern Territory, Queensland, New South Wales and Victoria), but mainly in drier areas west of the Great Dividing Range (Atlas of Living Australia, 2013d). Its flowers are fan-shaped and it produces a dark purplish berry (CRC Australian Weed Management, 2007).

Currant bush (Scaevola spinescens)

Spiky anchorplant (*Discaria pubescens*) is an uncommon or rare plant found in southern Queensland, New South Wales, Victoria and Tasmania (Atlas of Living Australia, 2013e). It differs from African boxthorn by having green thorns and not producing a berry.

Spiky anchor plant (Discaria pubescens)

Nitre bush (*Nitraria billardierei*) has a natural range across inland areas of all mainland states (and into the Northern Territory). It is not found on the coast of eastern Australia, but grows in both coastal and inland parts of southern Australia and Western Australia (Atlas of Living Australia, 2013f). It produces a purple, red or golden oblong berry containing only one seed (CRC Australian Weed Management, 2007).

Nitre bush (Nitraria billardierei)

CHAPTER 2

Managing African boxthorn

Friends of Bass Strait Islands

CHAPTER 2

Managing African boxthorn

For effective long-term management of African boxthorn, it is important to develop an appropriate plan before starting on-ground work. This chapter provides an overview that can be used as a basis for developing a local African boxthorn management plan.

2.1 Planning

In southern Africa where it originated, and as an invader of Australian environments, African boxthorn is recognised as a particularly resilient shrub (Muyt, 2001; Rutherford et al., 2012). The root system of mature plants will usually survive mechanical management and fire, and often chemical treatments also.

If unmanaged African boxthorn infestations occur in proximity to where it is being actively managed then birds and other fauna will almost certainly reintroduce it to the management area.

This resilience and mobility of African boxthorn are why poorly planned and executed attempts to control the species are likely to be a waste of effort and resources, and can potentially make the problem more difficult and expensive to manage.

One of the keys to success in controlling African boxthorn is careful planning that considers the broader context (such as managing seed sources and considering potential environmental impacts of control), the most appropriate and effective control methods, and the best combination of methods to use for each specific situation. It is critical also to recognise and commit to a realistic budget and timeline for control. For very large, remote, environmentally sensitive and/or difficult-to-access infestations, the timeline may need to be a decade or more.

One of the fundamental strategies of weed management planning involves working from the least to the most weed-infested areas of a site. The areas of lesser infestation will more readily recover and require less follow-up commitment. Figure 2.1 illustrates grades of weed invasion and how they might be considered from a planning perspective. Nonetheless, among the first considerations of weed management planning must be the pathways of spread.

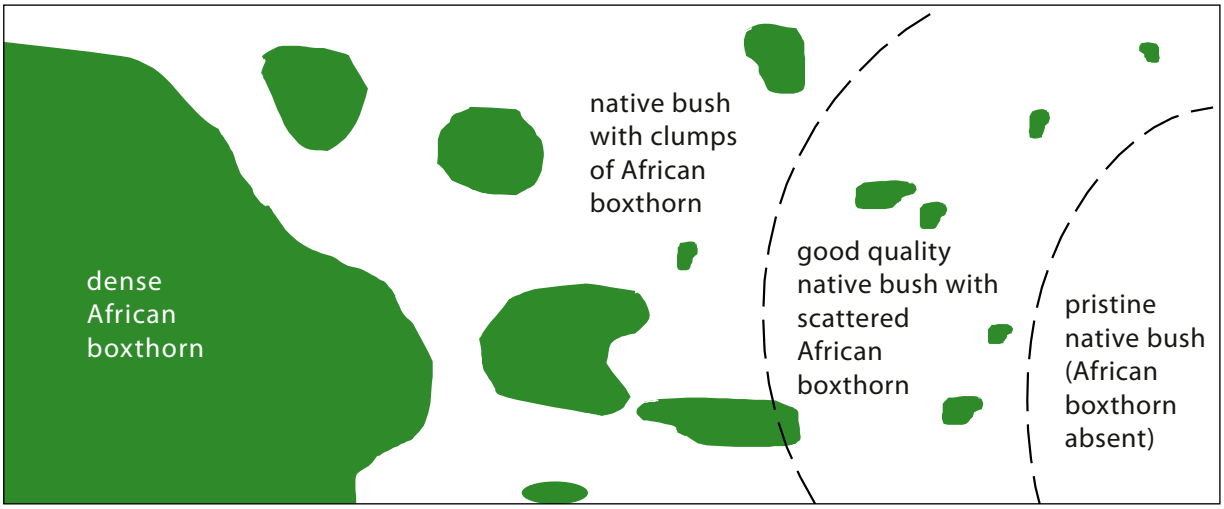


Figure 2.1 *Grades of weed invasion: dense infestation; patches of weed in native bush; good quality native bush with only scattered weeds; and native bush with no weeds. Adapted Brougham* et al. *(2006).*

2.2 Pathways of spread

When planning management of African boxthorn, it is important to consider how it got there, where it could move to, and if it could continue to arrive post-control.

2.2.1 Weed hygiene

The most cost-effective way to manage weeds is to prevent their spread. African boxthorn is sometimes spread via seed transported in gravel, soil or mud, on machinery and in agricultural produce (Muyt, 2001; Parsons and Cuthbertson, 2004).

Weeds can be spread by the vehicles and machinery of contractors or land managers travelling between sites and regions. Only use trusted suppliers to supply and transport soil and quarry materials to and from your sites, and ensure that all vehicles, machinery, equipment and clothing entering or leaving the site are inspected and cleaned. Soil, vegetative material, fruit and seeds should be removed and disposed of appropriately.

2.2.2 Movement with fauna

African boxthorn seed is spread primarily by fauna consuming boxthorn fruit and later excreting viable seed. Fauna species in Australia known to consume African boxthorn fruit include the following (Taylor, 1968; Quin, 1985; Harris et al., 2001; Stanley and Lill, 2002; Ziegler and Hopkins, 2011; Adair, 2013; Noble and Adair, 2014):

Animals known to consume African boxthorn fruit in Australia

Birds

Common blackbird (*Turdus merula*)*

Buff-banded rail (*Gallirallus philippensis*)

Cockatiel (*Leptolophus hollandicus*)

Currawong (*Strepera fuliginosa*)

Dusky moorhen (*Gallinula tenebrosa*)

House sparrow (*Passer domesticus*)

Kori bustard (*Ardeotis kori*)

Little raven (*Corvus mellori*)

Little wattlebird (*Anthochaera chrysoptera*)

Mistletoe bird (*Dicaeum hirundinaceum*)

Mulga parrot (*Psephotus varius*)

Pacific gull (*Larus pacificus*)

Purple-crowned lorikeet (*Glossopsitta porphyrocephala*)

Red wattlebird (*Anthochaera carunculata*)

European starling (*Sturnus vulgaris*)*

Silver gull (*Chroicocephalus novaehollandiae*)

Silvereye (*Zosterops lateralis*)

Singing honeyeater (*Lichenostomus virescens*)

Spiny-cheeked honeyeater (*Acanthagenys rufogularis*)

Stubble quail (*Coturnix pectoralis*)

Yellow-faced honeyeater (*Lichenostomus chrysops*)

Mammals

Eastern barred bandicoot (*Perameles gunnii*)

Red fox (*Vulpes vulpes*)*

Southern brown bandicoot (*Isoodon obesulus*)

Tasmanian pademelon (*Thylogale billardierii*)

Reptiles

Cunningham's skink (*Egernia cunninghami*)

Shingleback lizard (*Tiliqua rugosa*)

* Non-native pest animals

Starlings roost in dead boxthorn bushes, including this one on Chalky Island (Furneaux Group), Bass Strait

Available data and evidence indicates that, once expelled by fauna, seed frequently remains viable.

A study in the Canary Islands involving another *Lycium* species (*Lycium intricatum*) found that viable seed comes from shrikes and kestrels who regurgitate pellets containing the remains of lizards that have fed on the *Lycium* fruit (Nogales et al., 1998).

The experience of the Friends of Bass Strait Islands (FOBSI) illustrates some of the considerations and strategies involved. Boxthorn has established on many of the small islands in the Furneaux Group in Bass Strait. The original vegetation on many of these islands was native grasses and herbs, with no shrub layer. Where the African boxthorn plants had been poisoned and the plant debris left in place, it continued to provide roosting habitat for starlings. The birds brought and excreted boxthorn seeds, which then grew under the dead bushes. By not only poisoning stems, but also piling and burning the dead plants, FOBSI found that its projects were significantly more successful (Ziegler and Hopkins, 2011). Further information on this project is presented in a case study in Chapter 4 (Section 4.2).

Another example of managing African boxthorn that takes re-infestation into consideration comes from South Coast Natural Resource Management (NRM) Inc. in Western Australia, who developed an African boxthorn regional program (see case study in Chapter 4, Section 4.4). When planning to eradicate relatively isolated infestations, the group estimated that the likely maximum distance that seed could be spread by local vectors (e.g. native birds and foxes) was 5 km. Therefore, they sought to create and maintain an African boxthorn-free buffer zone of 5 km around each boxthorn eradication area (Kennewell and Simpson, 2013).

This approach is viable in south-west Western Australia because, unlike many other parts of Australia, there are no starlings. Should starlings establish in south-west Western Australia, it is likely that African boxthorn would be much more widely dispersed.

2.3 Management considerations for specific situations

As African boxthorn grows across many Australian landscapes, it can occur in areas with outstanding ecological and cultural values that have been recognised in national and state/territory legislation.

More broadly across Australian landscapes, African boxthorn is used by native fauna for habitat, often in lieu of alternative native vegetation that may have been cleared or become degraded. In some cases, the fauna species are listed as threatened at state or territory and/or national level.

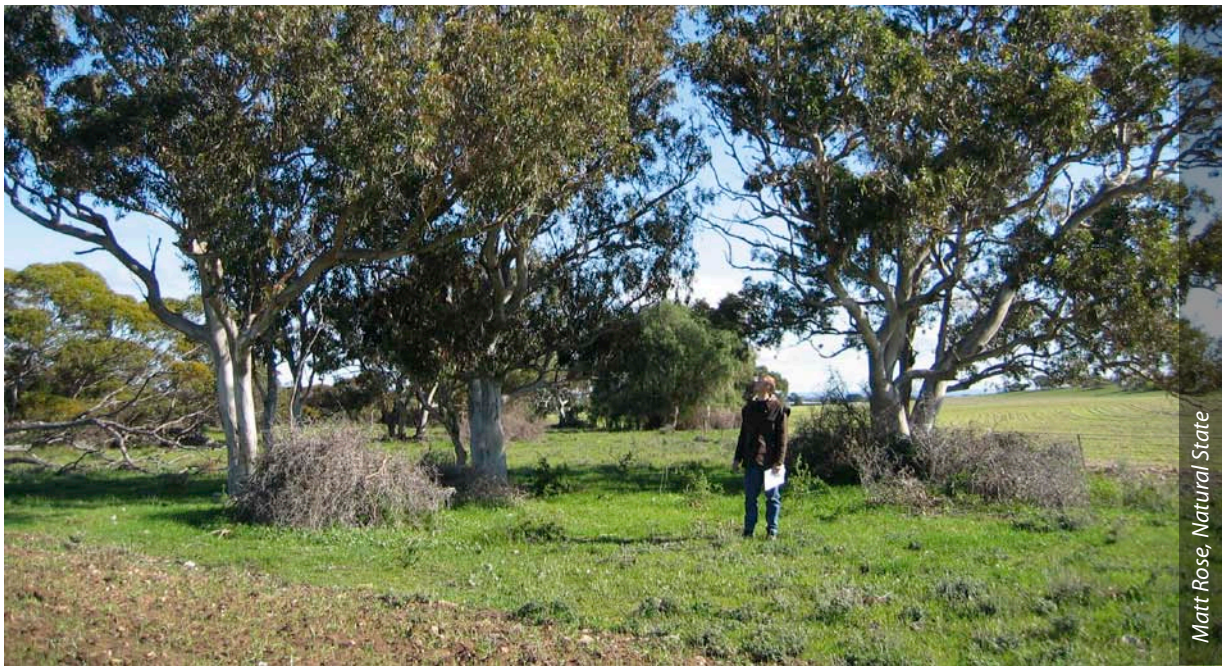
Ecological and heritage site surveys can provide important information for weed management planning, and may be required by the relevant jurisdiction's legislation. Cultural and historic heritage investigations will identify the presence and condition of sites and artefacts. The resulting baseline information can give land managers a better understanding of the values of the site and will be useful for making later comparisons.

Ecological surveys should record the flora and fauna, as well as the presence and condition of vegetation communities, providing information on the site's biodiversity. A survey might also find threatened species or identify native fauna habitats and corridors.

When planning a boxthorn control activity, it is very important to consider and manage any potential negative implications for landscape values.

2.3.1 Native fauna using African boxthorn

It is not unusual for weed species to provide some habitat value for native fauna. Hence, before removing the weed, it is important to assess whether this is the case. Having been in Australia for over 150 years, some native animals have adapted to utilise African boxthorn for shelter or food, particularly in cleared or degraded landscapes.



Ecological and/or heritage surveys provide important information for weed management planning

African boxthorn can provide habitat for a range of native fauna species, particularly birds. For example, where there is no indigenous vegetation to offer protective cover, it provides shelter for fairy wrens such as the superb fairy-wren (*Malurus cyaneus*). In saltmarsh vegetation in Victoria, African boxthorn was found to alter the types of bird species present, favouring fruit and nectar feeders over insectivores (Carlos et al., 2017).

Little penguins (*Eudyptula minor*) are also known to utilise boxthorn. For example, at Low Head at the mouth of the Tamar Estuary in northern Tasmania, land was cleared for grazing early after European settlement. African boxthorn now grows at this site and provides the local little penguin colony with cover. Holistic management of African boxthorn was needed in this situation, to ensure that its removal would not harm the little penguin colony. This involved planned removal, revegetation with 2200 suitable indigenous plants, and the provision of 100 artificial burrows. A detailed example of sensitive management of African boxthorn in little penguin habitat is provided in the Phillip Island Nature Parks case study in Chapter 4 (Section 4.3).

A more complex example of the relationship between native fauna and African boxthorn involves the critically endangered orange-bellied parrot (*Neophema chrysogaster*). Invasive weeds, including African boxthorn, threaten to degrade the parrot's ground foraging habitat (Department of Primary Industries and Water, 2006). However, in parts of coastal Victoria and South Australia where the species' native habitat is degraded or gone and boxthorn is established, the invader can provide roosting habitat. Although it is lower-quality habitat than native vegetation, it is an alternative that is better than nothing. In this type of situation, the best long-term solution may be to re-establish indigenous vegetation in combination with gradual (staged) boxthorn removal.

Superb fairy wrens make use of African boxthorn

Examples of usage of African boxthorn by mammals include documented evidence in southern New South Wales and northern Tasmania of a positive correlation between bare-nosed wombat (*Vombatus ursinus*) burrows and African boxthorn shrubs (along with blackberry *Rubus* spp. in the New South Wales case) (Taylor, 1993; Roger et al., 2007). The nationally endangered southern brown bandicoot is known to use African boxthorn fruit as a seasonal food supplement (Quin, 1985); and African boxthorn can provide habitat for the nationally vulnerable eastern barred bandicoot (Adair, 2013).

On islands off South Australia, the nationally vulnerable greater stick-nest rat (*Leporillus conditor*) has been observed to use African boxthorn for shelter, food and nesting material. On Bass Strait islands, Tasmanian pademelons (*Thylogale billardierii*) regularly climb into African boxthorn to feed on leaves and fruit (Noble and Adair, 2014).

These complex relationships between native fauna and African boxthorn illustrate how important it is to undertake considered research and management planning.

When planning a management regime for an African boxthorn infestation, it is important to survey the site to record the species present. Natural values databases or site-specific flora and fauna survey reports should also be checked, as they might contain records of threatened species on the site. Management actions can then take into account habitat requirements and threat abatement for native flora and fauna.

2.3.2 Native flora benefiting from African boxthorn

Where African boxthorn is invading quality, intact native vegetation, it will generally be providing little or no benefit to native flora, but rather posing a threat. Conversely, in some situations where native vegetation is significantly degraded and/or faces ongoing threats from browsing by livestock and wildlife, African boxthorn can provide some benefits worthy of consideration.

Where browsing pressures are high, African boxthorn thickets can exclude livestock and larger wildlife, allowing native vegetation to establish within the thickets, where it might otherwise have been vulnerable. For example, on the Eyre Peninsula in South Australia, African boxthorn seems to protect threatened west-coast mintbush (*Prostanthera calycina*) juveniles from grazing (Pobke, 2007).

In such cases, leaving dead African boxthorn in situ (after carefully targeted control; e.g.

Native boobialla (Myoporum insulare) *establishing under dead African boxthorn at Doctors Rocks, Tasmania*

through the basal bark application method) may keep protecting vulnerable native plants. A potential downside of this is that the dead shrubs can continue to harbour rabbits, which heavily browse flora seedlings and small plants—native or otherwise. Also, left in situ, dead boxthorn plants can harbour starlings and other birds that can continue to transport African boxthorn seed to the site.

Retaining dead boxthorn in combination with ongoing intervention can be a useful technique to encourage re-establishment of native vegetation. In circumstances where rabbits are less of an issue, such as at some coastal sites, dead boxthorn plants can be used to encourage visits by native birds that will carry and deposit seeds of native flora. However, the chances are that they will be carrying weed seed too, so ongoing intervention will be needed to prevent the establishment of undesirable vegetation.

2.3.3 Cultural heritage

Both the presence of African boxthorn and control activities can impact on cultural heritage sites and artefacts. To create an appropriate boxthorn management strategy, it is necessary to know the location of any heritage sites and artefacts on the property in question. In some cases, site surveys may be necessary. As an example, coastal areas are likely locations for Indigenous heritage such as artefacts and middens. Prior to starting any boxthorn control work, it is essential to seek advice and, where relevant, appropriate approvals under cultural heritage legislation. Removal of plants could damage heritage sites and materials both directly—for example, through mechanical damage—and indirectly; for example, by facilitating increasing soil erosion that might expose relics.

In certain situations, appropriate management of African boxthorn can benefit heritage management: for example, where African boxthorn is harbouring rabbits and burrowing activity might damage heritage sites and materials. African boxthorn plants could also have a direct physical impact on historic heritage sites: for example, if plants grow and expand through fences, monuments and other relics.

2.3.4 Riparian areas

Some states and territories require permits for works undertaken on waterways. It is important to carefully consider the appropriate control options, which may involve a combination of mechanical and chemical control techniques. In some cases, boxthorn plants may be the only vegetation stabilising the bank; consequently, total removal of the plant and roots may not be advisable. Where possible, machinery should not be used at the water's edge to avoid destabilising the bank.

In erosion-prone areas, it may be necessary to exclude stock and to stage works over several years to allow alternative vegetative cover to establish. In sensitive areas, specific mitigation strategies may be needed, such as retention of boxthorn roots in situ (e.g. using the cut stump method); soil or bank erosion protection; stock exclusion and provision of alternative watering points; and targeted revegetation. The most appropriate control techniques will depend on individual situations.

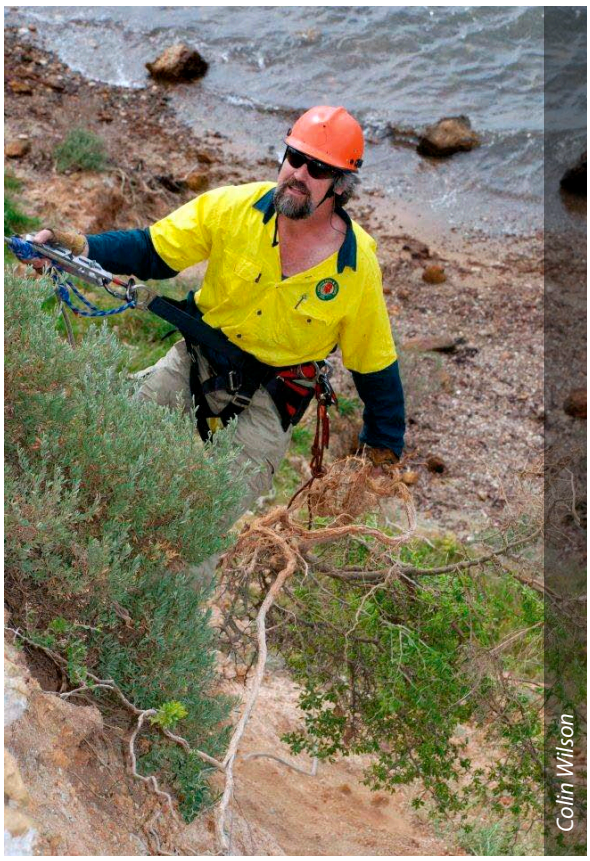
Application of herbicides should be avoided in riparian areas when rain is expected or when rising water levels or flooding are possible. Herbicides must always be registered or otherwise legally permitted for use in riparian and aquatic habitats.

When waterways are involved, try to work in conjunction with neighbouring property owners to plan efforts strategically. Consider the potential for seed to be spread downstream after flooding. In some cases, it will be best to start control work on the upstream properties first, and then work downstream.

2.3.5 Steep or inaccessible areas

When working on steep sites, always consider safety first. In some cases, exclusion zones may need to be created to prevent injury to operators and the public.

A Job Safety Analysis should be completed before work commences, detailing the proposed work methods, steps to be followed to prevent injury, a communications plan and who is responsible for specific tasks. Safe work practices should be the highest priority.



Boxthorn management activities on a steep site

If climbing equipment is necessary, ensure the operator is trained and holds the relevant permits for this task.

When planning to spray African boxthorn, monitor weather forecasts and spray only during favourable conditions. Remember that elevated or steep sites may be subject to higher winds.

If using residual herbicides, be aware that the residual effect can move downhill after rain and harm desirable vegetation growing further down the slope.

For inaccessible infestations of boxthorn, it may be necessary to employ mechanical control techniques or fire to create access to the site. Soil erosion risk needs to be managed.

2.4 Developing an African boxthorn management plan

African boxthorn can be a difficult weed to manage. For your efforts to succeed, you will need to plan well.

As the plant grows in diverse situations, its management requires a site-specific approach that takes into account a range of variables to determine the best management options for that situation. Every landowner or land manager will have different priorities and considerations.

Remember, whichever control techniques you choose, to be successful in the long term you will need to commit resources to ongoing follow-up.

Figure 2.2 provides a guide for developing an African boxthorn management plan.

DEVELOPING AN AFRICAN BOXTHORN MANAGEMENT PLAN

1 Define the problem

- Use aerial photos, GIS software or hand-drawn maps to view your site on a property scale.
- Map the location and density of African boxthorn infestations. Where possible, use the national core mapping attributes (see Chapter 5, Section 5.6 for details).
- Identify and, where possible, map 'valuable' assets within the control areas; these could be natural, heritage, agricultural or infrastructure assets.
  - **Natural assets** include the flora, fauna, vegetation communities and condition, waterways and threatened species that may be present.
  - **Heritage assets** include cultural and historic heritage sites and artefacts.
  - **Agricultural assets** include infrastructure, water sources, soils, livestock and crops.
  - **Infrastructure assets** include buildings, fences, gates, roads and potential water sources.

2 Determine priorities

- Prioritise each infestation (management area) on your map.
- Common priorities for treatment:
  - outliers (to prevent further spread into boxthorn-free areas)
  - easier areas to control
  - where a specific asset is at risk (e.g. natural, heritage, agricultural or infrastructure assets).
- Identify any difficult-to-control areas.
- What are your legal responsibilities in regard to weed control? (See Chapter 5, Section 5.1 for contact details of legal responsibilities relating to African boxthorn management in your state or territory.)
- Consider local government and regional natural resources management organisation priorities and plans.

3 Determine integrated management options

- Minimise the spread of African boxthorn seed or other propagules onto or around your property via animals or machinery (refer to Section 2.2 for further information).
- Identify the available resources and what will be needed to complete your project (factor in at least five to ten years), including:
  - labour
  - skilled, experienced and trained contractors
  - machinery and equipment (e.g. dozer, tractor, spray unit, chainsaws)
  - potential project partners or stakeholders (e.g. neighbouring properties, community groups, local government, regional natural resources management programs).
- Does legislation affect what you can do in regard to land clearing, threatened species, working on waterways, herbicide use and fire?
- Do you need to apply for permits for specific activities?
- Decide on management options for primary control, follow-up control and monitoring, for each infestation.

4

Develop a financial plan

- Estimate the costs associated with each infestation (management area). Include contractors, machinery/vehicle running costs, chemicals and fuel.
- Account for future follow-up control being required, for up to ten years.
- Determine whether there are financial incentives or labour programs available in your region that could provide assistance to your management and recovery program.
- Before committing a large amount of money, conduct small-scale control trials or seek advice from local weeds officers, environmental officers, farmers, land managers or experienced contractors.

5

Develop a management schedule

- Prepare a long-term timetable for boxthorn control.
- Begin primary control on areas small enough to follow-up annually.
- Return to all sites each year after treatment for at least five years to treat survivors, regrowth and new seedlings.
- Different control methods are effective in different seasons. Adapt your management approach as required.
- Try to build flexibility into your program to account for seasonal variability.
- Integrate boxthorn control with other existing management activities such as earthworks, pasture improvement, revegetation and weed control.

6

Monitor progress

- Monitoring is critical to the long-term success of your project.
- Record the control methods, timing, herbicides and costs for each management area.
- Check treated infestations for regrowth or germination.
- Regularly inspect disturbed areas (affected by soil disturbance, fire, flood) for new outbreaks.
- Evaluate the effectiveness of each method.
- Take photos of the site over time, from the same position, to show and record the progress achieved.

7

Follow-up what you have started

- Follow-up is critical!
- Follow-up all treated infestations annually, or when they are identified through monitoring.
- Use the most suitable follow-up method for your situation.

Figure 2.2 *Steps in developing an African boxthorn management plan. Adapted from Gouldthorpe (2009), Spies and March (2004) and Kirkpatrick and Gilfedder (1999).*

CHAPTER 3
Controlling African boxthorn

NSW National Parks and Wildlife Service

CHAPTER 3

Controlling African boxthorn

This chapter lists and considers the suitability of various methods that can be used to control African boxthorn. As boxthorn grows in a variety of agricultural and environmental situations, it is important to be aware of the range of options available, and which ones will best suit a specific site.

Chapter 2 outlined issues to be considered when planning on-ground works. Assess these issues for each site before proceeding with works.

African boxthorn infestations almost always require a range of treatments over many years, as this very resilient species has an outstanding capacity to regenerate from rootstock, stems and seed.

3.1 Mechanical control

Suitable mechanical techniques for managing African boxthorn include:

- winching
- pulling or plucking
- dozing, stick raking and blade ploughing
- cultivation
- machine-based cut stump.

Mechanical control of boxthorn is best done when the plant is not carrying fruit or seed; otherwise, fresh seed is likely to be deposited into freshly disturbed soil.

3.1.1 Winching

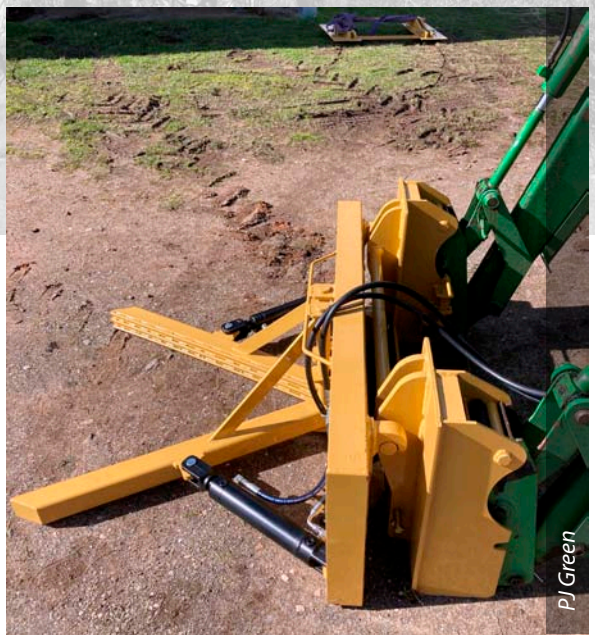
Pulling or winching (e.g. with a tractor and chain) can be used to remove large plants in difficult-to-access or fragile areas (such as coastal dunes). The technique involves connecting a chain or cable to the base of large individual plants and using slow, consistent force to remove the plant, and as much root matter as possible. Remaining roots are then herbicide treated using the cut stump technique to minimise regrowth (see Section 3.2.4).

3.1.2 Pulling or plucking

Grabbing and lifting the plants mechanically is a useful technique for treating light to moderate infestations, and minimises impacts on surrounding vegetation. The technique involves using a front-end loader, articulated loader or excavator to physically remove individual plants and as much root mass as possible.

Jon Fallaw, Phillip Island Nature Parks

Winching out an individual African boxthorn plant



African Boxthorn Puller

African Boxthorn Puller being used by NSW National Parks and Wildlife Service

The Boxthorn Puller (Green, 2020) is a two-armed puller for use on African boxthorn, originally developed in South Australia and now manufactured in Victoria by PJ Green Engineering. The Boxthorn Puller has hydraulically operated arms with a scissor action that closes against the trunk/stem of the boxthorn bush, then lifts and removes the bush and its root system. It attaches to a front-end loader, bobcat or excavator. A case study in Chapter 4 explains how the puller has been used in Oolambeyan National Park in New South Wales.

3.1.3 Dozing, stick raking and blade ploughing

Dozing, stick raking and blade ploughing are most suitable for moderate-to-heavy African boxthorn infestations where the risk of damaging non-target vegetation and the landscape is low. For example, this might be where boxthorn has established on production lands (typically beneath remnant trees in grazing country) and is preventing stock accessing pasture or water.

3.1.4 Following up after the above techniques

With each of the above techniques, boxthorn bushes should be piled and burnt. Dead boxthorn bushes can continue to harbour rabbits, starlings and other pests.

Dozing of African boxthorn in preparation for cultivation to manage rabbits

Return to the site and treat regrowth from the roots or plant base with herbicide, and hand pull, cut and paint or spray seedlings. Follow-up will be required until there is no more regrowth or seed germination.

3.1.5 Cultivation

In areas that are to be used for pasture or crops, after physically removing the African boxthorn, cultivation can be a useful technique. It will break up roots remaining in the soil and bring root fragments to the surface, where they will dry out and can be raked and burnt. The technique can also be used for the dual purpose of destroying rabbit burrows.

As cultivation may result in deeper root fragments shooting, it will almost certainly be necessary to follow-up with chemical application to ensure regrowth and seedlings

Machine-based cut stump in action: south coast, Western Australia

do not gain a foothold. Spray regrowth once it reaches a suitable height (e.g. 50 cm), to ensure there is enough foliage for the uptake of herbicide (Gray et al., 2012; Department of Natural Resources and Environment Tasmania, 2022a).

Establishing vigorous pasture or crop growth will help to prevent re-establishment of boxthorn, by providing competition (Green, 2020).

3.1.6 Mechanical cut stump

Another option is machine-based cut stump control, which involves cutting the plant near its base and then immediately applying herbicide. Being a mechanical technique, it can be done far more quickly and on a larger scale than is possible with traditional cut stump treatment.

Wet blade application uses a combined cutter and herbicide wiper. An Ecoblade® (pictured in the Phillip Island Nature Parks case study in Chapter 4, Section 4.3) is a machinery-mounted slasher and herbicide applicator as a single unit. Blades cut the boxthorn stem and then herbicide is wiped onto the cut surface from the bottom of the blades. This machinery is most suited to moderate-to-heavy African boxthorn infestations on sites where environmental (e.g. native vegetation) and cultural heritage values are low. It is not suitable, for example, for coastal sites where ground-nesting birds such as short-tailed shearwaters and/or middens might be found. Phillip Island Nature Parks has had success using Ecoblade® for follow-up where African boxthorn reshoots from roots after initial control efforts (Weston, 2013). One advantage of Ecoblade® is that the slashing process mulches the plant debris, reducing the need for burning.

Note that while various weed control contractors in Australia have the Ecoblade®, the USA manufacturer has ceased production. A simple version of the concept is attaching the spray head of a knapsack sprayer to the shaft of a brushcutter so that a single operator can do both (McKinnon, 2019).

3.2 Chemical control

This section provides an overview of chemical use certification requirements, background on herbicide choice and an overview of chemical control techniques suitable for use on African boxthorn.

3.2.1 Chemical use certification

In Australia, commercial operators who apply herbicides generally must have training and certification, though the situation varies among states and territories. Some jurisdictions require land managers to obtain certification before they apply certain chemicals (e.g. herbicides containing the active ingredient triclopyr).

An example of a nationally accredited chemical use training package is the ChemCert Australia Accreditation. The training package includes information on how to:

- follow basic chemical safety rules
- prepare and apply chemicals
- apply chemicals under supervision
- transport, handle and store chemicals.

It is your responsibility to comply with the relevant rules and legislation for your location. A summary of requirements can be found at www.chemcert.com.au/resources/state-legislation. Contact the relevant department in your state or territory for further information. These are listed in Chapter 5 (Section 5.5).

3.2.2 Herbicides

A wide range of herbicides are registered or otherwise permitted for various application techniques on African boxthorn in some or all locations in Australia. Details are provided in herbicide tables in Chapter 5 (Section 5.2) and an overview is given below.

There can be many commercial products for a particular type of herbicide and concentration. Registered products and uses can be searched at the Australian Pesticides and Veterinary Medicines Authority (APVMA) PubCRIS database website, portal.apvma.gov.au/pubcris.

Minor use permits enable specified uses of herbicides that are not otherwise registered and presented on product labels. A number of permits cover African boxthorn, as listed in the herbicide tables in Section 5.2. Note that permits have expiry dates and this should be checked to ensure use is still permitted. Permits and their current status can be accessed on the APVMA website.

All herbicides come with a label that is a legal document that the user must read and follow when preparing and applying the herbicide. The label details the personal protective equipment (PPE) required, the mix rate and the appropriate growth stage for application, as well as how to use the herbicide safely and effectively. Before undertaking chemical control, make sure you have read the Material Safety Data Sheets for the herbicides being used, and keep them close at hand in case of emergency.

In choosing the most appropriate herbicides to use on African boxthorn for your situation, you will need to decide:

- which application techniques are to be used (e.g. cut stump initially, and later foliar spray to manage regrowth)
- which herbicides are registered/permitted for application with those techniques in your state or territory.

Most state and territory jurisdictions provide specific herbicide advice for declared weeds on their websites. For example, the Tasmanian Government provides specific advice on herbicides for African boxthorn control at www.nre.tas.gov.au/invasive-species/weeds/weeds-index/declared-weeds-index/african-boxthorn/african-boxthorn-herbicides-for-control.

Regrowth after foliar spraying

Suitable chemical (i.e. herbicide-based) control techniques for managing African boxthorn include:

- foliar spraying
- cut stump application
- stem injection or frilling
- basal bark application
- soil–root zone application.

3.2.3 Foliar spraying

Foliar spraying is the use of herbicide diluted in water to a specific rate and sprayed as fine particles to wet the foliage of weeds. For boxthorn, foliar spray is usually applied as a 'spot spray', which targets the weed only. For small infestations, a hand-held or back-mounted knapsack sprayer is carried by a single person. For larger infestations requiring larger volumes of herbicide mix, a hand-gun is used that is connected via a long hose to a large tank mounted on a trailer or vehicle.

Large African boxthorn plants can potentially reach a height of several metres. For safety reasons, foliar spraying should be limited to the control of small to mid-sized plants, regrowth and seedlings. Also, mature African boxthorn plants often require numerous re-treatments to kill them. This may be partly due to their well established root systems.

Successful control of African boxthorn by spraying is dependent on the season, weather conditions during spraying, the vigour of the plants, how thoroughly the herbicide is applied, and the herbicide mix and application rate. To maximise effectiveness, plants should be sprayed when they are actively growing and have foliage to absorb the herbicide. Avoid spraying when plants are stressed by hot or dry conditions, or in periods of waterlogging or extreme cold.

Choose the appropriate herbicide for each situation. For example, when spraying boxthorn regrowth in or adjacent to a wheat cereal crop, broadleaf selective herbicides are more appropriate than non-selective herbicides, as they will not damage the crop.

Herbicides used for foliar application on African boxthorn are:

- triclopyr*
- triclopyr and picloram mix
- triclopyr, picloram and aminopyralid mix
- glyphosate
- picloram and 2,4-D

- glyphosate and metsulfuron methyl mix*
- metsulfuron methyl*
- 2,4-D*
- aminocyclopyrachlor.

** approved for use in certain jurisdictions only—refer Table A, Section 5.2*

Adding an adjuvant (e.g. wetting agent) when spraying can improve results by improving the rate of leaf wetting and herbicide absorption. Herbicide labels often state recommended adjuvants. Always read an additive's product label to ensure it is compatible with a particular herbicide. Do not add wetting agents to the mix when spraying near waterways. Using a marker dye to highlight the herbicide coverage will help the operator to spray efficiently, saving time and money.

A specialist type of foliar spraying is low volume/high concentration application using tools such as a drench gun, splatter gun or gas gun. These are generally used for woody weeds, and involve herbicide being squirted from up to 10 m away. Very large droplets are applied and only a small portion of the weed's foliage needs to be treated. The method is useful where weeds are otherwise difficult to access.

African boxthorn is renowned for losing its leaves after being sprayed and appearing to be dead, but then later producing new foliage. This can happen several times before the plants die, so follow-up control will be required for several years (Weston, 2013; Green, 2020).

3.2.4 Cut stump application

Sometimes called 'cut and paste' or 'cut and paint', this method involves cutting the stem or stump within 150 mm above ground level and then applying a herbicide to the surface of the cut ***within 15 seconds***. It is most easily done working in pairs, with one person cutting stumps and the other applying herbicide. The spray head of a knapsack sprayer can be attached to the shaft of a brushcutter so that a single operator can do both (McKinnon, 2019). The addition of a marker dye is recommended to indicate which plants have been treated.

The cut can be made with a range of tools, including a chainsaw, long-handled loppers, bowsaw or brushcutter. The NSW NPWS has successfully used pneumatic loppers for this purpose (see the Oolambeyan National Park case study in Chapter 4, Section 4.1 for more details). In some cases, it is necessary to prune the plant carefully to avoid the thorns, to gain access to the main stem and make the final cut.

Take great care to avoid injury when cutting and handling boxthorn. Protect your skin and eyes. The long, dangerous thorns can easily puncture skin, even through sturdy gloves. The resulting wound can become infected and might be painful for several weeks. Safety procedures should also be followed for the use of cutting devices.

The cut stump method uses a higher concentration of herbicide mix than foliar spraying. Chemicals applied to the cut surface will travel through the stem to the root system. The herbicide is often applied with a pump-spray bottle, trigger-spray bottle or knapsack sprayer.

As with foliar spraying, cut stump should be done when plants are actively growing and not under stress.

Completed cut stump work including indicator dye

Once the cut has been made, herbicide needs to be ***applied immediately***, before the wound dries. ***Do not make the cut unless herbicide can be applied within 15 seconds***.

Herbicides used for cut stump application on African boxthorn are:

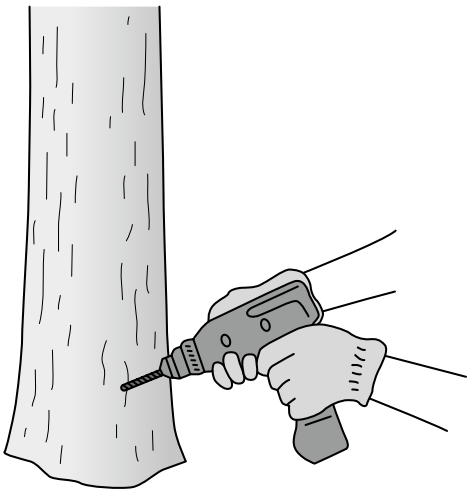
- glyphosate*
- glyphosate and metsulfuron methyl mix*
- 2,4-D*
- triclopyr
- triclopyr and picloram mix
- aminopyralid and picloram mix.

**approved for use in certain jurisdictions only – refer Table B, Section 5.2*

Dead boxthorn debris can continue to harbour rabbits, starlings and other pests. After they have been cut away, green boxthorn stems and trunks can survive and regrow if they are left in contact with moist soil. Therefore, it is important to destroy the remnants of the plant wherever possible. Depending on circumstances (such as environmental sensitivities), pile and burn or mulch this woody mass. At the very least, roll large bushes over so that they rest on the dead outer branches and the main trunk is not in contact with the ground.

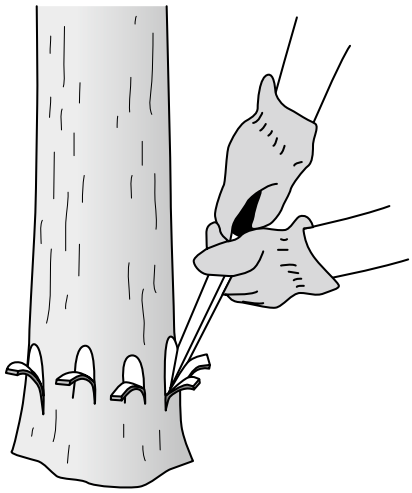
This method can be labour intensive, depending on the size of the plants, density of infestation and resources available. Regrowth will require follow-up control for at least several years.

The cut stump method is useful for isolated plants, smaller infestations near waterways and plants close to sensitive native vegetation or infrastructure.



Brett Littleton, DPIPWE Tasmania

Drilling holes for stem injection



Brett Littleton, DPIPWE Tasmania

Frilling bark for herbicide application

3.2.5 Stem injection/frilling

Stem injection is generally done using a cordless drill, pneumatic drill or specialised tree surgeon's tools to drill into the trunk at an angle. Frilling involves using an axe or similar tool to wedge/lever away a section of bark. Both methods involve making wounds at regular intervals around the whole trunk, just under the bark, between the living and dead wood. Herbicide is then applied immediately (***within 15 seconds***) directly into the cambium (actively growing) layer, using a spray bottle, tree injector or knapsack sprayer.

As with the cut stump method, beware of injury when in such close proximity to thorns. (See precautions outlined in Section 3.2.4.)

This method is best suited to large, isolated plants with a trunk diameter over 50 mm and that can easily be accessed at the base. It will not be practical for African boxthorn in most situations (where plants are smaller and closer together); in those circumstances, the cut stump or foliar spray methods are preferable.

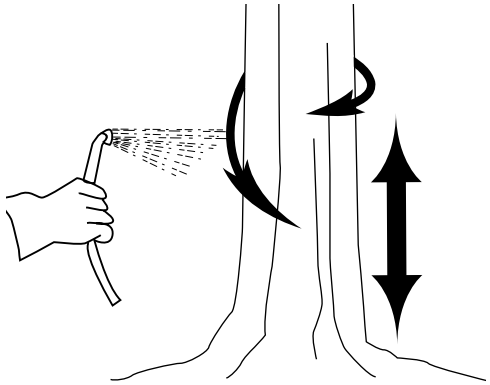
As with cut stump treatment, stem injection or frilling should be done when plants are actively growing and not under stress.

Stem injection or frilling will suit environmentally sensitive areas where it is desirable to retain dead standing boxthorn biomass to provide temporary habitat for native fauna, or for other environmental considerations. If there are no other boxthorn infestations nearby, it is possible that leaving the plant debris in situ will aid the re-establishment of native vegetation. For example, dead boxthorn plants can assist native vines by providing a framework for them to climb on, and native birds may roost in them and deposit local native plant seed on the ground below. Of course birds may also introduce more weeds to the site, so the decision to leave dead boxthorn also needs to consider this risk.

Herbicides used for stem injection/frilling application on African boxthorn are:

- glyphosate*
- glyphosate and metsulfuron methyl mix*
- aminopyralid and picloram mix
- aminocyclopyrachlor.

**approved for use in certain jurisdictions only – refer Table C, Section 5.2*



NSW NPWS

Applying herbicide via the basal bark method

3.2.6 Basal bark application

This technique is generally effective on bushes with a trunk diameter of up to 50 mm. Each trunk or stem needs to be wetted thoroughly around all stems, from ground level to a height of 400 mm. This can be done using a low-pressure, hand-directed sprayer with a curved end on the wand – making it easier to spray around the stems without the need to move. Alternatively, apply with a paint brush in backyard or other sensitive situations or sensitive environments where drift could cause damage to non-target plants. The herbicide is mixed with kerosene, diesel or biodiesel (as per label directions) and absorbed into the plant through the bark.

You might need to clear the vegetation beneath the boxthorn plants to ensure enough herbicide reaches the target area. Adding a marker dye is recommended to make it easy to see which plants have been treated.

As with the above herbicide methods, basal bark application should be done when plants are actively growing and not under stress.

Herbicides used for basal bark application on African boxthorn are:

- triclopyr
- triclopyr and picloram mix.

This method is best suited to isolated bushes where boxthorn trunks and/or stems are easily accessed, and is useful for boxthorn control where it is desirable to retain dead standing plants as temporary habitat for native fauna, or for other environmental reasons.

3.2.7 Soil–root zone application

In this method, herbicide is applied evenly to the soil near the drip line of the bush, when the soil is wet or rainfall is predicted. Soil-applied herbicides move through the root zone after rain and are absorbed into the roots.

Treated plants can lose and regrow their foliage several times before dying. It can take several years to kill the target plant.

It is important to note that residual herbicides can remain active in the soil for a long time, may travel downhill on steep or sloping ground, and can leach into the water table. Some native and ornamental trees and shrubs are very susceptible to residual herbicides. This method is generally used in pasture situations away from non-target trees and shrubs, native vegetation or waterways. Its use in environmentally sensitive areas is restricted to certain users and herbicides because of risks of off-target damage.

Herbicides used for soil–root zone application on African boxthorn are:

- hexazinone
- picloram*
- tebuthiuron*.

**approved for use in certain jurisdictions only – refer Table D, Section 5.2*

3.3 Biological control

Biological control involves the careful selection of insects and pathogens from the native range of a weed to help reduce its abundance and impacts in the introduced range. Before a new weed 'biocontrol agent' can be introduced to Australia, it needs to be demonstrated to attack the weedy forms of the plant in Australia and not significantly impact on any closely related native plants or economically important plants.

Once a biocontrol agent has been approved for release in Australia it can be released in any state or territory where there are no further quarantine impediments. A permit may be required to transport the weed on which the agent is living. Check with your local weed authority for more information.

Initial investigations into potential biocontrol agents for African boxthorn were led by Dr Robin Adair, with a desktop review and local surveys of existing insects and diseases present on the weed in Australia (Adair, 2013). From 2016, CSIRO led further research across the weed's native range in South Africa and identified four promising candidate agents for further host specificity testing under quarantine conditions in Australia: a rust fungus (Ireland et al., 2019) and three leaf-feeding beetles (Chari et al., 2020).

The rust fungus *Puccinia rapipes* has been formally approved by federal regulators as a biocontrol agent for African boxthorn. The rust infects young, fleshy African boxthorn leaves, reducing their photosynthetic capacity. Host-specificity testing by CSIRO found that goji berries (*L. barbarum*, *L. chinense* and *L. ruthenicum*) can also be infected by the rust. However, in its native range in South Africa the rust has not been detected on goji berry crops. It can also be readily controlled by fungicides and does not infect fruit. The overall off-target risk estimate for the release of the rust fungus in Australia was assessed to be very low (Department of Agriculture, Water and the Environment, 2021).

Dr Kylie Ireland and Dr Gavin Hunter establishing a culture of the African boxthorn rust fungus at CSIRO Black Mountain quarantine facilities

Laboratory infection of African boxthorn leaves with the rust fungus Puccinia rapipes

In 2022, CSIRO commenced field experiments to develop a suitable release methodology to enable mass release of the fungus across Australia, in partnership with local community organisations. The fungus is released on African boxthorn by spraying spores onto young, fleshy leaves that are then covered with a large plastic bag for 12–24 hours to maintain a humid microclimate that stimulates infection.

Further information on the rust and its release is available on the internet (Gooden, 2022).

The impact of the rust on African boxthorn infestations, and how this will differ between different Australian environments, will not be known for several years. However, as with many rusts, it is likely to be more effective under humid conditions, especially in coastal and higher rainfall areas.

Two leaf-feeding beetles investigated by CSIRO in quarantine were found to feed and reproduce on the native plant *Lycium australe*. Hence they were not sufficiently host-specific to seek formal approval for release. Investigations into the host specificity, life cycle and rearing of a third beetle commenced in 2022 (Rafter, 2022).

3.4 Other control options

Hand pulling can be an option for very small plants. It is generally easier to do after rain, when the soil is wet. The entire tap root and large lateral roots must be pulled out, or the plant will regrow.

A manual device called a Tree Popper (Etherington, 2022) has a plier-like jaw to grip a plant's stem and a long handle that works as a lever. A person's body weight provides lifting force to pull whole woody weeds out of the ground. The Tree Popper has been used to control small African boxthorn plants in sandier soils. However, care needs to be taken to use the device on both the main stem and lateral roots to ease out plants and avoid root breakage. To prevent regrowth from any broken roots remaining in the soil, these should be immediately treated using cut-and-paste herbicide application. Follow-up checking for regrowth is also advised (Gould, 2022).

Applying rust fungus Puccinia rapipes *to African boxthorn*

African boxthorn re-sprouting after the 2013 bushfires in south-eastern Tasmania

Fire can be useful to clear African boxthorn's woody branches and improve access, but will also encourage regrowth from rootstock. Fire can be useful for small-to-medium infestations where foliar spraying is the preferred follow-up control method. However, as mature boxthorn rootstock is substantial and difficult to kill, it is better to wait until sufficient re-sprout (leaf area) has grown before foliar spraying. Appropriate safety and environmental approvals should be sought, where required, before fire is used.

As mentioned in Section 3.1.4, piling and burning the dead bushes can help to prevent injury to animals and humans, reduce habitat for rabbits and starlings, and avoid the risk of puncturing vehicle tyres. Mulching is an alternative, but will likely leave thorn and seed residue on site.

Grazing is not a recommended control option. African boxthorn plants (fruit, leaves, stem and roots) are considered poisonous to livestock (Parsons and Cuthbertson, 2004; McKenzie, 2012).


DPIPWE Tasmania

Vehicle wash-downs on entering and leaving sites can help minimise the spread of weeds. African boxthorn seed can be spread in mud and carried by vehicles

3.5 Hygiene protocols

The most cost-effective way to manage weeds is to prevent their spread. African boxthorn is sometimes spread via seed or vegetative material that is transported in gravel, mud and agricultural produce, either in or attached to vehicles and machinery (Muyt, 2001; Parsons and Cuthbertson, 2004). State and territory laws prohibit the transporting of legally recognised (declared) weeds.

Weeds can be spread by the vehicles and machinery of contractors or land managers travelling between sites and regions. Only use trusted suppliers to supply 'clean' soil and

Ross Gardiner, NSW NPWS

Integrating control methods in southern New South Wales: the NSW National Parks and Wildlife Service found that boxthorn pulling needed to be followed up with foliar spraying of regrowth

quarry materials to your sites, and ensure all vehicles, machinery, equipment and clothing entering or leaving any site are inspected and cleaned. Soil, vegetative material, fruit and seeds should be removed and disposed of appropriately.

3.6 Combining methods for long-term control

Every site is different and will present its own unique challenges for African boxthorn management. For effective long-term results, the planning and management approach should combine all control methods that best suit the situation.

Experience outlined in the Oolambeyan National Park (New South Wales) case study (Chapter 4, Section 4.1) showed that the combination of cut stump and machinery-based plucking of plants could be followed up by foliar spraying of regrowth to achieve lasting results. The team on this project found that it was best to use manual cut stump in environmentally sensitive areas, but this was more labour intensive and slow. The quicker technique of machinery-based plucking or, more recently, machinery-based cut stump was suitable for less sensitive areas.

Foliar spraying, with its limited effectiveness on African boxthorn, was mainly used for follow-up spraying of regrowth.

It is clear that with African boxthorn, as with many other weeds, the keys to success include persistence and flexibility in the use of integrated control methods.

3.7 Post-control monitoring and evaluation

It is important to monitor and evaluate the results of control efforts. This can potentially save a lot of time and money by increasing efficiency, learning from mistakes and making ongoing improvements.

Ongoing monitoring will help to plan and implement follow-up control when it needs to be done. If treated areas are not inspected for several years, regrowth may reach the size of the original infestation, meaning time and money has been wasted.

Evaluating the results of control efforts will show which management regime works best for a particular situation. This need not be an onerous process. A good start would be to record the time of year control work is done and the herbicide mix used, and to take some 'before' and 'after' photos. Even basic documented evaluations can be useful to share with managers of neighbouring properties, community groups, contractors and funding bodies.

3.8 Site rehabilitation

To prevent re-infestation of control sites, a long-term approach should be taken to restoration of native vegetation, pasture or other desirable vegetation. Also, it should be remembered that, if some African boxthorn remains in the general area of the control site, seeds can readily be re-deposited on site by fauna; hence, ongoing management will be necessary.

Where primary control efforts have disturbed the soil, many weeds are likely to take advantage of the situation. The species that germinate in the bare ground, both native and weedy, should be monitored. It may be

necessary to selectively control any new weeds to assist more desirable species to become established.

3.8.1 Restoring native vegetation

When African boxthorn occurs where native vegetation is present or desired, promoting regeneration or revegetation with local native species can provide improved wildlife habitat and, if managed well, reduce the likelihood of boxthorn re-establishing.

To restore native vegetation successfully, it is necessary to consider whether the site is best suited to regeneration or revegetation. Deciding this will inform the most appropriate approach to the ongoing management of African boxthorn.

Natural regeneration is the process in which indigenous species recolonise a site, over time, either via seed bank or from adjacent areas. Natural processes such as soil disturbance, fire or seed deposited on site by animals, wind or water, may be required to facilitate regeneration. Native vegetation can sometimes be slow to establish via natural regeneration but, compared with revegetation techniques, the resulting plants are hardier and more likely to persist in the long term. Encouraging natural regeneration processes can be the most cost-effective way to restore native vegetation.

Revegetation involves introducing native plants to a site using tube stock, direct seeding or other methods. This is generally done on sites that have been degraded. Local-provenance seed or vegetative material should be collected from indigenous species that suit the soil type and vegetation community being restored. Seek advice on this from your local council, regional natural resources management organisation or conservation organisations such as Greening Australia. Permits may be required to collect seeds and cuttings of native plants for propagation.

For large sites where dispersal of boxthorn seed is still a risk, it may be better to focus efforts on follow-up control for several years (up to ten), before attempting revegetation. If the boxthorn regrows or germinates within revegetated areas, care needs to be taken in doing targeted control to avoid damaging the new native plants. Other environmental weeds can co-occur with African boxthorn and also need to be controlled prior to and during revegetation.

Revegetation needs to be planned at least 6–12 months ahead, and in some circumstances even longer. Depending on the scale of the task, seed may need to be collected and plants grown and hardened, either by a nursery or by you, well in advance. Generally, it is cheaper to order plants at least six months before they are required than to buy 'off the shelf'. The tube stock method potentially allows a wider variety of species to be used in the mix than does direct seeding. Monitoring conditions in the lead-up to planting can maximise success. Undesirable events such as drought or flood may require a contingency plan.

Direct seeding relies on rainfall and can be done on prepared sites by hand sowing or machine direct seeding. Hand sowing is useful for small, rocky, steep or otherwise hard-to-access sites. Another method is to lay seed-laden branches on the surface. Machine-based direct seeding uses specialised seeding machinery calibrated to handle various seed sizes and sowing depths. This is useful for establishing a vegetation community 'structure' on a broadacre scale. For maximum success, sites must be properly prepared, including weed control.

All revegetation methods require site preparation, which may include controlling weeds with a knockdown spray or scraping away the topsoil to provide a weed-free area to plant or sow seed into. It may take several years of weed control to exhaust the weed seed bank and regeneration capacity. For some sites, ground preparation might involve ripping, mounding or cultivation to aid planting or sowing of seed.

It will be necessary to control browsing by stock, rabbits, deer and wildlife before attempting to restore native vegetation and for several years afterwards, until the plants are established. Depending on the type of browsing pressure, management options could include fencing, tree guards and, in some situations, seeking permits to control animals to reduce the impacts of browsing.

Ongoing maintenance of sites is important. Areas of natural regeneration and revegetation are both prone to weed re-invasion and should be monitored and treated as required.

3.8.2 Restoring agricultural lands

On agricultural land where African boxthorn is controlled and debris managed, re-establishment of pasture or other crops should be carried out as soon as possible where the ground is disturbed. Land management practices such as pasture improvement and encouragement of adequate ground cover can prevent or reduce boxthorn seedling establishment.

State and territory agriculture departments have online information regarding establishment of competitive pastures. For example, NSW Department of Primary Industries has extensive information on pasture species, and outlines eight steps for successful perennial pasture establishment: www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/establishment-mgmt/establishment/eight-steps.

Follow-up control measures will be required when boxthorn reshoots from rootstock or germinates from the soil seed bank. Livestock grazing is generally not a good follow-up strategy for African boxthorn control because of the weed's toxicity, limited palatability and thorns. Agricultural lands cleared of African boxthorn should be revegetated with pasture grasses; selective herbicide can later be applied to boxthorn regeneration with minimum impact on non-target vegetation.

CHAPTER 4
Case studies

Jon Fallaw, Phillip Island Nature Parks

CHAPTER 4

Case studies

4.1 Oolambeyan National Park, south-west New South Wales

A concerted, long-term effort has 'broken the back' of African boxthorn In Oolambeyan National Park in south-west NSW.

Jim Balnaves (former Pest Control Officer, NSW NPWS) and Ross Gardiner (former Technical Officer Pest Management, NSW NPWS), along with other Riverina area staff, have been part of a substantial effort since 2006 to reduce the African boxthorn infestation across the park. In 2022, Senior Field Officer Glenn Currie and Ranger Michael Murphy are overseeing regular, strategic control of African boxthorn in Oolambeyan National Park, under Area Manager Robin Mares.

Having a boxthorn control strategy for the park and a range of control tools, and ensuring follow-up have been key to Riverina Area NSW NPWS staff and contractors' ability to suppress the weed's negative impacts on the values of Oolambeyan National Park.

Oolambeyan National Park was created in 2002 and covers an area of 21 851 hectares near Carrathool and Hay in the Western Riverina region of New South Wales. It was formerly a wool-growing property and has a broad range of important environmental and heritage values. These include provision of habitat for threatened fauna such as the Plains-wanderer (*Pedionomus torquatus*)—a ground-dwelling bird; a diverse range of significant vegetation communities; and substantial Aboriginal and historic heritage values (NSW National Parks and Wildlife Service, 2012).

African boxthorn has been a major problem in Oolambeyan National Park, affecting approximately 5000 hectares of the park (Balnaves, 2013). Boxthorn provides habitat for foxes, rabbits and feral cats (*Felis catus*), compounding park management challenges. Where African boxthorn is present, effective rabbit control is near impossible until the boxthorn has been controlled.

Work to manage boxthorn at Oolambeyan began around 2006. Jim Balnaves was part of the crew that worked on the infestation during the first couple of years. He recalled that a key part of the formula was putting together a specialised set of tools for the job. The team used pneumatic shears (usually used

NSW NPWS staff using pneumatic shears to gain access to an African boxthorn base for cut stump treatment

The blade of the pneumatic shears; the shears are run from an air compressor based on a trailer

Boxthorn Puller mounted on a tractor

for pruning in vineyards, though a higher-capacity compressor was required for boxthorn plants) to cut branches and eventually the base of plants (up to approximately 50 mm in diameter). Once the plant was cut to a stump, to avoid contact with the thorns, a specialist handmade tool was used to push away the bulky mass of the plant. A mix of triclopyr/picloram-based herbicide (e.g. Access®) and diesel was painted onto the stump as soon as possible following cutting. This was found to be very effective. The removed plant debris was stockpiled and burnt at a later date. If the debris is not piled and burnt, it can continue to harbour rabbits (Balnaves and Gardiner, 2013).

In this situation it was important to minimise harm to the surrounding environment, and an advantage of this approach was that it had a low impact on non-target plants (e.g. salt bush and eucalypts). In many instances in the national park, alternative techniques such as use of machinery (e.g. dozing) and different herbicide application methods (e.g. foliar spraying or the broadscale use of granule-based herbicides) would have had the potential to cause unacceptable levels of damage to and destruction of non-target plants.

The success of foliar herbicide application to African boxthorn can depend heavily on the season, the health of the plants and local conditions. However, cut stump is a more reliable technique that can be used successfully in any season.

In sandy soil areas, for smaller-to-mid-sized plants and where treatment was less likely to damage non-target plants (e.g. in relatively pure stands of boxthorn), a Boxthorn Puller mounted (in this case) on a tractor was used to physically remove plants. It was found that follow-up was critical with this technique, as any roots left behind would subsequently send up shoots. Regrowth was later foliar sprayed.

In suitable situations (i.e. where off-target damage was less likely), chains were also used to physically remove plants. As was the case with the Boxthorn Puller, regrowth was later foliar sprayed.

Problems encountered by the Oolambeyan crew included boxthorn bushes growing near to buildings or fences and in native vegetation, making access more difficult. They also needed to consider cultural heritage and threatened species issues, and manage them appropriately. However, Jim Balnaves recalls that tackling these situations was made much easier by having a range of control tools at their disposal. For example, pneumatic shears made it possible to cut and paint boxthorn bushes near buildings and fences.

African boxthorn in natural sand-hill area vegetation, southern NSW

Ross Gardiner says that in the 2010s, foliar spraying was successfully used in Oolambeyan (Gardiner et al., 2022). Once the larger plants had been removed, foliar spraying (of regrowth) was much simpler. The crew used a glyphosate-based herbicide with a surfactant. Ross found that the most effective time to spray was August–September when the plants are a vibrant green before flowering.

In 2019, a boxthorn control strategy was produced for the park to coordinate containment and control activities. Robin Mares describes it as a straightforward plan that involves regularly working through a large area of sparse boxthorn, plus systematically working around the edges of the remaining worst infested areas to contain them. They will then move into treating within those areas.

Currently, a contractor is employed annually in autumn to undertake control in strategic areas of the park. The contractor uses a skid steer machine with a tree shear attachment, to which a spray treatment nozzle has been attached. This is used to 'cut and paste' by cutting with the shears then twisting sideways a little to spray the stump using a glyphosate–metsulfuron methyl herbicide mix. Where access is good, this method is quick. There is virtually zero regrowth and no off-target damage has been observed. This herbicide mix is also relatively cheap compared with other chemicals.

After primary control, follow-up is now mostly with foliar spray using glyphosate–metsulfuron methyl. Manual 'cut and paste' continues to be used where disturbance around cultural sites, infrastructure and natural heritage needs to be kept to a minimum.

NSW NPWS is also looking into the possibility of a minor use permit to use granular soil–root zone herbicide within the park. Neighbouring private landholders have had good success with hexazinone in pasture paddocks.

Ross says that they are now (in 2022) seeing paddocks with no boxthorn, other than the occasional recruitment from bird scats.

For Jim Balnaves, the satisfaction has been in acquiring and using the right tools to achieve efficient and successful treatment of this notoriously hard-to-kill weed. Looking back, Jim says:

> ***The follow-up is the critical thing. You must go back and spray the regrowth. On the positive side, each time you go back it is an ever-decreasing problem.***

4.2 Furneaux Group of islands, north-east Tasmania

Karen Ziegler and Katriona Hopkins work as natural resource management professionals and volunteers with Friends of Bass Strait Islands (FOBSI). In 2011, they produced a report entitled Furneaux Islands Boxthorn Control, which documented FOBSI's findings through experience with boxthorn management. In 2022 the work continues, building on the group's accumulated knowledge and successes. Having both an established and proven boxthorn control method and a schedule for ongoing management are key components of the group's work in the Furneaux Group of islands.

The Furneaux Group of islands, to the north-east of mainland Tasmania, consists of around 50 islands (or up to 100 if rocky outcrops and reefs are included) and centres on Flinders, Cape Barren/truwana and Clarke/lungtalanana islands (the three biggest). Many of the islands have limited vegetation diversity, but provide good seabird and marine mammal habitat.

African boxthorn (which appeared on a Tasmanian nursery list from as early as 1845) was introduced to the islands to establish windbreaks. In seabird rookeries on the islands, the soil is highly fertile and is significantly disturbed by seasonal seabird activities. This is an ideal environment for the establishment of weeds like boxthorn.

It is thought that African boxthorn spread within the Furneaux Group has occurred via starlings, ravens (*Corvus* spp.), blackbirds and silvereyes (Parsons and Cuthbertson, 1992; Harris et al., 2001; Ziegler and Hopkins, 2011).

Bird ensnared in African boxthorn, Furneaux Group Islands, Bass Strait

Other species such as the black currawong (*Strepera fuliginosa*), silver gull (*Chroicocephalus novaehollandiae*) and Pacific gull (*Larus pacificus*) also play a role (the latter species are recognised as having spread the weed in South Australia) (Government of South Australia, 2022). African boxthorn shrubs impede the nesting activities of certain seabird species, such as the short-tailed shearwater and white-faced storm petrel, and the thorns can ensnare birds. For pest species such as starlings, African boxthorn shrubs (which often establish on islands that have no other shrubs) increase their nesting habitat.

Concerted efforts to control African boxthorn in the Furneaux islands began in 2002. Boxthorn has been treated by volunteers on 19 islands, as well as on some coastal reserves on Flinders Island (Ziegler and Hopkins, 2011, 2022).

Karen Ziegler and Kat Hopkins of FOBSI say that, through experience, the group developed a very successful control technique for African boxthorn, as follows.

- work from the least infested areas back towards the core infestations, using the cut-and-paste technique
- make a cut as low as possible and then quickly apply a 1:1 glyphosate–water mix (with marker dye)

Cut stump African boxthorn control—ensuring every last stem is severed

- before treating a large plant, check the periphery for small plants and seedlings, and treat these first so you do not lose track of them
- then treat the large plant and fastidiously check the area below it for small shoots and suckers.

For boxthorn shrubs that are large, thorny and difficult to handle, the group recommends initially cutting quite high and removing the bulk of the plant. Ropes and driftwood can be used for additional leverage to topple intimidatingly large bushes (Ziegler and Hopkins, 2011). Once it is possible to access the base of the stem (which can consist of anything from one trunk to dozens of smaller stems), a fresh surface is cut on each stem and herbicide applied immediately, ensuring all stems are cut and poisoned. No matter how large the plant, it must be tipped over to ensure every last stem is severed.

Karen and Kat say that once this process is completed, burning or physical removal of larger boxthorn is an imperative. Large dead boxthorn can remain a hazard even after two decades, still impaling shearwaters and ensnaring the smaller storm petrels in the dried material. Starlings can also still roost and deposit new seed in dead boxthorn. From a follow-up perspective, keeping dead boxthorn makes it hard to find and access the base of any regeneration, to effectively cut and paste with herbicide.

Follow-up is vitally important and should entail a return visit within 12–24 months. At this time, FOBSI treats any surviving plants with the cut stump method, and hand pulling of small seedlings. Thereafter, they aim to revisit the site annually to determine the need for follow-up treatments. The stimulus for regeneration from soil-stored seed is poorly understood and seedling emergence has been highly variable in different years (Ziegler and Hopkins, 2022).

Karen says that they treat other significant environmental weeds during the same site visit; otherwise these may fill the gap created by boxthorn removal. Mirror bush (*Coprosma repens*) is another bird-dispersed woody plant appearing on the offshore islands. Frequent visits will keep this species in check also.

The advantage of the technique outlined above is that it can be readily carried out by volunteers on small islands where machine-based removal is not possible or desirable. Foliar spraying requires the use of higher-impact herbicides and could be less effective given that African boxthorn can drop leaves after spraying, and then regenerate. Unlike foliar spraying, the cut stump technique is not season- or wind-dependent. However, when working on islands with breeding colonies of seabirds, it is important to schedule works for the off-season. In the Furneaux islands, FOBSI considers May the ideal time to minimise the impact of the work on breeding seabirds (Ziegler and Hopkins, 2011). However, timing will vary from place to place, depending on the habits of the seabirds and/or sea mammals using the area.

Karen says that some of the boxthorn treated earlier on Flinders Island was found to have re-sprouted, and was re-treated by FOBSI. She believes that variability in the project's success is due to different levels of attention to detail. It is essential that the cut stump work is thorough and consistent. If it is carried out properly, she says, six months to a year later most sites are covered with native colonisers.

African boxthorn infestations growing in areas with mobile sands have proven challenging to manage. Karen says that the depth of sand in places makes it difficult to tell whether all the stems have been found and treated. The group has noticed that there tends to be more post-control regrowth in these situations.

Kat says an additional boxthorn control strategy was trialled and proved to be both effective and efficient by FOBSI volunteers working on the Wybalenna Historic site on Flinders Island. Portions of this Aboriginal site remain open grassland, having been grazed farmland until returned to Aboriginal control (Ziegler and Hopkins, 2022).

Rather than spending days cutting their way into some truly enormous boxthorns at the Wybalenna site, the volunteers experimentally burnt them where they stood; then cut and painted all stumps and visible roots as soon as the fire had sufficiently cooled (24-48 hours).

Kat says they found that mature boxthorn burnt sufficiently well as a live plant, particularly if it had been used as a roost by a flock of starlings. There was very little unburnt debris remaining and the main stems were exposed for treatment. The live-burning method proved as effective in killing plants as the usual cut and paint, then burn technique.

This method is only appropriate for free-standing boxthorn bushes in a non-flammable matrix, such as bare sand or well-grazed paddocks. It offers a quick, effective strategy to farmers or other land managers who may otherwise be inclined to push over or pull out large boxthorns with heavy machinery. In Kat's experience, that approach typically leads to increased regeneration from the many broken roots and stems, as well as the unnecessary spreading of tyre-puncturing fragments of boxthorn.

In general, FOBSI has found that boxthorn seedling regeneration is hugely variable between sites: years can go by without significant regeneration and then there might be a bumper crop. Karen suggests that seasonal and local habitat factors play a role, and warns of being prescriptive with the follow-up interval as FOBSI has been caught out. She says the aim is to treat all regeneration before it is mature and starts to produce seed:

> ***Check treated sites annually, then plan follow-up according to on-ground evidence.***

Burning piles of boxthorn after cut stump treatment

With islands it can be expensive, so go as frequently as possible to assess. Be adaptive and not prescriptive!

Seed viability in soil is considerable. Karen says they can still find occasional seedlings in areas that were cleared of thickets 20 years ago. The evidence that these seedlings are from soil-stored seed is the spatial pattern of regeneration. This pattern reflects that of the past boxthorn distribution rather than seedlings being found more broadly across whole islands, which is what you would expect if it was purely seed reintroduced in bird faeces (Ziegler and Hopkins, 2022).

She notes that the longevity of boxthorn seed appears to be unknown. However, field evidence suggests that emergence of seedlings declines rapidly after four years. Also, she believes that grazing by native Cape Barren geese (*Cereopsis novaehollandiae*) has helped to reduce the number of seedlings that survive.

Perhaps the key message from the experience of FOBSI is that it is possible to achieve good long-term outcomes from African boxthorn control in coastal situations. Karen says:

Even we have been surprised at the level of success we have had. For example, on low- to mid-infestation islands, after ten years of work and follow-up, only three-to-four-year follow-ups are required, and only for minimal boxthorn presence, to maintain the status quo.

In 2022, controlling African boxthorn on offshore islands remains vital conservation work. In addition, the fleshy fruit of the boxthorn is a food source for Queensland fruit fly, of which there was an outbreak on Flinders Island several years previously. Hence, the widespread distribution of boxthorn presents a biosecurity risk to local fruit and vegetable production.

Lastly, there are other weeds that should not be overlooked. While boxthorn remains FOBSI's focus on the offshore islands, there is an emerging weed problem with mirror bush, another species with fleshy, bird-dispersed seed. Volunteers need to be trained in what other plants to look for and how to treat them effectively.

Progressive control at a site on Roydon Island

a. April 2017 before control; boxthorn cover was very high

b. May 2017 after cut and paste control; native shrubs left intact

c. May 2018; almost continuous native ground cover one year on

d. June 2019 boxthorn seedlings have been removed twice; annuals are being replaced by longer-lived natives

e. May 2021 seedling boxthorn still germinating and needs annual follow-up; tussock grasses, perennial herbs and woody shrubs giving almost continuous cover

f. May 2022 still removing occasional boxthorn seedlings; native shrubs now dominating the treated site

4.3 Phillip Island, southern Victoria

Jarvis Weston, Manager Projects and Planning (former Ranger in Charge), Jon Fallaw, Ranger, and Ben Thomas, current Ranger in Charge at Phillip Island Nature Parks have worked on a long-term project to restore little penguin habitat on the island. African boxthorn has been one of numerous factors that have, over time, reduced the quality of seabird habitat in the park, causing little penguin numbers to decline. However, 38 years into an ongoing major habitat restoration project, their numbers have stabilised. Over the project much has been learnt about African boxthorn control in a coastal environment.

Phillip Island is around 140 km south-east of Melbourne and approximately 100 km^2 in area. Around 90% of the island has been cleared of native vegetation, with conversion to farming and urban areas. The island hosts seabird colonies, primarily little penguins and short-tailed shearwaters. Phillip Island Nature Parks ('the Nature Parks') is a not-for-profit organisation charged by the Victorian Government, since 1996, with managing conservation parks and infrastructure on Phillip Island. The Nature Parks manages a total area of 1805 hectares of reserves, and its work is funded through revenue generated by ecotourism activities, including the renowned Penguin Parade—a tourist attraction that enables viewing of the nightly return of little penguins to their burrows and draws more than 500 000 visitors per year to the island (Weston, 2012).

African boxthorn is a high-priority weed for management on Phillip Island. The species threatens little penguin and short-tailed shearwater habitat and is a physical hazard: birds have been trapped in the thorny bushes, which also harbour feral predators (Weston, 2012; Phillip Island Nature Parks 2018).

Jarvis Weston has worked at the Nature Parks since 1998. He says that when the parks were created, many of the reserve areas were significantly degraded, partly because of major infestations of African boxthorn. At the Penguin Parade on the island's south-western Summerland Peninsula, boxthorn control had been ongoing for decades. A Community Employment Program (1984–86) removed most of the large boxthorn at the Parade and along sections of the north coast of Summerland Peninsula, but it was not until 1998 that clearing began in earnest in other areas of little penguin habitat. Staff spent hundreds of hours cut stumping boxthorn and then burning the plant debris (Weston, 2013).

Jon Fallaw says that in 2022, staff continue to have success with the cut stump method, using pure glyphosate herbicide (or a minimum 80% mix with water) or Vigilant Gel (aminopyralid + picloram).

In 2000, in addition to the cut stump efforts, local contractors began using a tractor and backhoe to remove boxthorn mechanically. This used a grab on a backhoe to pluck plants from the ground. Boxthorn plants in more difficult-to-access sites (e.g. among sand dunes) were removed by running a cable and chain from a tractor-based winch, securing it around the base of mature plants and winching them from the ground. Immediately afterwards, neat glyphosate was applied to any fragments of root that remained embedded in the ground.

After removal, plants were piled and burnt. However, these days this soil-disturbing technique has been largely discontinued to protect cultural heritage sites.

The Nature Parks staff have tried foliar spraying of large African boxthorn bushes with a broad range of herbicides, but with limited success. Jarvis puts this down to the coastal environment where the hardened boxthorn plants have small leaves, resulting in poor uptake of herbicide. Another downside of foliar spraying is that because the dead plants remain in place (i.e. are not piled and burnt), new growth results in a thick lattice of shoots that makes follow-up more difficult, and increases their potential to snare seabirds.

Follow-up has been an ongoing challenge. Jon says that it is still necessary to return to and manage many sites treated more than a decade previously, as seed germination or root regeneration persists. Follow-up during most of the control work period has consisted mainly of foliar spraying of multi-stemmed small bushes; and cut stump treatment of new germinants and regrowth from remnant roots (Fallaw and Thomas, 2022).

Around 2006, African boxthorn control work extended to new areas such as Cape Woolamai and along the south coast of Phillip Island. Several years after this, Jarvis recalls, the team realised they had done so much primary control work that the follow-up task had become difficult to handle. He says:

> ***We nearly made the mistake of biting off more than we could chew and without follow-up work we would have been in a worse situation than we were to begin with. Where we once had one mature plant, we now had 50 new plants to replace it (Weston, 2013).***

Cut stump control of mature boxthorn in little penguin habitat on Phillip Island

On Phillip Island, a winch on the back of the tractor pulls boxthorn out of the ground by putting a chain noose around the stump and winching it out

The winch used by the Nature Parks pulls out mature boxthorn, roots and all

The tractor used on Phillip Island, adapted to grab the uprooted boxthorn and place it on piles for burning

The Ecoblade® in action on Phillip Island, treating boxthorn regrowth

Follow-up foliar spraying did not prove effective and cut stump had become logistically impossible because of the size of the area that now required follow-up. Relief came in the form of an Ecoblade®. John Baulch, the owner–operator of Regional Vic Farm Services worked for the Nature Parks using this machine-based blade with herbicide applicator on African boxthorn. Jon says that their trials of Ecoblade® for follow-up work showed it to be 80–90% effective. The Ecoblade® was used for large-scale follow-up in relatively open, undulating sections of the park until 2018, at which stage most of the seed and regrowth from roots had been exhausted. The Ecoblade® was extremely cost and time effective and greatly reduced the manual labour and safe handling issues that would have arisen if the Nature Parks had instead done a large follow-up cut and paint job.

Critical considerations when planning boxthorn work programs on Phillip Island are the breeding habits of little penguins and the migratory patterns of short-tailed shearwaters.

The shearwaters breed on the island between September and April. Each April they migrate to the northern hemisphere, returning in September. The penguins breed between June and September. Some little penguins return consistently to their burrows year round but most stay at sea throughout the autumn–winter period. With these movements in mind, the Nature Parks determined that the best time to undertake works on African boxthorn in the vicinity of burrows is May–September.

The Nature Parks has found that where cultural heritage has been taken into account, machinery can be safely used around the

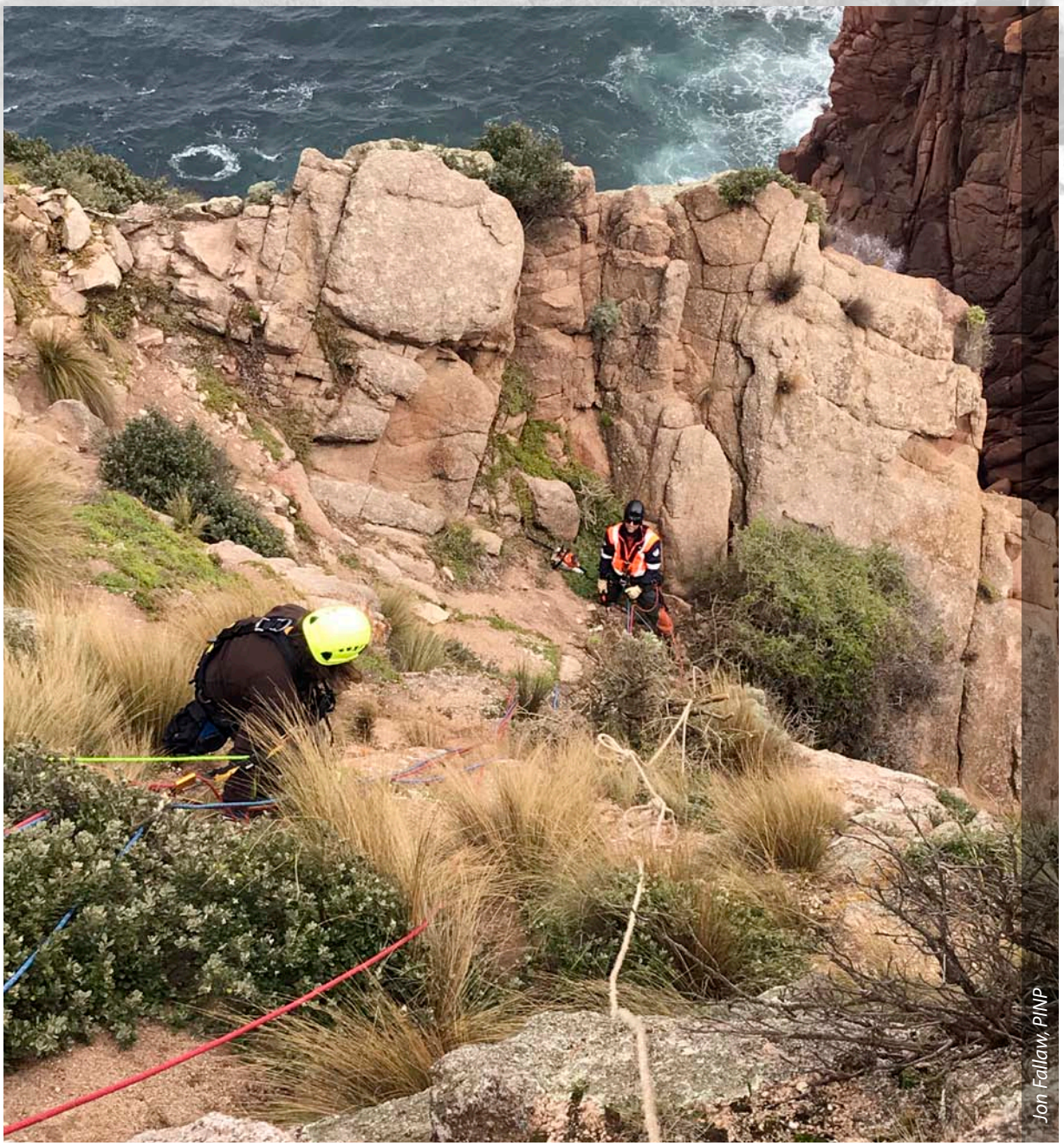
Burnt piles of boxthorn need to be fenced to prevent penguins walking through the hot coals when they return to land at night

shearwater burrows, but not around the little penguin burrows. This is because shearwaters are absent from May to September and will renovate burrows when they return, but some penguins occupy their burrows all year round. Therefore, work around penguin burrows is restricted to cut stump and foliar spraying.

The Nature Parks also realised that burn piles must be either thoroughly extinguished or fenced off from little penguins. The penguins appear not to have evolved with an awareness of the danger of fire and, if there is no fence, will readily walk straight into hot coals.

As in any bird rookery, many African boxthorn infestation areas have a high level of soil nutrients, so removing the boxthorn often provides opportunities for new weed species. Jarvis reports that species such as apple of Sodom (*Solanum linnaeanum*), fat hen (*Chenopodium album*), inkweed (*Phytolacca octandra*) and various thistles commonly appear, and that a good way to prevent them becoming an ongoing problem is to encourage regeneration of local native species such as bower spinach (*Tetragonia tetragonoides*) and seaberry saltbush (*Rhagodia candolleana*).

After nearly 25 years of work, the Nature Parks considers it is now well advanced on the path to eradicate African boxthorn from the parks. The group also works with Phillip Island Landcare and the Bass Coast Landcare Network to promote removal of boxthorn and other weeds on private land. There is enthusiasm for eradicating boxthorn on private land as it is a rabbit harbour and birds can re-infest the park from neighbouring properties. Fortunately, on Phillip Island there are only a couple of major boxthorn infestations outside the park.



Susan Spicer and Andrew Dallinger on ropes removing boxthorn from Cape Woolamai cliffs

Ben Thomas says that the Nature Parks acknowledges that follow-up work will always need to be done if African boxthorn is to be kept under control. As of 2022, most of the accessible country on the reserve network has been cleared and is now subject to regular follow-up monitoring and control (Fallaw and Thomas, 2022; Phillip Island Nature Parks 2018).

Boxthorn re-sprouts are coming up and some bushes have been hiding in among seaberry saltbush and bower spinach, particularly on Cape Woolamai. Much of the attention is now focused on the coastal cliffs. The Nature Parks has seven staff trained in rope access and working at heights. Although the work is slow going, these staff are gradually working around the southern coastline, abseiling down and removing infestations (Fallaw and Thomas, 2022).

4.4 South coast, Western Australia

Matt Kennewell was formerly the Invasive Species Coordinator with South Coast NRM Inc. based in Albany, Western Australia. From 2011 to 2013 he led a large Australian Government-supported African boxthorn management project on the south coast, tackling more than 1500 hectares of infestations, from Bremer Bay and Ravensthorpe through to Esperance. Matt and his project manager Graeme Simpson used a range of African boxthorn control methods in the project.

The Fitzgerald Biosphere covers over 15 000 square kilometres to the north-east of Albany. It has the 330 000-hectare Fitzgerald River National Park at its core, which contains 15% of Western Australia's described plant species. This biodiversity hotspot area provides habitat for an extraordinary number of nationally listed threatened species (more than 40 fauna and over 100 flora species) (Gilfillan et al., 2009). The region is internationally recognised for its biodiversity through the Fitzgerald Biosphere (United Nations designation) and two Ramsar-listed wetlands.

African boxthorn is present particularly around Ravensthorpe and Esperance to the east of the national park. Its ongoing spread poses a significant threat to a range of environmental and production values on the south coast, because of its capacity to change the structure and floristic composition of vegetation communities (Gilfillan et al., 2009). Following its deliberate introduction to Australia, African boxthorn has spread in the South Coast NRM region as it has in other parts of Australia, primarily via seeds dispersed by birds and foxes.

At the outset of the regional boxthorn management project, a steering committee was formed, consisting of representatives of organisations, agencies and industry that owned or managed boxthorn-affected lands and/or had an interest in and capacity for helping to guide project implementation. Matt believes that the committee was critical in providing direction, making decisions about methodology, prioritising control areas and maintaining communication between project partners and the broader community.

The committee decided on the following top priorities:

- Contact stakeholders who could/should fund and undertake African boxthorn works themselves, such as roads and power authorities, government agencies and local government.
- Establish a 5-km African boxthorn-free buffer zone around high-value assets such as Fitzgerald River National Park and Ramsar sites.
- Focus efforts on public and private land at Stokes Inlet, an isolated area of African boxthorn infestation surrounded by high-value natural assets.
- Aim to prioritise control of boxthorn at the top of waterway catchment areas before areas lower down.

Matt believes that the absence of starlings (not established in Western Australia thanks to ongoing eradication efforts by the Western Australian Government) has, so far, limited the dispersal of boxthorn in the South Coast NRM region. This thinking is supported by research indicating that the greater the diversity of species that disperse seeds, the greater the

potential for the plant to move to different microhabitats and for seeds to be dispersed to suitable germination sites (Stanley and Lill, 2002).

Indigenous work teams and contractors received training in plant identification, pesticide handling and weed hygiene protocols prior to the project commencing

The regional African boxthorn control project used a number of control methods, giving the team flexibility for various situations and the opportunity to compare effectiveness. The methods used included foliar spraying, cut stump, basal bark, soil–root zone application, plucking/pulling and machine-based cut stump. To help with later monitoring and evaluation of control efforts, the team kept Global Positioning System (GPS) details for each treated site.

The on-ground work was delegated to Indigenous work teams and two contractors, who were given training in plant identification, pesticide handling and hygiene protocols to prevent the spread of weeds and diseases.

Before the project began, Matt researched successful African boxthorn control work done in South Australia. From this, the Western Australian team understood that the success

Regeneration after spraying with glyphosate, metsulfuron-methyl, penetrant and water

Herbicide treatments of African boxthorn in the Esperance area

Plucking African boxthorn at Ravensthorpe

of foliar application of herbicides depends on correct timing. In particular:

- Foliar spraying should only be undertaken when plants are actively growing and leaves are present (usually between autumn and spring).
- Temperatures must be below 28°C.
- Ideally, herbicides should be applied shortly before rain, as the plant system is more active after rain and this will maximise chemical uptake.

The herbicides they used for foliar application included triclopyr–picloram-based herbicide, and a mix of glyphosate, metsulfuron methyl, penetrant and water.

Early results from using the latter mix on approximately 3000 plants in Esperance show that this was effective (90% die-off) on boxthorn plants with stems smaller than 140 mm. However, 80% of plants with stems larger than 140 mm were regenerating six months after initial treatment. The contractor working in the Ravensthorpe area reported similar results. In both cases, the kill rate was improved by multiple follow-up foliar sprays.

In areas where plants were sprayed with triclopyr–picloram-based herbicide, Matt said no regeneration was observed. This was likely because of picloram's residual qualities extending its impact.

Also in the Esperance area, the team applied tebuthiuron pellets to the root zone of African boxthorn plants. As this method has the potential to cause significant off-target damage, it was used cautiously and in situations where there was minimal potential to damage non-target species. The observed result was 100% die-off.

Another control method used was mechanical plucking or pulling. Graeme and Matt said that the team found this most effective with larger plants whose stronger root systems are most effectively removed from the ground. Herbicide was applied to any remaining roots. The plucking process was easier if the ground was moist to some degree.

The team used the plucking method at Ravensthorpe Golf Club over a 100 × 50 m area, then piled and burnt the African boxthorn debris. The team estimated that this method achieved 90% mortality of the plants; it was effective but expensive.

The project also trialled a mechanical cut stump operation using custom-built equipment: a chainsaw on the end of a small excavator, plus a mechanism to apply herbicide immediately after cutting. This proved successful: two years after the trial, only a small amount of regrowth had appeared, mainly under trees, and this may have been from seed germination.

Matt and Graeme said that a major benefit of the machine-based methods they trialled was the capacity to remove the plant debris and apply herbicide to the stump without exposing workers to the weed's hazardous thorns.

The South Coast NRM African boxthorn project team enlisted the support of local media and placed signage at work sites to inform the community about threats posed by African boxthorn and to detail how it is being managed.

Matt and Graeme said that two of the most important factors contributing to the success of the project had been the commitment of landholders and having adequate human and financial resources. However, for a weed like African boxthorn, the time limitations on resourcing provide an ongoing challenge.

4.5 West coast of Eyre Peninsula, South Australia

Gaining access to treat African boxthorn on islands and in isolated, dense scrub can be very difficult. Robbie Sleep from the South Australian Department of Environment and Water (SA DEW), and Andrew Freeman and Liz McTaggert from the Eyre Peninsula Landscape Board (EPLB) have developed an innovative and cost-effective method for hand application of soil-active granular herbicide—out of a helicopter! (McTaggert et al., 2022).

Much of the Eyre Peninsula's boxthorn infestation in conservation areas occurs in difficult-to-access coastal situations and on offshore islands. Dense, snake-filled scrub and limited road access means much time can be taken to safely search for and treat boxthorn plants from the ground.

On remote, offshore islands there are the further challenges of safe boating access and the need to not disrupt bird and seal rookeries, let alone using spraying equipment there. These logistical challenges can make African boxthorn control programs very costly.

An APVMA permit for application of tebuthiuron for African boxthorn control in non-crop areas and grazing land in South Australia was granted in 2008. Given the challenges of boxthorn control in remote conservation areas, the SA DEW decided to look into the effectiveness and efficiencies of using a helicopter to gain easier access for hand application.

Three tebuthiuron trials on the west coast of Eyre Peninsula were led by Robbie Sleep of

Dispensing tebuthiuron onto an African boxthorn plant

SA DEW and Andrew Freeman of EPLB. The trials were designed to provide local baseline information on the effectiveness of tebuthiuron herbicide pellets, and to compare ground-based methods versus use of a helicopter to hover just above bushes for hand application.

A two-year trial commenced in 2010 to evaluate the effectiveness of hand-applied tebuthiuron herbicide pellets, in comparison with the traditional control methods of cut and swab, and foliar spraying, at two sites at Elliston. Time spent, cost of materials and total cost per boxthorn (labour and materials) were compared for the three ground-based methods. At both sites, time spent on boxthorn control per plant was significantly less with the use of tebuthiuron, compared with the foliar spray and cut, and swab methods. At both sites, total chemical and labour cost per boxthorn plant was significantly lower using tebuthiuron:

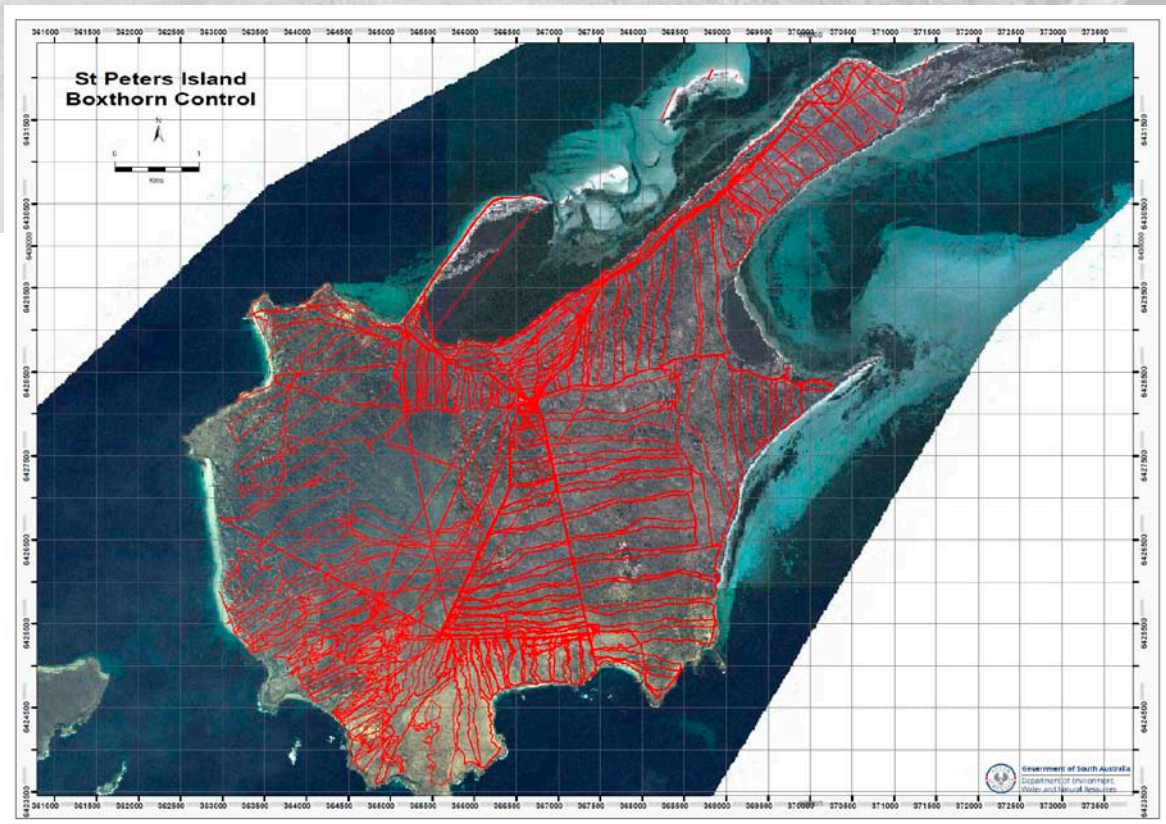
TREATMENT	Site 1	Site 2
tebuthiuron pellets	$0.34	$0.37
foliar spray with glyphosate–metsulfuron methyl mix	$1.04	$1.31
cut and swab with glyphosate	$1.90	$3.49

Second, in 2012, hand application of tebuthiuron from the ground versus helicopter was trialled on St Peter Island, south of Ceduna, looking at the cost, effectiveness and accuracy of application. To treat 470 ha of moderate-density boxthorn from the ground took 8.5 days with five to six staff; whereas to treat 1110 ha from a helicopter took 8.5 hours (7.5 control and 1 hour ferry time) with two staff and a pilot. The ground-based method had an operational cost of $12.00/ha whereas the helicopter method cost $7.65/ha, including staff costs.

Canister for hand application of tebuthiuron granules

In the third trial, hand application of tebuthiuron herbicide pellets by helicopter was tested at a landscape scale through the WildEyre Project (2013–17). At three coastal sites of medium African boxthorn infestations—Lake Newland Conservation Park, Kiana Crown Land and Point Drummond Heritage Agreements—hand application from helicopter cost an average of $5.14/ha; or $3.87/plant. This was estimated as only 4.5% of the cost of equivalent ground application.

Robbie says that the trials showed that the helicopter method of hand applying tebuthiuron was clearly cost effective. Results



Tamahina Cox, DEW

Helicopter flight path for St Peters Island

showed a positive cost comparison for the use of tebuthiuron herbicide pellets to control boxthorn and for the efficiency of using a helicopter to gain easy access for hand application.

Minimal off-target damage to native plants has been observed. Photopoint monitoring and other observations on re-establishing plants showed good recovery. For example, on west coast islands, ruby saltbush (*Enchylaena tomentosa*) has come back vigorously and provided an indigenous fruit source.

The helicopter method of hand application of tebuthiuron has now expanded to other parts of South Australia, including around 25 000 hectares treated via helicopter for African boxthorn in coastal dunes of the Coorong and Canunda national parks.

Various safety and environmental precautions are strictly adhered to in applying tebuthiuron herbicide.

APVMA permit PER87341 only allows SA DEW and EPLB staff that are trained and experienced in the use of agricultural chemical products to apply tebuthiuron in non-crop areas, including native vegetation, according to the permit's directions for use. Unless otherwise stated in the permit, the use of the product must be in accordance with instructions on the label.

Buffers of a minimum width of 100 m are maintained around waterways, waterbodies and marine areas as per label instructions. These areas can be treated by basal bark or cut and swab methods instead. Likewise, boxthorns growing at the bases of native trees, including mallee (*Eucalyptus* spp.), dryland tea tree (*Melaleuca lanceolata*) and she-oaks (*Allocasuarina verticillata*) are not treated with tebuthiuron, to avoid off-target impacts. Dead African boxthorn plants are left in situ to provide windbreaks, habitat and soil protection.

Timing is important. The boxthorn needs to be in full leaf and bright green—that is, actively growing— when treated. Helicopter use is avoided during raptor breeding and shorebird nesting times in areas where these species are present.

Safety is paramount. Risk assessments, safety protocols and standard operating procedures must be followed. To date, helicopter services have been provided by the company Helifarm.

Erin Gibson from Helifarm says that DEW/EPLB staff are inducted into the company's safety protocols, including normal and emergency procedures, emergency contacts, entry and exit from the helicopter and herbicide granule preparation and loading. The pilot and the applicator passenger, the 'chucker', are harnessed in with doors removed from the helicopter. The work is not for those who suffer from motion sickness.

The chucker leans out of the helicopter to use a metered canister to click-release the tebuthiuron herbicide over a target bush. Snail pellet-sized granules are dropped from above into the centre of boxthorn bushes.

Erin says the helicopter pilot needs to be experienced in flying at low levels and skilled in spotting boxthorn plants among native vegetation. While flying, a GPS data logger is used by the applicator to record locations of treated plants. Grid-referenced PDF maps are important in providing the pilot with information on the appropriate scale to zoom in to areas to be treated.

Liz McTaggert from EPLB says that tebuthiuron application has a very high kill rate for African boxthorn if label instructions for application are administered. Follow-up is essential and was undertaken in years three and five after initial treatment. With the limitation of funding availability, the aim is not to completely eradicate boxthorn, which will continue to arrive from adjacent areas with bird dispersal of seed. Rather, the aim is to manage impacts by keeping boxthorn infestations at a low level.

Dead boxthorn plants among native vegetation on St Peters Island, two years after treatment

CHAPTER 5
Further information

Friends of Bass Strait Islands

CHAPTER 5
Further information

5.1 African boxthorn legal status and responsibilities in Australia

JURISDICTION	LEGISLATION	DECLARATION	DESCRIPTION
Australia	*Biosecurity Act 2015*	Not permitted	Not permitted for entry into Australia.
Australian Capital Territory	*Pest Plants and Animals Act 2005*	Declared	Must be suppressed. Propagation and supply prohibited.
New South Wales	*Biosecurity Act 2015*	Declared	Must not be imported into the state, sold, bartered, exchanged or offered for sale. General biosecurity duty to ensure a biosecurity risk is prevented, eliminated or minimised, so far as is reasonably practicable. Regional priority in 2022 for asset protection in certain parts of the state (refer to NSW government website for current regions).
Northern Territory	*Weeds Management Act 2001*	Declared	Infestations to be eradicated (Class A). Not to be introduced to the Northern Territory (Class C).
Queensland	*Biosecurity Act 2014*	Declared	Category 3 restricted invasive plant. Illegal to give away, sell or release into the environment. General biosecurity obligation to take all reasonable and practical measures to minimise the biosecurity risks associated with dealing with African boxthorn. Contact local councils for any additional control requirements.
South Australia	*Landscape South Australia Act 2019*	Declared	Declared state-wide. Cannot be moved or sold as a plant or contaminant. Land owners to control the plant on their properties. Recovery of control costs on adjoining road reserves.
Tasmania	*Biosecurity Act 2019* (Note the *Weed Management Act 1999* is to be repealed in the first quarter 2023)	Declared	Importation, propagation, and supply are prohibited dealings under the *Biosecurity Regulations 2022*. Weed Management Plans/Biosecurity Programs include provisions for the requirement of eradication or containment measures in each municipality.
Victoria	*Catchment and Land Protection Act 1994*	Declared	Declared as regionally controlled in each region.
Western Australia	*Biosecurity and Agriculture Management Act 2007*	Not declared	

5.2 Registered and permitted herbicides

Tables A–D list types of herbicides and their registered or permitted uses for African boxthorn control in Australia, as at July 2022 (Australian Pesticides and Veterinary Medicines Authority, 2013; Growcom, 2022; Department of Primary Industries, 2022; Queensland Government, 2021; Department of Natural Resources and Environment Tasmania 2022b; Department of Primary Industries and Regions, 2022).

Individual herbicide products are not listed as there are many hundreds registered for use on African boxthorn, their availability may change over time and new products may enter the market.

To perform a current search on registered herbicide products for African boxthorn, go to the APVMA website www.apvma.gov.au and click on 'PUBCRIS: search registered chemical products' in the right-hand 'services' menu.

African boxthorn control minor use permits for some herbicides have been issued for specific situations in individual state and territory jurisdictions. To perform a current search for off-label and minor use permits, go to the APVMA website www.apvma.gov.au and click on 'PERMITS: search' in the right-hand 'services' menu.

Alternatively, herbicide registrations and permits can be obtained through the INFOPEST Database www.infopest.com.au.

In addition to an APVMA search, it is recommended that you review current herbicide information on the website of the relevant organisation/s of your state or territory government.

5.2.1 State/territory 'Control of use' legislation and off-label use

Pesticide use in Australia varies between states and territories as each jurisdiction has responsibility for developing local regulations on their use. This includes jurisdictional requirements and abilities for off-label use of herbicides, and any restrictions on use or application of particular herbicides. It is your legal responsibility to be aware of and comply with these state/territory requirements, in addition to following product label instructions.

Off-label use is the use of a herbicide to control a weed that is not covered by an APVMA approved product label, or by a permit allowing 'persons generally' or specific groups of people to use the herbicide as stated on the permit. Wilful misuse on the other hand represents an active or negligent disregard for all instructions and legal requirements with no consideration of the risks.

Table 5.1 summarises current provisions for control of use (off-label use) across states and territories. Table 5.2 provides web links for further information on state or territory pesticide control of use. State/territory contacts for weed control information are given in Section 5.5.

If you are unsure which herbicides can be legally used on a particular weed in your state, contact the weed or biosecurity section of your state department of agriculture or your local biosecurity officer.

WARNING!

Off-label practices DO NOT exclude or override product maximum residue limits, work health and safety or environmental safety.

If going off-label the decisions the user must consider include the rate of pesticide; time and frequency of application; the likelihood of residues; and the potential for worker exposure.

'Off-label use' does not override Directions for Use 'DO NOT' statements on labels and permits such as 'DO NOT apply to crops or pastures with clover, lucerne or medics'.

There is no liability by the pesticide manufacturer for off-label uses of their product.

Table 5.1 State control of use legislation (off-label) in agricultural chemicals (as of May 2022). For more information: www.awe.gov.au/agriculture-land/farm-food-drought/ag-vet-chemicals/domestic-policy/haccut

HERBICIDES ALLOWED YES (Y) / NO (N)		ACT	NSW	Qld	WA	SA	NT	Tas	Vic
Rates of application	Lower rate than on label	Y	Y	Y	Y	Y	Y	Y	Y
	Higher rate than on label	N	N	N	N	N	N	N	N
	Lower frequency than on label	Y	Y	Y	Y	Y	Y	Y	Y
	Higher frequency or rate than on label	N	N	N	N	N	N	N	N
Weed	Different weed than on label	Y	Y	Y	Y	Y	Y	Y	Y
Situations & crops	Different crop or situation than on label	N	N	N	N	N	N	N	Y
Application equipment	Different application equipment than on label	N	N	Y	Y	Y	Y	N	Y
Preparation	Tank mixes	Y	Y	Y	Y	Y	Y	Y	Y

Table 5.2 Sources of further information on state/territory pesticide control of use. For weed control contacts see Section 5.5.

JURISDICTION	WEB LINK/S
ACT	www.accesscanberra.act.gov.au/s/article/pest-and-weed-control-tab-Agvet-chemical-use
New South Wales	www.epa.nsw.gov.au/your-environment/pesticides/pesticides-nsw-overview
Northern Territory	nt.gov.au/industry/agriculture/farm-management/using-chemicals-responsibly
Queensland	www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/land-management/chemical-controls
South Australia	www.pir.sa.gov.au/biosecurity/rural_chemicals
Tasmania	nre.tas.gov.au/agriculture/agvet-chemicals
Victoria	agriculture.vic.gov.au/farm-management/chemicals/offlabel-chemical-use
Western Australia	www.agric.wa.gov.au/biosecurity/pest-and-disease-information-service-padis ww2.health.wa.gov.au/Articles/U_Z/Using-pesticides-safely

Table A Herbicides registered and permitted for foliar spraying of African boxthorn (as at July 2022).

Foliar spray (spot spray)

- Apply to healthy, actively growing plants that have foliage to absorb the herbicide.
- Avoid spraying when plants are stressed by hot or dry conditions, or in periods of waterlogging or extreme cold.
- Spray to wet all foliage but not to cause excessive runoff.
- Refer to product labels for recommended additives (e.g. wetting agents) to boost herbicide efficacy.

Herbicide	State or territory [a]	Application	Situations in which the herbicide can be used on African boxthorn	Comments
Glyphosate [b]	All	***Handgun or knapsack application*** Follow label directions for dilution rate and wetting agent.	Agricultural areas, pasture, forestry, non-agricultural areas (domestic, commercial and industrial), rights of way. Additional uses under permit: • PER11916 (NSW only) urban bushland, forests, coastal reserves • PER82307 (Qld only) native vegetation, bushland reserves, revegetation areas, non-crop areas, open public spaces • PER13371 (SA only) conservation areas • PER84775 (Tas only) non-crop and bushland	• Glyphosate products where African boxthorn specified on the label. • Use a lower rate for young bushes and a higher rate for bigger, mature bushes, as per label directions. Further treatment may be needed to control seedlings and regrowth. • Irritant. Follow safety directions. • Non-selective. Need to avoid contact with desirable plants.
	ACT, NSW, Qld	***Low-volume/high-concentration foliar application*** [c] Follow label directions for dilution rate and wetting agent.	Uses under permit: • PER9907 (NSW & ACT only) native vegetation, forests, non-crop areas, open public spaces, domestic and urban areas • PER81752 (Qld only) agricultural non-crop areas, commercial and industrial areas, forests, pastures, rights of way	
Glyphosate [b] & metsulfuron methyl (600 g/kg) *tank mix of two herbicides*	ACT, NSW, Qld, SA	***Handgun or knapsack application*** Follow permit directions for dilution rate. Consult labels for wetting agent.	Uses under permit: • PER9907 (NSW & ACT only) native vegetation, forests, non-crop areas, open public spaces, domestic and urban areas • PER82307 (Qld only) native vegetation, bushland reserves, revegetation areas, non-crop areas, open public spaces • PER13371 (SA only) conservation areas	• Refer to comments on glyphosate above. • Harmful if swallowed. Irritant. Follow safety directions on both labels.
	Qld	***Low-volume high-concentration foliar application*** [c] Follow permit directions for dilution rate. Consult labels for wetting agent.	Uses under permit: • PER81752 (Qld only) agricultural non-crop areas, commercial and industrial areas, forests, pastures, rights of way	

Metsulfuron methyl (600 g/kg)	ACT, NSW, Qld, SA, Tas	***Handgun or knapsack application*** Follow permit directions for dilution rate. Consult label for wetting agent.	Uses under permit: PER9907 (NSW & ACT only) native vegetation, forests, non-crop areas, open public spaces, domestic and urban areas PER82307 (Qld only) native vegetation, bushland reserves, revegetation areas, non-crop areas, open public spaces PER13371 (SA only) conservation areas PER84775 (Tas only) non-crop and bushland	• Harmful if swallowed. Irritant. Follow safety directions.
	Qld, Tas	***Low-volume/high-concentration foliar application*** [c] Follow permit directions for dilution rate. Consult label for wetting agent.	Uses under permit: PER81752 (Qld only) agricultural non-crop areas, commercial and industrial areas, forests, pastures, rights of way PER84775 (Tas only) gas gun use in non-crop and bushland	
2,4-D [b]	All or [d] SA, Vic only	***Handgun or knapsack application*** Follow label directions for dilution rate.	Pastures, rights of way and industrial	• Certain products only registered for this use in SA or Vic. • 2,4-D products where spot spraying specified on the label only. • Poisonous if inhaled or swallowed. Avoid skin contact. Irritant. Follow safety directions. • Warning—spray drift risk. Phenoxy herbicides can cause severe damage to native vegetation and susceptible crops such as cotton, grapes, tomatoes, oilseed crops and ornamentals. • Withholding period—do not graze or cut pastures for stock food for 7 days after application.
2,4-D (300 g/L) + picloram (75 g/L)	ACT, NSW, Qld, Vic, WA	***Handgun or knapsack application*** 1.3 L/100 L water	Agricultural non-crop areas, pastures, rights of way, commercial and industrial	• Treat small plants only. Thorough coverage is essential. • Harmful if inhaled, swallowed or contact with eyes. Irritant. Follow safety directions. • Warning—spray drift risk. Phenoxy herbicides can cause severe damage to native vegetation and susceptible crops such as cotton, grapes, tomatoes, oilseed crops and ornamentals. • Withholding period—do not graze or cut pastures for stock food for 7 days after application. • Tank mix using 240 g/L picloram product and 2,4-D product is also registered—refer to label for rates and directions.

Triclopyr [b]	Tas	***Handgun or knapsack application*** Follow label directions for dilution rate.	Commercial and industrial situations, rights of way, pastures, forests	• Apply as a thorough foliage spray to bushes less than 2 m tall. • Poisonous if swallowed. Irritant. Follow safety directions. • Many broadleaved plants are highly susceptible, including legumes, vines, vegetables tomatoes, ornamentals, native vegetation and planted trees.
Triclopyr (300 g/L) + picloram (100 g/L)	All	***Handgun or knapsack application*** 500 mL/100 L	Agricultural non-crop areas, pastures, rights of way, commercial and industrial, forests	• Apply to bushes less than 2 m tall that have good leaf cover, active growth and no leaf fall. • Harmful if swallowed. Irritant. Follow safety directions. • Many broadleaved plants are highly susceptible, including legumes, vines, vegetables tomatoes, ornamentals, native vegetation and planted trees. • Tank mix using 240 g/L picloram product and triclopyr product is also registered—refer to label for rates and directions.
Triclopyr (300 g/L) + picloram (100 g/L) + aminopyralid (8 g/L)	All	***Handgun or knapsack application*** 500 mL/100 L	Agricultural non-crop areas, pastures, rights of way, commercial and industrial, forests	• Apply to bushes less than 2 m tall that have good leaf cover, active growth and no leaf fall. • Irritant. Follow safety directions. • Many broadleaved plants are highly susceptible, including legumes, vines, vegetables tomatoes, ornamentals, native vegetation and planted trees. • Nil mandatory withholding period for cutting or grazing pastures for stockfood. However, certain export markets have restrictions—consult the product label.
Aminocyclo-pyrachlor (240 g/L)	All	***Handgun or knapsack application*** 200–500 mL/100 L	Native conservation areas, pastoral grazing land, industrial sites such as railways, roadways and utility rights-of-way	• Manufacturer advises that 'pastoral grazing land' is equivalent to 'pastures' (Envu 2022). • Follow safety directions. • May injure or kill crops and other desirable vegetation. Certain trees, shrubs, legumes are susceptible to very low doses. May suppress or severely injure certain established grasses. • Aminocyclopyrachlor in soil can be taken up by plant roots. Beware of contaminating irrigation water. Follow label directions. • Nil mandatory withholding period for grazing pastures. However, certain export markets may have restrictions. Hay and manure management requirements. Consult the product label.

[a] Products may be registered for use on African boxthorn in all states and territories (shown as 'All') or only in the specific states and territories listed. Further, additional uses not on the label may be allowed under permit, for specified states or territories. Where a state or territory is not listed on the label and there is no applicable permit, use as specified on the label for use in the same situation may still be allowed under jurisdictional legislation, where considered low risk—refer to Section 5.2.1.

[b] Products containing different concentrations of the active ingredients. Check the label for rates.

[c] Low-volume/high-concentration foliar application methods include drench, splatter or gas gun.

[d] Certain products only registered for this use in specific states or territories.

Table B Herbicides registered and permitted for cut stump, stem injection and/or frilling of African boxthorn (as at July 2022).

Cut stump, stem injection & frilling

- Apply herbicide to cut surface within 15 seconds.
- Plants should be actively growing and not under stress.

Herbicide	State or territory[a]	Application	Situations in which the herbicide can be used on African boxthorn	Comments
Glyphosate[b]	ACT, NSW, Qld, SA, Tas, WA	***Cut stump*** Follow permit directions for dilution rate. ***Drill, frill or stem scrape*** Follow permit directions for dilution rate.	Uses under permit: • PER9907 (NSW & ACT only) native vegetation, forests, non-crop areas, open public spaces, domestic and urban areas • PER81752 (NSW only) urban bushland, forests, coastal reserves • PER82307 (Qld only) native vegetation, bushland reserves, revegetation areas, non-crop areas, open public spaces • PER11463 (Qld only) non-agricultural areas, domestic and public service areas, commercial and industrial areas, bushland/native forests, roadsides, rights of way, vacant lots, wastelands, wetlands, dunal and coastal areas. • PER13371 (SA only) conservation areas • PER84775 (Tas only) non-crop and bushland • PER13333 (WA only) agricultural non-crop areas, non-crop areas, commercial and industrial areas, wetlands, bushlands and forests	• Irritant. Follow safety directions. • Non-selective. Avoid contact with desirable plants.
Glyphosate (360 g/L) & metsulfuron methyl (600 g/kg) mix of two herbicides	ACT, NSW, Qld	***Cut stump*** Follow permit directions for dilution rate. ***Drill, frill or stem scrape*** Follow permit directions for dilution rate.	Uses under permit: • PER9907 (NSW & ACT only) native vegetation, forests, non-crop areas, open public spaces, domestic and urban areas • PER82307 (Qld only) native vegetation, bushland reserves, revegetation areas, non-crop areas, open public spaces	• Harmful if swallowed. Irritant. Follow safety directions on both labels. • Non-selective. Avoid contact with desirable plants.
2,4-D[b]	All or[d] SA, Vic only	***Cut stump***	Pastures, rights of way, industrial	• Certain products only registered for this use in SA or Vic. • 2,4-D products where cut stump specified for African boxthorn on the label only. • Poisonous if inhaled or swallowed. Avoid skin contact. Irritant. Follow safety directions.
Triclopyr (50 g/L)	All	***Cut stump*** 100 mL/250 mL kerosene	Home garden	• Poisonous if swallowed. Irritant. Follow safety directions. • Avoid contact with desirable plants.
Triclopyr (600 g/L)	All	***Cut stump*** 2 L/60 L diesel	Agricultural non-crop areas, commercial and industrial areas, forests, pastures, rights of way Additional uses under permit: • PER84775 (Tas only) non-crop, bushland	• Poisonous if swallowed. Irritant. Follow safety directions. • Avoid contact with desirable plants.

Triclopyr (240 g/L) + picloram (120 g/L)	All	***Cut stump*** 1 L/60 L diesel	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures and rights of way Additional uses under permit: • PER84775 (Tas only) non-crop and bushland • PER13333 (WA only) agricultural non-crop areas, non-crop areas, commercial and industrial areas, wetlands, bushlands, forests	• Treat all stems on multi-stem plants. • Harmful is swallowed. Irritant. Follow safety directions. • Avoid foliage and soil contact with desirable plants. Can spread to and damage desirable plants where intertwined with roots of target plant. • Picloram remains active in the soil for extended periods and may leach into groundwater. • The localised regeneration or establishment of sensitive species may be adversely affected by soil residues.
Aminopyralid (4.47 g/L) + picloram (44.7 g/L) gel product	All	***Cut stump/stems*** Small plants immediately apply a 3–5-mm layer to cut stems within 10 cm of ground. ***Frilling*** Cut 15–20 mm deep around main trunk every 20–40 mm. Immediately apply a 5 mm layer at the base of the cut.	Non-crop areas, including native vegetation, conservation areas, gullies, reserves, parks	• Treat at least 80% of stems on multi-stem plants, including all main stems. • Possible irritant. Follow safety directions. • Not for use in home gardens, turf or lawns. • Avoid foliage and soil contact with desirable plants. Can spread to and damage desirable plants where intertwined with roots of target plant. • Picloram and aminopyralid can remain active in the soil for extended periods and may leach into groundwater. • The localised regeneration or establishment of sensitive species may be adversely affected by soil residues.
Aminocyclo-pyrachlor (240 g/L)	All	***Trunk injection/frilling*** 0.5 mL (undiluted) per cut Inject or apply into cuts every 50 mm around the diameter of the stem.	Native conservation areas, pastoral grazing land, industrial sites such as railways, roadways and utility rights-of-way	• Manufacturer advises that 'pastoral grazing land' is equivalent to 'pastures' (Envu 2022). • Follow safety directions. • May injure or kill crops and other desirable vegetation. Certain trees, shrubs, legumes are susceptible to very low doses. May suppress or severely injure certain established grasses. • Aminocyclopyrachlor in soil can be taken up by plant roots. Beware of contaminating irrigation water. Follow label directions. • Nil mandatory withholding period for grazing pastures. However, certain export markets may have restrictions. Hay and manure management requirements. Consult the product label.

[a] Products may be registered for use on African boxthorn in all states and territories (shown as 'All') or only in the specific states and territories listed. Further, additional uses not on the label may be allowed under permit, for specified states or territories. Where a state or territory is not listed on the label and there is no applicable permit, use as specified on the label for use in the same situation may still be allowed under jurisdictional legislation, where considered low risk—refer to Section 5.2.1.

[b] Products containing different concentrations of the active ingredients. Check the label or permit for rates.

[d] Certain products only registered for this use in specific states or territories.

Table C Herbicides registered and permitted for basal bark treatment of African boxthorn (as at July 2022).

Basal Bark

- Paint or spray herbicide mixture from ground level to 400 mm up stem.
- Plants should be actively growing and not under stress.
- For boxthorn plants with stems up to 50 mm in diameter.

Herbicide	State or territory[a]	Application	Situations in which the herbicide can be used on African boxthorn	Comments
Triclopyr (50 g/L)	All	***Basal bark method*** 100 mL/250 mL kerosene	Home garden	• Poisonous if swallowed. Irritant. Follow safety directions. • Avoid contact with desirable plants.
Triclopyr (600 g/L)	All	***Basal bark method*** 2 L/60 L diesel	Agricultural non-crop areas, commercial and industrial areas, forests, pastures, rights of way	• Do not apply to wet stems as this can repel the diesel mixture. • Poisonous if swallowed. Irritant. Follow safety directions. • Avoid contact with desirable plants.
Triclopyr (240 g/L) + picloram (120 g/L)	All	***Basal bark method*** 1 L/60 L diesel	Agricultural non-crop areas, commercial and industrial areas, fence lines, forestry, pastures, rights of way Additional uses under permit: • PER13333 (WA only) agricultural non-crop areas, non-crop areas, commercial and industrial areas, wetlands, bushlands, forests	• Harmful is swallowed. Irritant. Follow safety directions. • Treat all stems on multi-stem plants. • Avoid foliage and soil contact with desirable plants. Can spread to and damage desirable plants where intertwined with roots of target plant. • Picloram remains active in the soil for extended periods and may leach into groundwater. • The localised regeneration or establishment of sensitive species may be adversely affected by soil residues.

[a] Products may be registered for use on African boxthorn in all states and territories (shown as 'All') or only in the specific states and territories listed. Further, additional uses not on the label may be allowed under permit, for specified states or territories. Where a state or territory is not listed on the label and there is no applicable permit, use as specified on the label for use in the same situation may still be allowed under jurisdictional legislation, where considered low risk—refer to Section 5.2.1.

Table D Herbicides registered and permitted for soil–root zone application of African boxthorn (as at July 2022).

Soil–root zone • Carefully follow label directions to limit risk of spread to non-target plants.				
Herbicide	**State or territory[a]**	**Application**	**Situations in which the herbicide can be used on African boxthorn**	**Comments**
Hexazinone (250 g/L)	All	***Ground spot application*** 4 mL per spot. One spot for each metre in height. Apply between stem and drip line, evenly spaced around the plant. ***Grid pattern spot application*** 1 mL per spot for bushes up to 1 m tall, where plants occur <1 m apart. Treat on 1 × 1 m grid pattern. 4 mL per spot for bushes 1–3 m tall, where plants <2 m apart. Treat on a 2 × 2 m grid pattern.	Around agricultural buildings, in pasture situations	• Bushes/trees up to 3 m tall, in active growth. • Moist soil at application or sufficient rainfall after treatment to promote root absorption. • Irritant. Follow safety directions. • Warning—product may kill many trees and other desirable plants if not correctly applied. Follow label directions.
Picloram (20 g/kg)	Qld, SA, Vic, WA	***Granular application*** 35–45 g/m^2	Grazing pastures, forests, rights of way Additional uses under permit: • PER13333 (WA only) Allows rate of 50 g/m^2 in agricultural non-crop areas, non-crop areas, commercial and industrial areas, bushlands, forests	• Treat before growth begins or during vigorous growth, when good rainfall can be expected. Rainfall is required to move the herbicide into the root zone. • Do not apply when plants are stressed (and not actively growing). • Sprinkle granules evenly around base of plant extending out to 30 cm outside the drip line. • Can be thrown over the top of the bush taking care to obtain even distribution. • Use the higher rate on larger bushes. Also on very sandy, gravelly or rocky soil and where very high rainfall is usual. • Irritant. Follow safety directions. • Wide range of susceptible crops, including legumes, cotton, ornamentals, shade trees, pines, vegetables and vines. Avoid dust drift and do not apply close to roots of desirable vegetation. Planting restrictions apply. Will kill pasture legumes, including medics and clovers. • May spread via surface water runoff or erosion of treated soil. • Remains active in the soil for extended periods and may leach into groundwater. • The localised regeneration or establishment of sensitive species may be adversely affected by soil residues.

Tebuthiuron [b]	NSW, NT, Qld, WA (SA) (Vic)	***Granular application*** Follow label directions for application rate.	Grazing lands	• Can be applied at any time of year. However, rainfall is required to move the herbicide into the root zone. • Sprinkle granules evenly around base of plant extending out to 30 cm outside the drip line. • Harmful if swallowed. Irritant. Follow safety directions. • Do not allow any roots of desirable plants, trees or ornamentals to come into contact with the herbicide. In NSW may not use within 30 m of trees. • May spread via surface water runoff or erosion of treated soil. • Remains active in the soil for extended periods and may leach into groundwater. • The localised regeneration or establishment of sensitive species may be adversely affected by soil residues. • Higher rates of application may damage or kill grasses and pasture legumes. • Field crops cannot be grown within 5 years of application.
	SA, Vic (limited users)	***Granular application*** Follow permit directions for application rate.	Additional uses under permit: • PER87341 (SA only, specified persons only) non-crop areas including native vegetation • PER86406 (SA and Vic only, specified persons only) non-crop areas, domestic and public service areas, commercial and industrial areas, bushland/native forests, roadsides, rights of way, vacant lots, wastelands	

[a] Products may be registered for use on African boxthorn in all states and territories (shown as 'All') or only in the specific states and territories listed. Further, additional uses not on the label may be allowed under permit, for specified states or territories. Where a state or territory is not listed on the label and there is no applicable permit, use as specified on the label for use in the same situation may still be allowed under jurisdictional legislation, where considered low risk—refer to Section 5.2.1.

[b] Products containing different concentrations of the active ingredients. Check the label or permit for rates.

5.3 Chemical and chainsaw use training certification

Chemical users may be required to have training and certification to apply certain herbicides and/or to apply them in a commercial context. The situation varies among Australian states and territories; hence, when planning African boxthorn management, you should seek advice from your state's or territory's relevant agency.

Before on-the-ground work commences, project managers should ensure that staff and contractors involved in the application of herbicides have the required training and qualifications.

Also, project managers should ensure that people using chainsaws have the required training, experience and PPE. Chainsaw users may be required to undertake training and certification depending on the state or territory in which they are operating. It is recommended that you contact your relevant state or territory government department for advice.

Contact details for relevant state and territory departments are provided in Section 5.5.

5.4 Regulations and permits for works in riparian lands

Some states and territories have regulations and/or require permits for works in riparian lands. Riparian lands are those that adjoin, directly influence or are influenced by a body of water at any time of the year (Department of Primary Industries, Parks, Water and Environment, 2013).

As the situation varies among Australian states and territories, when planning to control African boxthorn that is in or influencing riparian lands, you should seek advice from your state's or territory's relevant agency.

5.5 Government contacts for weed control information

National	Australian Pesticides and Veterinary Medicines Authority	02 6770 2300	enquiries@apvma.gov.au	www.apvma.gov.au
ACT	ACT Parks & Conservation Service	13 22 81	ACTBiosecurity@act.gov.au	www.environment.act.gov.au/parks-conservation/plants-and-animals/Biosecurity/invasive-plants
NSW	Department of Primary Industries	1800 680 244	weeds@dpi.nsw.gov.au	www.dpi.nsw.gov.au/biosecurity/weeds
NT	Department of Environment, Parks and Water Security	08 8999 4567	weedinfo@nt.gov.au	www.nt.gov.au/environment/weeds
Qld	Department of Agriculture and Fisheries	13 25 23	info@daf.qld.gov.au	www.daf.qld.gov.au/business-priorities/biosecurity/invasive-plants-animals/plants-weeds
SA	Department of Primary Industries and Regions	08 8303 9620	invasivespecies@sa.gov.au	www.pir.sa.gov.au/biosecurity/weeds
TAS	Department of Natural Resources and Environment Tasmania	1300 368 550	biosecurity.tasmania@nre.tas.gov.au	www.nre.tas.gov.au/invasive-species/weeds
Vic	Agriculture Victoria	13 61 86	Refer to www.agriculture.vic.gov.au for contact options	www.agriculture.vic.gov.au/biosecurity/weeds
WA	Department of Primary Industries and Regional Development	08 9368 3333	enquiries@agric.wa.gov.au	www.agric.wa.gov.au/pests-weeds-diseases/weeds

5.6 National core attributes for weed mapping

Consistent mapping of African boxthorn across the nation is an essential component of establishing and maintaining a greater national understanding of distribution and management of the weed.

In 2006 the Australian Government (Bureau of Rural Sciences) published *A Field Manual for Surveying and Mapping Nationally Significant Weeds* (McNaught et al., 2013). This can be downloaded from https://weeds.org.au/wp-content/uploads/2020/04/Weeds_Manual.pdf. The WoNS mandatory and optional core mapping attributes (mapping features to be recorded consistently at a national level) taken from this manual are provided below.

Mandatory and optional core mapping attributes for Weeds of National Significance

	ATTRIBUTE	DESCRIPTION
1	Data record	Unique identifier for the site record. Allocated and maintained by the data custodian.
2	Name of weed	Common name, genus, species, sub-species, variety, hybrid. Any uncertainty on naming recorded in the 'comments' field.
3	Day/month/year	Collection/observation date or the date the survey commenced. Prefer DD-MON-YYYY; e.g. 12-DEC-2001 as this format is less error-prone than pure numeric dates.
4	Source of data	Name of collector or institution, identifies either personal contact details or the name of the institution from which the record is derived.
5	Purpose of visit	Reason/s site was chosen; e.g. to assess type and extent of WoNS prior to treatment or monitoring to determine effectiveness of management action after treatment.
6	Place name or locality	Plain language description of location; e.g. '10 km west of Bourke'. Provides a useful cross-check against specified geocode (latitude & longitude).
7	Latitude	Latitude in degrees, minutes and seconds. Prefer decimal degrees or Australian Map Grid coordinates with zone and datum noted—for GPS entries.
8	Longitude	Longitude in degrees, minutes and seconds; as for latitude.
9	Precision of latitude & longitude	Precision of measurement in its locating the site. Measured in metres. Records how the latitude and longitude were determined (GPS, topographic map or estimated).
10	Area	Area of the infestation measured in hectares. Area of the infestation defined by the outside boundary. For infestations measured by transect, indicate length of transect (in metres).
11	Cover/density	Measured by class intervals. Prefer data that records raw density as a percentage. For rapid survey density, data may be collected as classed data; e.g. 55–100% cover = dense. CLASS NO. — CLASS DESCRIPTIONS 1 — absent 2 — less than 1% 3 — 1% to 10% 4 — 11% to 50% 5 — greater than 50% 6 — present (density unknown) 7 — not known or uncertain 8 — not assessed
12	Treatment/s	Types/s of control or management. Management could include subcategories of mechanical, chemical, biological. No treatment should also be recorded.
13	Comments	Qualifications and factors likely to affect the adequacy of the record; e.g. inadequate time spent. Anecdotal observations of the sites or photograph/s.
14	*Core site number of records**	Number of records for the site or overlapping site. Records multiple sites spatially or multiple visits over time. May be left blank.
15	*Land use category**	Land use/s observed at the site according to agreed national classification. Select from Australian Land Use and Management Classification land use categories.

* Attributes 1–13 are mandatory core attributes. Attributes 14 and 15 (shown in italics) are optional core attributes.

REFERENCES

Jon Fallaw, PINP

REFERENCES

Adair, R. (2013). Feasibility of biological control of African boxthorn (*Lycium ferocissimum*). Unpublished report to Department of Primary Industries, Parks, Water and Environment, Tasmania. 61 p

Atlas of Living Australia (2013a). Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Lycium+australe [Accessed 25 November 2022].

Atlas of Living Australia (2013b). Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Bursaria+spinosa [Accessed 25 November 2022].

Atlas of Living Australia (2013c). Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Melicytus+dentatus [Accessed 25 November 2022].

Atlas of Living Australia (2013d). Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Scaevola+spinescens [Accessed 25 November 2022].

Atlas of Living Australia (2013e). Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Discaria+pubescens [Accessed 25 November 2022].

Atlas of Living Australia (2013f). Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Nitraria+billardierei [Accessed 25 November 2022].

Atlas of Living Australia (2022). Occurrence records map for *Lycium ferocissimum*. Australian Government, Canberra. [online] Available at: bie.ala.org.au/species/Lycium+ferocissimum [Accessed 25 November 2022].

Australian Pesticides and Veterinary Medicines Authority (2022). Public Chemical Registration Information System Search, Australian Pesticides and Veterinary Medicines Authority, Canberra. [online] Available at: www.apvma.gov.au/ [Accessed 25 November 2022].

Balnaves, J. and Gardiner, R. (2013). Face-to-face/telephone interview, 22 February 2013.

Blood, K. (2001). Environmental weeds: A field guide for SE Australia. CH Jerram & Associates—Science Publishers, Mt Waverley. 228 p.

Brothers, N., Pemberton, D., Pryor, H. and Halley, V. (2001). Tasmania's offshore islands: Seabirds and other natural features. Tasmanian Museum and Art Gallery, Hobart. 643 p.

Brougham, K.J., Cherry, H. and Downey, P.O. (eds) (2006). Boneseed Management Manual: current management and control options for boneseed (*Chrysanthemoides monilifera* ssp. *monilifera*) in Australia. Department of Environment and Conservation NSW, Sydney. 79 p.

Carlos, E.H., Weston, M.A. and Gibson, M. (2017). Avian responses to an emergent, wetland weed. *Austral Ecology* 42: pp. 277-287.

Chari, L.D., Mauda, E.V., Martin, G.D. and Raghu, S. (2020). Insect herbivores associated with *Lycium ferocissimum* (Solanaceae) in South Africa and their potential as biological control agents in Australia. *African Entomology* 28(2): pp. 359-373.

Choate, J. (1997). Plant species response to fire. Department of Environment and Natural Resources, Adelaide.

Cousens, R., Kennedy, D., Maguire, G. and Williams, K. (2013). Just how bad are coastal weeds? Assessing the geo-eco-psycho-socio-economic impacts. Rural Industries Research and Development Corporation, Canberra. 85 p.

Cowling, R.M., Richardson, D.M. and Paterson-Jones, C. (1995) Fynbos: South Africa's Unique Floral Kingdom. Fernwood Press, Vlaeberg, South Africa. 151 p.

CRC for Australian Weed Management (2007). Weed management guide—African boxthorn (*Lycium ferocissimum*). CRC for Australian Weed Management, Glen Osmond.

Department of Agriculture, Water and the Environment (2021). Final risk analysis report for the release of *Puccinia rapipes* for the biological control of *Lycium ferocissimum*. Australian Government Department of Agriculture, Water and the Environment, Canberra.

Department of Natural Resources and Environment Tasmania (2022a). African Boxthorn. Tasmanian Government. [online] Available at: nre.tas.gov.au/invasive-species/weeds/weeds-index/declared-weeds-index/african-boxthorn [Accessed 2 August 2022].

Department of Natural Resources and Environment Tasmania (2022b). Herbicides for African Boxthorn Control. Tasmanian Government. [online] Available at: nre.tas.gov.au/invasive-species/weeds/weeds-index/declared-weeds-index/african-boxthorn/african-boxthorn-herbicides-for-control [Accessed 3 August 2022].

Department of Primary Industries (2022). African boxthorn (*Lycium ferocissimum*). NSW Government. [online] Available at: weeds.dpi.nsw.gov.au/Weeds/AfricanBoxthorn [Accessed 2 August 2022].

Department of Primary Industries, Parks, Water and Environment (2013). Guidelines for safe and effective herbicide use near waterways. Department of Primary Industries, Parks, Water and Environment, Hobart. [pdf] Available at: nre.tas.gov.au/Documents/herbicide_guidelinesFINAL2012.pdf [Accessed 3 August 2022].

Department of Primary Industries and Regions (2022). African boxthorn *Lycium ferocissimum*. South Australian Government. [online] Available at pir.sa.gov.au/biosecurity/weeds/controlling-weeds/african_boxthorn [Accessed 3 August 2022].

Department of Primary Industries and Water (2006). National recovery plan for the orange-bellied parrot (*Neophema chrysogaster*). Department of Primary Industries and Water, Hobart.

DiTomaso, J.M. and Healy, E.A. (2007). Weeds of California and other western states—Volume 2. University of California, Oakland, USA. 1808 p.

Envu Australia & New Zealand. Email correspondence, October 2022.

Etherington, R. (2022). Tree Popper Australia. Email, 20 April 2022.

Fallaw, J. and Thomas, B. (2022). Phillip Island Nature Parks. Email correspondence, May 2022.

Gardiner, R., Murphy, M., Hazell, D., Barrott-Brown, G. and Mares, R. (2022). NSW NPWS. Email correspondence, April–May 2022.

Gilfillan, S., Mitchell, P., Newell, J., Danks, A. and Comer, S. (2009). South Coast threatened species & ecological communities regional strategic management plan. Department of Environment and Conservation, Albany. [pdf] Available at: southcoastnrm.com.au/wp-content/uploads/2021/07/SC_ThreatenedSpeciesRP.pdf [Accessed 3 August 2022]. 131 p.

Gooden, B. (2022). CSIRO. Email, 30 May 2022.

Gould, B. (2022). Murraylands and Riverland Landscape Board. Email, 13 May 2022.

Gouldthorpe, J. (2009). Weeds of National Significance gorse national best practice manual. Department of Primary Industries and Water, Hobart. 100 p.

Government of South Australia (2022). Declared plant policy—African boxthorn (*Lycium ferocissimum*). Government of South Australia, Adelaide. [pdf] Available at: www.pir.sa.gov.au/__data/assets/pdf_file/0005/137291/African_boxthorn_policy.pdf [Accessed 2 August 2022].

Gray, P.G., Joshua, E.M.K. and McCaffery, A.C. (2012). African boxthorn, 2012. Department of Primary Industries. [pdf] Available at: www.murrumbidgee.nsw.gov.au/documents/ENVIRONMENT/African-boxthorn-Primefact-654-2nd-Ed-Press-Quality-PDF.pdf [Accessed 2 August 2022].

Green, P.J. (2020). PJ Green Engineering. [online] Available at: www.boxthornpuller.com.au/boxthorn-puller [Accessed 9 June 2022].

Growcom (2022). Infopest AgVet Chemical Information Online. [online] Available at: www.infopest.com.au/ [Accessed April–May 2022].

Harris, S., Buchanan, A. and Connolly, A. (2001). One hundred islands: The flora of the outer Furneaux. Tasmanian Department of Primary Industries, Water and Environment, Hobart. 361 p.

Invasive Species Compendium (2013). CABI, Wallingford, UK. [online] Available at: https://www.cabidigitallibrary.org/product/QI [Accessed 25 November 2022].

Ireland, K.B., Hunter, G.C., Wood, A., Delaisse, C. and Morin, L. (2019). Evaluation of the rust fungus *Puccinia rapipes* for biological control of *Lycium ferocissimum* (African boxthorn) in Australia: Life cycle, taxonomy and pathogenicity. *Fungal Biology* 123: pp. 811-823.

Ireland, K.B., Rafter, M., Kumaran, N., Raghu, S. and Morin, L. (2019). Stakeholder survey reveals priorities for African boxthorn biocontrol research in Australia. *Biocontrol Science & Technology* 29: pp. 1123-1128.

Jobson, P. (2022). Northern Territory Government. Email, 22 May 2022.

Kennewell, M. and Simpson, G. (2013). Telephone communication, 24 May 2013.

Kirkpatrick, J.B. and Gilfedder, L.A. (1999). Tasmanian Bushcare Toolkit. Department of Primary Industries, Water and Environment, Hobart. 186 p.

Kriticos, D.J., Crossman, N.D., Ota, N. and Scott, J.K. (2010). Climate change and invasive plants in South Australia. Report for the South Australian Department of Water, Land and Biodiversity Conservation, CSIRO, Canberra. 92 p.

Kriticos, D.J., Ireland, K.B., Morin, L., Kumaran, N., Rafter, M.A., Ota, N. and Raghu, S. (2021). Integrating ecoclimatic niche modelling methods into classical biological control programmes. *Biological Control* 160(3): Article 104667.

Lawley, E.F., Lawley, J.J. and Page, B. (2005). Effects of African boxthorn removal on native vegetation and burrowing of short-tailed shearwaters on Althorpe Island, South Australia. *Transactions of the Royal Society of South Australia* 129(2): pp. 111-115.

Magnussen, C. (2011). Weed management guide—African boxthorn. Queensland Department of Agriculture, Fisheries and Forestry, Brisbane.

Martin, T.G., Campbell, S. and Grounds, S. (2006). Weeds of Australian rangelands. *The Rangeland Journal* 28: pp. 3-26.

McKenzie, R. (2012). Australia's poisonous plants, fungi and cyanobacteria. CSIRO Publishing, Collingwood. 960 p.

McKinnon, A. (2019). Western Local Land Services. Email, 16 May 2019.

McNaught, I., Thackaway, R., Brown, L. and Parsons, M. (2013). A field manual for surveying and mapping nationally significant weeds. Bureau of Rural Sciences, Canberra. [online] Available at: https://weeds.org.au/wp-content/uploads/2020/04/Weeds_Manual.pdf [Accessed 29 November 2022].

McTaggert, L., Gibson, E., Haebich, K. and Palmer, J. (2022). Meeting on boxthorn control by helicopter, 11 April 2022.

Miller, J.S., Levin, R.A. and Feliciano, N.M. (2008). A tale of two continents: Baker's rule and the maintenance of self incompatibility in *Lycium* (Solanaceae). *Evolution* 62: pp. 1052-1065.

Moritz, C. and Kikkawa, J. (1994). Conservation biology in Australia and Oceania. Surrey Beatty, Chipping Norton. 404 p.

Muyt, A. (2001). Bush invaders of south-east Australia. RG and FJ Richardson, Meredith. 304 p.

Noble, M. and Adair, R. (2014). African boxthorn (*Lycium ferocissimum*) and its vertebrate relationships in Australia. *Plant Protection Quarterly* 29: pp. 80-84.

Noble, M.R., Adair, R.J. and Ireland, K.B. (2021). Biology of invasive plants 2. *Lycium ferocissimum* Miers. *Invasive Plant Science & Management* 14: pp. 41-56.

Nogales, M., Delgado, J.D. and Medina, F.M. (1998). Shrikes, lizards and *Lycium intricatum* (Solanaceae) fruits: A case of indirect seed dispersal on an oceanic island (Alegranza, Canary Islands). *Journal of Ecology* 86: pp. 866-871.

NSW National Parks and Wildlife Service (2012). Draft plan of management—Oolambeyan National Park. NSW Office of Environment and Heritage, South Sydney.

Parsons, W.T. and Cuthbertson, E.G. (2004). Noxious weeds of Australia. Inkata Press, Melbourne. 698 p.

Phillip Island Nature Parks. (2018). Phillip Island Nature Parks Weed Management Strategy 2018-2023. Phillip Island Nature Parks. [pdf] Available at: www.penguins.org.au/assets/Conservation/Environment/PDF/PINP-Weed-Strategy-ONLINE.pdf [Accessed 3 August 2022].

Pobke, K. (2007). Draft recovery plan for 23 threatened flora taxa on Eyre Peninsula. Department of Environment and Heritage, Adelaide.

Podda, L., Santo, A., Puddu, S., Biagini, L. and Bacchetta, G. (2015). Germination ecophysiology of three invasive Solanaceae species in Sardinia (Italy). II International Plant Science Conference. 110th Congresso della Società Botanica Italiana. Pavia, Italy, September 14-17, 2015.

Priddel, D., Carlile, N. and Wheele, R. (2000). Eradication of European rabbits (*Oryctolagus cuniculus*) from Cabbage Tree Island, NSW, Australia, to protect the breeding habitat of Gould's petrel (*Pterodroma leucoptera leucoptera*). *Biological Conservation* 94: pp. 115-125.

Queensland Government (2021). African boxthorn *Lycium ferocissimum*. Department of Agriculture and Fisheries, Brisbane. [pdf] Available at: www.daf.qld.gov.au/__data/assets/pdf_file/0016/64042/african-boxthorn.pdf [Accessed 3 August 2022].

Quin, D. (1985). Observations on the diet of the southern brown bandicoot, *Isoodon obesulus* (Marsupialia: Peramelidae), in southern Tasmania. *Australian Mammalogy* 11:pp. 11-25.

Rafter, M. (2022). CSIRO. Email, 2 June 2022.

Roger, E., Laffan, W. and Ramp, D. (2007). Habitat selection by the common wombat (*Vombatus ursinus*) in disturbed environments: Implications for the conservation of a 'common' species. *Biological Conservation* 137: pp. 437-449.

Rutherford, M.C., Powrie, L.W. and Husted, L.B. (2012). Herbivore-driven land degradation: Consequences for plant diversity and soil in arid subtropical thicket in south-eastern Africa. *Land Degradation & Development* 25(6): pp. 541-553.

Shabani, F. (2002). Macquarie University, Sydney June 2022

Shepherd, R.C.H. (2004). Pretty but poisonous. RG and FJ Richardson, Melbourne. 202 p.

Spies, P. and March, N. (2004). Prickly acacia National Case Studies Manual. Department of Natural Resources, Mines and Energy, Brisbane. 97 p.

Stanley, M.C. and Lill, A. (2002). Avian fruit consumption and seed dispersal in a temperate Australian woodland. *Austral Ecology* 27(2): pp. 137-148.

Taylor, R.H. (1968). Introduced mammals and islands: priorities for conservation and research. *Proceedings of the New Zealand Ecological Society* 15: pp. 61-67.

Taylor, R.J. (1993). Observations on the behaviour and ecology of the common wombat *Vombatus ursinus* in northeast Tasmania. *Australian Mammalogy* 16: pp. 1-7.

Thorp, J.R. and Lynch, R. (2000). The determination of Weeds of National Significance. National Weeds Strategy Executive Committee, Launceston. 234 p.

Timmins, S.M. and Mackenzie, T.W. (1995). Weeds in New Zealand protected natural areas database. Department of Conservation, Wellington, New Zealand.

Turner, P. (2012). Email, 23 May 2012.

Vereijssen, J., Smith, G.R. and Weintraub, P.G. (2018). *Bactericera cockerelli* (Hemiptera: Triozidae) and *Candidatus Liberibacter solanacearum* in potatoes in New Zealand: Biology, Transmission, and Implications for Management. *Journal of Integrated Pest Management* 9: pp. 1-21.

Walker, R. (2013). Email via Sandy Lloyd, 8 May 2013.

Weston, J. (2012). Weed management to optimise seabird habitat in the Phillip Island Nature Park, in: Eighteenth Australasian Weeds Conference 2012, Council of Australasian Weed Societies Inc. [pdf] Available at: http://caws.org.nz/old-site/awc/2012/awc201211541.pdf [Accessed 29 November 2022].

Weston, J. (2013). Phone conversation, 22 January 2013.

Yen, A.L. (2013). Email, 6 June 2013.

Ziegler, K. and Hopkins, K. (2011). Furneaux Islands boxthorn control. Friends of Bass Strait Islands—Wildcare Tasmania, Hobart.

Ziegler, K. and Hopkins, K. (2022). Friends of Bass Strait Islands. Email correspondence, May–June 2022.