Weeds of National Significance

Managing Opuntioid Cacti in Australia

Best practice control manual for *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* species

Australian Government

Department of Primary Industries and Regional Development
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Primary Industries and Regions SA

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M.R. Sheehan and S. Potter

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Disclaimer:

This publication is intended to provide information only on the subject under review. It is not intended to provide, nor does it constitute, expert advice. Readers are warned against relying solely on the information herein. Further professional advice should be sought before acting on the information supplied in this manual.

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Cover images
FRONT: *Cylindropuntia pallida* – Sandy Lloyd; *Opuntia robusta* – Shauna Potter.
BACK: *Cylindropuntia fulgida* var. *mammillata* – Sandy Lloyd; *Opuntia sulphurea* (fruit) and *Opuntia tomentosa* (flowers) – Shauna Potter.

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WoNS management workshops

Workshops and field trips were held with professional weed managers, community volunteers and researchers in Western Australia, South Australia, Northern Territory, Victoria, New South Wales and Queensland in 2017. Contributions from over 200 dedicated opuntioid cacti managers provided valuable information on current management and control practices, much of which forms the basis of this manual. Many thanks to all who contributed.

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Foreword

The twenty-seven species of opuntioid cacti that are recognised as Weeds of National Significance are some of Australia's worst weeds. They grow over a wide climatic range and have impacted on pastoral and agricultural use of large tracts of land; pose an environmental risk to wildlife; and reduce aesthetic and recreational use, with direct impact on human safety.

Weedy infestations occur in all states and territories. Some are extensive, covering hundreds of thousands of hectares with a significant potential for range expansion.

Over time there has been a substantial effort by government, industry, landholders and community groups to manage opuntioid cacti. Whilst there are a number of valuable publications available on opuntioid cacti, to date there has been no consolidated management information for these weeds.

To address this need,the Western Australian Department of Primary Industries and Regional Development (DPIRD) and Biosecurity South Australia, lead the development of a comprehensive Opuntioid Cacti Management Manual.

This manual will increase the capacity of industry and land managers to effectively and efficiently manage these weeds. Funding provided by the Australian Government in 2016, through an initiative of the Agricultural Competitiveness White Paper, made this possible. With DPIRD leadership, a Cactus Reference Group was formed specifically to provide national input and ensure the collective knowledge of cacti in Australia was brought together. I thank the members for their input.

This manual brings together the current best practice information about existing management options for opuntioid cacti species and provides knowledge gathered from government, community groups and land managers across Australia about the ecology, identification, impacts and distribution of these species.

I recommend this manual to everyone who is interested in the effective management of opuntioid cacti. Reference to its contents will assist in the ongoing task of controlling these weeds and preventing their spread.

Kay Bailey, Chair, Cactus Reference Group

Approximately one tenth of our sheep grazing property became unproductive as a result of coral cactus (*Cylindropuntia fulgida* var. *mamillata*) establishment. We were forced to remove stock from approximately 1200 hectares to prevent the risk of further spread.

While cactus has had a significant impact on our livelihood, one of the biggest motivations for managing cacti, both on our property and adjacent lands, is to prevent it spreading to the Cooper Creek system, which drains into the Lake Eyre Basin. Coral cactus entering the basin would severely impact grazing and organic production in this iconic and ecologically significant area of Australia.

Many people are not aware that ALL cacti in Australia have been introduced, nor know the national threat posed by the thoughtless disposal of a pot plant of cacti. It is our responsibility as landholders to think beyond our property boundaries, both to protect our livelihood and also the ecology of our landscape.

We knew nothing about cacti management when we started in the 1970s and there were very few resources available to help. Consequently, we made many mistakes, yet through trial and error we have learnt that a long-term plan and a coordinated approach are critical. Best results can be achieved through integrated management. We currently use biological control, exclusion fencing and foliar spraying. Constant and vigilant follow-up and monitoring are essential for long-term success.

We learnt this the hard way, but now this manual provides tips and exposes the traps of cacti management. It provides a helping hand to develop a realistic management program and gives an insight into what you are in for, with case study accounts of other people's experiences. This manual will be an asset to any land manager dealing with cacti, and we recommend it.

Peter and Elizabeth Clark, Landholders, 'Leander', central west Queensland
Read more of Peter and Elizabeth's story on page 134.

Contents

Contents

Using this manual

Who should use this manual?

This manual has been written to assist anyone with an interest in managing opuntioid cacti, from site managers, community groups, private landholders and volunteers to government agency staff. This manual is intended to help people make decisions about opuntioid cacti management by providing a guide based on current knowledge and understanding of best practice.

Where does the information come from?

The information in this manual has been sourced from published material, existing research, reviews by technical experts and the experiences of individuals and organisations currently managing opuntioid cacti in Australia and internationally. It also incorporates the outcomes from a series of workshops held throughout Australia in 2017 with those directly involved in cacti management.

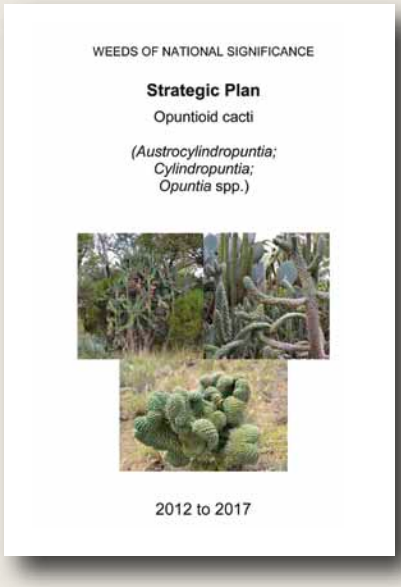
Over 200 participants, representing landholders, state and local government weeds officers, utilities, scientists, and agricultural, environmental and natural resource management professionals, took part in the workshops, sharing what they know and don't know about opuntioid cacti and their management.

While this manual aims to provide a synthesis of the most current information on best practice management of opuntioid cacti, it is acknowledged that our understanding of the 27 cacti species covered here, and our experience in managing many of them in Australia, is incomplete. Our understanding of cacti and our approach to management is expected to evolve in the future as research unfolds and the experiences of land managers increase. The planning chapter of this manual (pages 49–62) emphasises the importance of documenting and monitoring cacti management efforts to allow assessment, adaptation and improvement of what we currently consider to be best practice management.

Opuntioid cacti management: a national approach

The National Opuntioid Cacti Strategic Plan (2012–2017) was developed under the Australian Weeds Strategy as part of the Weeds of National Significance (WoNS) initiative. This Plan provides a framework to prevent the spread and reduce the impacts of the 27 WoNS-listed opuntioid cacti species. Implementation of the Plan by all stakeholders nationally will allow for better protection of priority assets through the provision of tools and information, identifying management priorities, and fostering partnerships that lead to more strategic, collaborative management. Development of this manual fulfils an important action of the Plan by providing tools and information to inform management options for opuntioid cacti.

The Plan is available at: http://weeds.ala.org.au/WoNS/opuntioidcacti/, together with a range of management and identification resources.



Using this manual

How to use this manual

This manual has been designed to allow easy access to information and provide the necessary tools and knowledge to successfully manage opuntioid cacti. Arranged in six stand-alone yet complementary chapters, the manual presents a guide, from understanding and identifying cacti, through to developing and implementing a strategic approach to their management.

It is important that the information provided in this manual is adapted by individuals to reflect their own environmental, financial and social circumstances. To increase the usability of this manual and enable it to be applied to different situations, the following tools and features have been provided:

- A quick look-up index to cross-reference botanical and common names of each of the 27 WoNS opuntioid species;
- Checklist and summaries of key steps and considerations for planning and management purposes;
- A decision support tool for selecting an appropriate management approach and treatment technique;
- Useful templates and links to external resources; and
- A glossary of key terms and abbreviations.

Summary of the six chapters

1. BIOLOGY AND THREAT
- What are opuntioid cacti and why are they a problem?
- What do they look like?
- How do they spread?

2. PLANNING
- Why is planning important?
- How do I prioritise areas for control?
- How do I develop a cacti management plan?

3. SAFETY AND WELFARE
- What risks do cacti pose?
- How do I avoid, manage and treat injury?
- How do I identify and assess risk?

4. MANAGING CACTI
- Which management methods are best for my situation?
- How should I integrate management methods?
- How can I get the best results?

5. CASE STUDIES
- What are other land managers doing?
- What has been tried on hard-to-access land?
- Examples of how the information in this manual can be used in practice.

6. FURTHER INFORMATION
- What is my legal obligation to manage opuntioid cacti?
- Who can I contact if I need more help?
- What other information is available?
- What do terms used in the manual mean?

Chapter 1

Biology and threat

Understanding opuntioid cacti

Cacti is a collective term for a diverse range of species belonging to the Cactaceae family. There are between 1500 and 2000 species (Rojas-Arechiga and Vazquez-Yanes, 2000) and all but one species (*Rhipsalis baccifera*) are native to the Americas (Anderson, 2001). Australia does not have any native cacti.

All cacti are **succulents** – a term given to plants that use modified tissues to store water, enabling survival during periods of drought. However, not all succulents are cacti!

Cacti are distinguished from other succulents by the presence of **areoles**, the point from which new shoots, spines, glochids, flowers, fruit and roots can grow. Areoles are cushion-like bumps that occur on the surface of segments and fruit of opuntioid cacti.

Opuntioid cacti in Australia – what have we got?

Of the 15 opuntioid genera that occur worldwide, only four genera (and approximately 21 species) are known to have naturalised in Australia. Infestations occur in all states and territories.

This manual focuses on the 27 opuntioid cacti species listed as Weeds of National Significance (WoNS) in Australia. Several other species of cacti and succulents have become weedy in Australia but are not specifically addressed in this manual. Many of the principles and techniques for their control, however, will be similar to those for the WoNS listed species.

A complete list of the opuntioid cacti WoNS species can be found in Table 1.2 on page 7.

Shauna Potter

Fruit and new cladodes arise from areoles of Opuntia elata – note the small brown spots on the fruit are also areoles

Shauna Potter

Spines emerging from a Cylindropuntia imbricata areole

Shauna Potter

Glochids and flower buds on Opuntia robusta fruit

What are opuntioid cacti?

Opuntioid cacti are a group forming one of the sub-families of the Cactaceae family – sub-family Opuntioideae. Cacti from the Opuntioideae sub-family are commonly referred to as opuntioid cacti or opuntioids. There are up to 350 species of opuntioid cacti worldwide (Griffith and Porter, 2009).

Opuntioid cacti are set apart from other Cactaceae sub-families by the presence of **glochids** – small, detachable, barbed bristles that are found in the plant's areoles. Glochids detach readily by disturbance such as wind or touch, often causing irritation to skin, eyes and lungs (see Chapter 3). Some species, such as *Opuntia microdasys*, have numerous glochids giving the plants a distinct, furry appearance, while *Austrocylindropuntia* species have very few.

The structure of the Cactaceae family as it relates to opuntioid cacti is shown in Figure 1.1 and a complete list of opuntioid species that have naturalised in Australia is provided in Table 1.2.

Shauna Potter

Opuntia microdasys areoles covered in golden glochids

What's in a name?

'Opuntioid cacti' or 'opuntioids' are terms used to describe cacti species in the opuntioid sub-family. This manual focuses on species from the *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* genera.

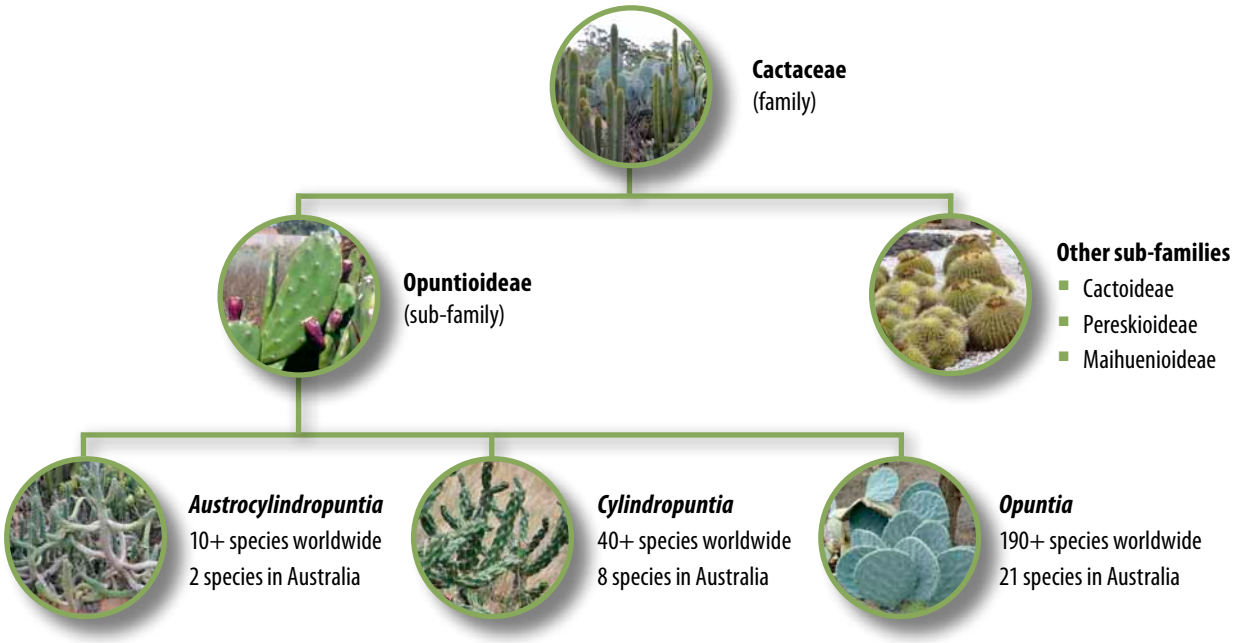


Figure 1.1 The Cactaceae family tree, focusing on the Opuntioideae sub-family and the number of species of opuntioid cacti naturalised in Australia

You say 'cladode', I say 'stem segment', they say 'pad'

In Australia, the stems of opuntioid cacti are known by several names – cladodes, stem segments or pads (commonly applied to *Opuntia* species).

These terms are used interchangeability throughout this manual.

In addition to the presence of glochids, opuntioid cacti are characterised by:

- Jointed cladodes. At the end of each growing season cladodes stop developing and the next season's growth starts with new segments and flowers arising from the areoles of the old ones.
- Seeds that have a hard, pale sheath called an **aril**. Most other cacti have shiny black seeds.

Opuntioid cacti are long lived (greater than 10 years) and have adapted to arid environments through the use of an evolved form of photosynthesis known as Crassulacean Acid Metabolism (CAM). This allows the plant's **stomata** (pores) to close during the day, reducing moisture loss. Gas exchange then occurs when the stomata re-open during cooler night hours.

Opuntioid cacti – what makes them unique?

- **Glochids** Glochids are small hair-like bristles that grow from areoles.
- **Jointed cladodes** Jointed cladodes are a common characteristic of opuntioid cacti. A joint occurs at the areole, where new cladodes emerge during the growing season. Over time, as more cladodes form a segmented stem is formed. Cladodes can break off at the joint and grow into new plants. Cladodes are commonly cylindrical or flattened.
- **Seeds** While most cacti seeds are black, opuntioid cacti seeds have a hard, pale coat called an aril.

Greg Patrick

Numerous glochids on Opuntia engelmannii cladodes (pads)

Shauna Potter

Shauna Potter

Jointed cladodes of Opuntia (above) and Cylindropuntia species

Shauna Potter

Opuntia cacti seeds, showing the hard, pale aril

Biology and threat

What are succulents?

Succulents are plants (including opuntioid cacti) that have evolved to cope with dry conditions through the use of water storage tissues in the form of thickened, fleshy or swollen stems, roots and leaves.

Other features that allow succulents to reduce water loss and thrive in dry conditions include:

- Waxy, spiny or hairy surfaces;
- Growth that is reduced or cylindrical, cushion-like or columnar;
- Small, absent or cylindrical-shaped leaves;
- Crassulacean Acid Metabolism (CAM) (see page 3 for further information).

Examples of succulents include agaves, aloes, *Carpobrotus* (pig faces), euphorbias, *Mesembryanthemum* (ice plants) and yuccas.

In Australia invasive succulents are often found growing with opuntioid cacti. It is worth noting that while there are no native cacti, there are some native succulents.

Rob Richardson

The succulent shrub Aloe arborescens (tree aloe)

Rob Richardson

The succulent herb Carpobrotus aequilaterus (Chilean pig face)

Where do they come from?

Cacti have a wide distribution and are found throughout the Americas, from southern Chile and Argentina north through to Canada (Nobel, 2002).

The Opuntioideae sub-family is thought to have originated from west-central South America (Griffith and Porter, 2009), with its native distribution later extending throughout the arid and semi-arid zones of South and North America (Snyman, 2013).

Many opuntioid species have naturalised throughout the Mediterranean, South Africa and Australia, and in some instances cacti are considered weedy in their native range, where human disturbance has aided vegetative spread, resulting in competition with other native species (Anderson, 2001).

The introduction of cacti to Australia

The introduction of unknown *Opuntia* species, recorded as 'prickly pear', was attributed to Governor Phillip at Port Jackson in 1788. The intent of introduction is thought to have been to establish a cochineal industry for dying the distinctive red coats worn by British soldiers. Multiple introductions of different species followed and evidence suggests that *Opuntia stricta* plants were growing in cultivation at Parramatta prior to 1840, and had spread to Chinchilla in Queensland by 1843.

As settlements expanded, so too did opuntioid cacti. One of Australia's best known invasive weeds is *Opuntia stricta*, which covered 240,000 km² before the introduction of *Cactoblastis cactorum*, a highly successful biological control agent, in 1926. The case study on page 109 provides further information.

Many species, particularly *Cylindropuntia* species, were planted around mining leases and tenements, presumably to prevent intruders. Many other cacti, deliberately introduced for ornamental and culinary purposes, subsequently became weeds by escaping gardens and through dumping on roadsides and in bushland.

Shauna Potter

Opuntia microdasys growing around an old homestead, Flinders Ranges SA – opuntioid cacti are also often found in suburban and country gardens

Where do they grow?

Naturalised (weedy) populations of opuntioid cacti exist in all states and territories (Figure 1.2), and collectively have the capability to establish in the majority of soil types and climatic zones throughout Australia.

Naturalised populations of cacti are commonly associated with urban gardens, old homesteads and peri-urban areas, where the ornamental value of these plants remains important. Mining areas, where cacti were historically used to delimit and secure leaseholds, and dumping sites for garden and household refuse, are also hotspots. From these point sources, cacti have invaded grazing land, range lands, pastures, as well as native vegetation, from coastal systems to open grassland and woodlands, roadsides, gardens and recreational reserves. They also commonly occur along water courses and floodplains.

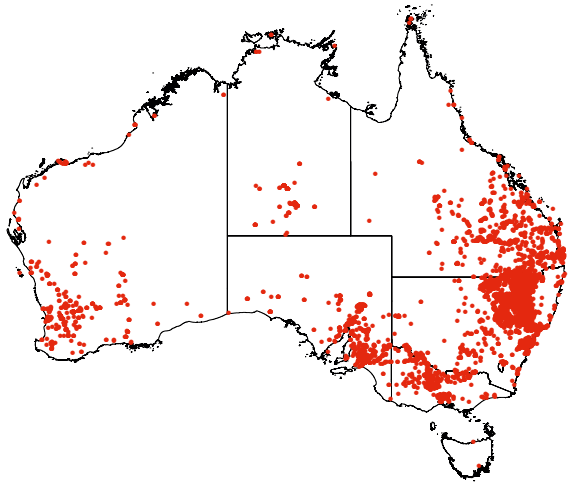


Figure 1.2 Records of naturalised occurrences of all 27 WoNS-listed opuntioid cacti species (•), demonstrating the range of soil types, climates and habitats in which they can establish

Table 1.1 Generalised growth and treatment calendar for all opuntioid cacti species across Australia

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering												
Fruiting												
Germination												
Vegetative regrowth												
Optimal treatment time	**General tips:** Treat weeds when they are young. Wear appropriate PPE (personal protective equipment) when working in dry conditions to avoid glochid injury. **Chemical control:** Treat weeds when actively growing and as per label. **Mechanical removal:** Avoid working in wet conditions to minimise weed spread. **Hand removal:** This works best when soils are moist. **Biological control:** These should be released between August and May.											

general growth period

growth under suitable conditions

Biology and threat

Shauna Potter

Cacti featured as waterwise plants in botanic gardens

Gaps exist in our understanding of cacti distribution throughout Australia, but as our awareness of the impacts improves, so does reporting of infestations. This in turn enhances what we know of habitat suitability (including climate) and where opuntioid cacti can grow. Habitat suitability models are currently being developed for all opuntioid cacti species and will be available at www.weedfutures.net in the near future.

Non-opuntioid cacti

Non-opuntioid cacti and other succulents have also become weedy in some parts of Australia. While these are not WoNS species or necessarily declared weeds in all states and territories, many occur in association with opuntioid cacti and present a similar risk to agriculture, the environment and community values, and are spread by similar means. While key species will be briefly described, management of non-opuntioids is not covered in this manual, so seek advice from your local weed officer about control options.

Naming opuntioid cacti (nomenclature)

Using common names for opuntioid cacti can be very confusing, as many species have multiple common names and are referred to by different names in different regions. Also, the same common name can refer to a number of species. For example, the general term prickly pear is used to describe over ten *Opuntia* species.

To avoid confusion, scientific names are used for all species throughout this manual.

This manual focuses on the 27 species that are listed as Weeds of National Significance (WoNS), and are included in Table 1.2.

How opuntioid cacti spread

Opuntioid cacti can reproduce in two ways; by seed (sexual) or by vegetative means (such as rooting of cladodes, fruit or flowers), so long as the plant material has areoles. Not all opuntioid cacti produce seed (or viable seed) in Australia, however, all species can reproduce, and spread, vegetatively.

Austrocylindropuntia species and *Cylindropuntia* species are mainly spread vegetatively. Cladodes of many *Cylindropuntia* (and *Opuntia* species such as *O. aurantiaca*) break off easily and are moved about by people, animals, vehicles and machinery, water and gravity. *Opuntia* species are more commonly spread by seed, although vegetative spread, by cladodes falling from parent plant or being transported in a waterway, is also possible.

Seed (sexual reproduction)

The fleshy, brightly coloured fruit of many *Opuntia* species provides an attractive food source and is eaten by birds, reptiles and mammals. Species known to eat opuntioid cacti fruit are included in Table 1.3 on page 11. The impacts, if any, on the health of animals eating cacti fruit are unclear.

Table 1.2 Scientific and common names of opuntioid cacti that have naturalised in Australia

Scientific name	Common names
Austrocylindropuntia cylindrica	Cane cactus
Austrocylindropuntia subulata	Eve's needle cactus
Corynopuntia* sp.	–
Cylindropuntia fulgida* var. *mamillata	**Coral cactus**, boxing glove cactus
Cylindropuntia imbricata	**Devil's rope**, rope pear
Cylindropuntia kleiniae	Klein's cholla
Cylindropuntia leptocaulis	Pencil cactus
Cylindropuntia pallida (syn. *C. rosea*)	White-spined Hudson pear
Cylindropuntia prolifera	Jumping cholla
Cylindropuntia spinosior	Snake cactus
Cylindropuntia tunicata	Brown-spined Hudson pear
Opuntia aurantiaca	Tiger pear
Opuntia dejecta*	–
Opuntia elata (syn. *O. paraguayensis*)	Riverina pear
Opuntia elatior	Red-flower prickly pear
Opuntia engelmannii	Engelmann's prickly pear
Opuntia ficus-indica*	Indian fig
Opuntia humifusa	–
Opuntia leucotricha	–
Opuntia microdasys	**Bunny ears**, golden bristle cactus, teddy bear cactus
Opuntia* sp. aff. *microdasys	–
Opuntia monacantha (syn. *O. vulgaris*)	Drooping tree pear
Opuntia* aff. *polyacantha	–
Opuntia puberula	–
Opuntia robusta	Wheel cactus
Opuntia schickendantzii	Chicken dance cactus
Opuntia streptacantha	**Westwood pear**, Cardona pear, Gracemere pear
Opuntia stricta* var. *stricta and **var. *dillenii***	Common prickly pear
Opuntia sulphurea	–
Opuntia tomentosa	**Velvet tree pear**, velvety tree pear

* Not a WoNS listed species

Bold denotes the most widely accepted common name where more than one name is used in Australia

Biology and threat

Seed germination in Australia often occurs following heavy rain events, and is staggered such that it may occur over many years. This is consistent with research that suggests seed coats have a dormancy factor that is triggered or removed after long periods of soaking (Chinnock, 2015; Rojas-Arechiga and Vazquez-Yanes, 2000).

Opuntia robusta, *O. stricta* and *O. monacantha* plants grown from seed do not develop flowers until they are three years old (Parsons and Cuthbertson, 2001) and field observations suggest that this may be true for other seed-producing opuntioids as well. It is not known how long seeds remain viable, however expert opinion suggests a period of 10–20 years is possible in Australian conditions.

This information is important when planning management programs and the frequency and timing of follow-up work.

Matt Sheehan

Opuntia tomentosa seedling emerges

Matt Sheehan

Seed of Opuntia robusta still evident in emu droppings, Burra SA

The importance of hygiene

Because opuntioid cacti are so well adapted to spread, it is important to remain vigilant when undertaking management activities. Species that are especially well adapted to vegetative spread, such as *Cylindropuntia prolifera* and *Opuntia aurantiaca*, are easily moved around on clothing, backpacks, machinery, even shoe laces, without detection.

Chapter 4 (pages 78–79) has further information on hygiene measures.

Matt Sheehan

Opuntia robusta plants growing under mature trees, likely a result of 'seed rain' from birds that perched in trees overhead, central Vic

Vegetative (asexual reproduction)

The arid environments that opuntioid cacti are often found in experience low rainfall and extreme temperatures – features not conducive to seedling germination. The ability of many opuntioid cacti to reproduce vegetatively (or without seed) is an adaptation to the arid climates from which many originate (Bobich, 2005).

All opuntioid cacti can spread vegetatively from cladodes, fruit (including those that are green and not fully ripened) and flowers. Once contact has been made with the soil, roots will develop from

the areoles within weeks. Following this, new stems will emerge from the areoles on the upper side of the vegetative material (Chinnock, 2015).

In Australia, opuntioid cacti species with easily detachable cladodes (e.g. *Cylindropuntia prolifera*, *C. fulgida* var. *mamillata*, *Opuntia aurantiaca*) are spread primarily (or solely) by vegetative means. In fact, many of these species do not produce seed (or viable seed) (Chinnock, 2015). Opuntioid cacti are considered long-lived plants (Parsons and Cuthbertson, 2001), typically surviving upward of 10 years. Research indicates that some opuntioid cacti species reproduce vegetatively throughout their lives, regardless of age.

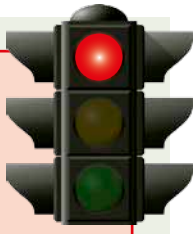
The spiny cladodes of opuntioid cacti are perfectly suited to vegetative spread, readily attaching to animals, machinery, vehicles and humans.

Confident or cautious about cacti knowledge?

Anyone who has sought out information on opuntioid cacti will know it can be hard to come by, especially examples relevant to Australia. Much of the research on biology relates to species and sites from the Americas.

Whilst we can extrapolate some useful data for Australian purposes, it's important to remember that opuntioid cacti species found in Australia differ from their northern hemisphere counterparts. For example, *Cylindropuntia fulgida* var. *mamillata* is not known to produce seed in Australia, yet it does in southern USA (Bobich, 2005; Chinnock, 2015).

Australian cacti managers provide a wealth of knowledge based on their observations in the field. Many of these observations are captured in Figure 1.3, including current knowledge gaps.

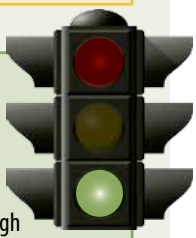


CONFIDENCE IS LOW – knowledge gap

- Seed dormancy, or germination triggers such as light.
- Whether death of mature cacti triggers mass germination events.
- Impact of fire on seeds (either as a trigger for germination or destruction).
- How long seeds of specific species remain viable.
- Seed bank dynamics.
- The role, if any, insects such as ants play in seed spread (this has been documented for northern hemisphere *Opuntias*).
- Whether ingestion of fruit has negative impacts on stock/wildlife.

CONFIDENCE IS MODERATE

- Seed is probably spread by soil movement (e.g. on car tyres, shoes).
- The role of disturbance factors, such as fire, land clearance and machinery, on germination.
- Temperature requirements for germination (20–25°C is suggested as optimum) (Noble, 1988).
- Seeds may take several months to germinate (Rojas-Arechiga and Vazquez-Yanes, 2000).



CONFIDENCE IS HIGH

- Seed is spread via humans, birds, animals and water (e.g. flood events).
- Seeds remain viable after passage though most animal guts.
- Soaking rains trigger germination (particularly when coupled with warm summer temperatures) (Chinnock, 2015).

Figure 1.3 Knowledge on opuntioid cacti spread mechanisms in Australia, and the associated level of confidence

Biology and threat

Matt Sheehan

Small, readily detachable Cylindropuntia fulgida var. mamillata cladodes – they can be very difficult to detect, particularly when amongst other vegetation

Shauna Potter

Cylindropuntia tunicata cladodes found on car tyres after driving through a lightly infested area

Shauna Potter

Extremely sharp spines of Cylindropuntia tunicata easily penetrate leather boots – another spread vector

The fleshy and bouyant properties of cacti also make them suited to spread by water. Some species, such as *Cylindropuntia fulgida* var. *mamillata*, produce cladodes so small and lightweight that wind can spread them short distances.

As succulents, opuntioid cacti store water within their stems. This allows the cladode to remain alive for extended periods out of the soil. Cladodes have been reported as taking root and growing new segments following five years of being kept under a desk without soil, water or light! The combination of being easily detachable from the parent plant, attaching to anything that brushes past and persisting for long periods is the perfect long-distance dispersal strategy.

Spread also occurs via water, with **propagules** (any plant matter that can become detached from a plant and give rise to a new plant) easily carried down creeks, streams and across floodplains. There is considerable potential for new populations to emerge where flooding co-occurs with opuntioid cacti infestations (see the case study on page 130 for further information).

Cladodes and fruit easily wash, slide or roll down slopes where they grow into new plants. This is often observed on railway cuttings, gullies and other steep country.

Table 1.3 lists the different vectors for seed and vegetative spread.

Humans and horticulture

Horticultural interest in cacti dates back many hundreds of years and has given rise to a hugely popular worldwide trade industry. This has contributed to the weedy spread of cacti throughout Australia. Declared species are still commonly found in trade, particularly on the internet. You can help by reporting any trade of declared cacti to the weed authority in your state or territory (see page 147).

Table 1.3 Vectors known to spread opuntioid cacti by seed or vegetatively

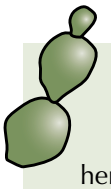
Source of spread	Seed	Vegetative	Comments
Rabbits	✓		Also shelter in cacti
Pigs	✓		Also shelter in cacti
Goats	✓?	✓	Eat and spread cladodes. Unknown if seed is eaten and, if so, whether it would survive gut passage, but is considered likely
Foxes	✓	✓?	
Birds	✓		Especially emus, ravens, crows
Cattle	✓	✓	
Sheep	?	✓	Cladodes stick to fleece and spread
Kangaroos	?	✓	Cladodes spread on coats, uncertain if they eat fruit
Large feral herbivores	?	?	E.g. donkeys, camels. No data or observations to support
Bats	✓		Eat fruit in the northern hemisphere
Reptiles	?	?	No data or observations to support
Insects	?	?	Ants transport seed in the northern hemisphere
Water (rain events, waterways, etc.)	✓	✓	Supported by extensive field observations as key spread mechanism
Vehicles and machinery	✓	✓	Cladodes stick to tyres or undercarriage of vehicles
Humans	✓	✓	Deliberate (e.g. dumping, planting) and accidental (e.g. poor hygiene)
Soil	✓?	✓	E.g. mud sticking to car tyres, shoes
Wind		✓	Very small cladodes short distances

Impacts of opuntioid cacti

Opuntioid cacti are highly invasive weeds that have a serious impact on Australia environmentally, agriculturally and aesthetically, as well as posing a risk to human and animal welfare and safety.

Agricultural impacts

Many species of opuntioid cacti establish dense, impenetrable thickets that reduce or prevent grazing activities and negatively impact productivity. Dense infestations can also limit access for mustering activities. Cacti often establish around infrastructure such as fences and gates, restricting access and impeding maintenance activities. Cacti often establish in remnant vegetation and wind breaks at property or paddock boundaries, or beneath paddock trees, reducing habitat quality and access to shade for stock. Cacti propagules can also be spread by machinery and establish in cropping land.



This manual focuses on 27 species of opuntioid cacti. The impacts listed here are general impacts that apply to all opuntioids, however the severity of impacts can vary between species.

These impacts also apply to non-opuntioid invasive cacti such as *Acanthocereus*, *Cereus*, *Harrisia* and *Pereskia* species.

Biology and threat

Rory Graham

Cacti establishing in a crop from seed or fragments spread by machinery

While cacti are generally avoided by stock, injury and spread can occur from stock brushing past them. Sharp spines and glochids (fine barbed bristles) can: cause injury; contaminate and devalue wool and hides; and pose a risk to shearers and stock handlers. Farmers have reported injury to working dogs and sheep being moved along roadsides through infestations. Stock may eat fruit or cladodes in the absence of more desirable species or during times of drought, causing injuries to the eyes, nose, lips and mouth. Cattle with diets rich in *Opuntia* species may suffer from bloat, and there have been some reports of death from the accumulation of fibre in the gut (DeFelice, 2004).

Cacti infestations can harbour pests like fruit fly, and provide shelter for foxes and rabbits, which can be detrimental to production systems, industry and the environment (Harvey, 2009).

Shauna Potter

Austrocylindropuntia and Opuntia species growing on a roadside – note the dumped garden refuse in the foreground

Environmental impacts

Opuntioid cacti grow in a wide variety of soil types, climatic zones and vegetation communities throughout Australia. They are highly competitive in rangelands, woodlands, grasslands, mallee scrub and marginal grazing areas, filling a niche for succulent shrubs that native flora leaves vacant. Dense patches exclude other species, changing the structure of native vegetation communities. In coastal and island situations, cacti can inhibit nesting of coastal birds and cause a general reduction in the habitat available for fauna (McCallie, 2009). Cacti can also cause injury and death to native animals. Field observations have found reptiles, birds and mammals trapped by or impaled on cacti spines. Other reported impacts to wildlife include injuries to eyes and feet of mammals, particularly arboreal mammals such as koalas and possums, and infections caused by spines and glochids.

Jennifer Jackson

The remains of a kangaroo carcass covered in spines, WA goldfields

Many cacti – including *Austrocylindropuntia* species, shrub-forming species (e.g. *Opuntia aurantiaca* and *Cylindropuntia leptocaulis*), and some non-opuntioid species like *Harrisia* and *Acanthocereus* – establish at the base of existing vegetation and use them for structural support, growing up and through native trees and shrubs.

Matt Sheehan

Rubbish dumps can be the source of new infestations

This adds to the difficulty of management and can lead to considerable off-target damage to desirable vegetation through control.

Linear reserves

Linear reserves such as roadsides, rail corridors, powerline easements, stock routes and riparian areas often contain heavy infestations of opuntioid cacti, whilst also acting as refuges for threatened vegetation communities. Linear corridors act as pathways of spread to adjacent agricultural land, native vegetation and urban areas. Animals, vehicles and machinery carrying cladodes or seed are the greatest source of spread of opuntioid cacti along linear reserves.

Matt Sheehan

Here Opuntia stricta has spread out from an old homestead

Shauna Potter

Scattered infestations of Opuntia aurantiaca are found along this peri-urban creek line in Victoria

Urban situations

In urban areas, opuntioid cacti can occur as a weed on neglected land, parks, gardens and reserves where garden waste is commonly disposed. Old homesteads (in urban and rural settings) are a frequent source of invasion. Cacti impact on recreational activities in urban areas, and pose a risk to humans and domestic pets.

Community values, recreation and amenity

Opuntioid cacti restrict recreational opportunities and access to land. They also reduce the natural attraction and value of landscapes, particularly in wilderness and pastoral areas. The risk of injury from spines and glochids in areas of recreational pursuits is high.

Economic impacts

There is currently a limited ability to quantify the economic cost of cacti for all opuntioid species across the range of situations and values that they impact. For example, it is very difficult to quantify the economic cost cacti have on the environment. Similarly, current control costs vary considerably depending on the species, the management approach employed and the density and remoteness of the infestation.

Where information is available, estimates of control costs are given for individual situations throughout the manual and in several case studies.

Biology and threat

In broad terms, we know that cacti have the following impacts which have a direct economic implication that could be costed:

- Dense cacti infestations further devalue land;
- Dense cacti infestations reduce carrying capacity of what is often already marginal land;
- Cacti devalue agricultural products such as wool and hides;
- Cacti increases mustering costs.

We also know that once established, the cost of controlling a cactus infestation often exceeds the value of the land.

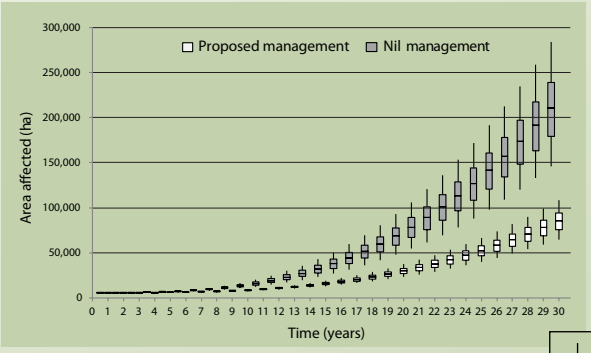
Useful modeling has been developed for specific situations that attempt to quantify the economic impacts of cacti. The box below shows an example of cost/benefit analysis for *Cylindropuntia* species in Western Australia. While this is an example of a formalised model using modeling software and is specific to a particular agricultural practice in Western Australia, the principles can be applied to develop a simplified cost/benefit assessment for any situation at any scale. The important variables to quantify are (i) cost of control, (ii) area of control, (iii) estimated cost of loss incurred through cacti establishment (e.g. productivity), and (iv) prediction of spread over time if not controlled.

Cost/benefit analysis for *Cylindropuntia* species – a West Australian example

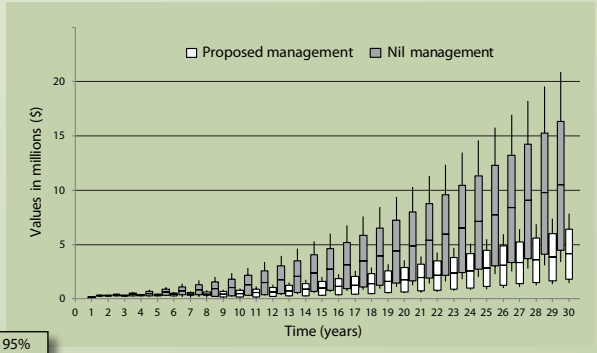
Cylindropuntia fulgida var. *mamillata* (coral cactus), *C. imbricata* (devil's rope), and *C. pallida* and *C. tunicata* (Hudson pear).

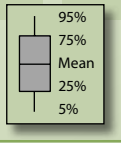
The likely economic impacts of four *Cylindropuntia* species in Western Australia relied on a model that simulated cacti spread over a 30-year period, together with the resultant cost and revenue implications under two different scenarios: control and nil management. The difference between these two scenarios indicates the likely financial benefits of control, taking into account the dynamics and uncertainty of each species' spread and impacts over time.

The analysis predicted that if current rates of establishment continue over the next 30 years, *Cylindropuntia* species have the potential to affect large areas of Western Australia's cattle and sheep grazing country in the Wheatbelt, Goldfields, Pilbara, Gascoyne and Murchison regions (A). A **nil management** scenario, where current infestations continue to expand unabated over a 30-year period, is predicted to cost an average of $3.6 million per year. In comparison, a **proposed management** scenario in which coral cactus spread is slowed and eradication efforts are directed towards devil's rope and Hudson pear, average costs are $2.1 million per year (B).



A. *Expected area affected by Cylindropuntia species in WA under the proposed and nil management scenarios (Source: Cook, 2015)*





B. *Predicted industry losses from Cylindropuntia species in WA under the proposed and nil management scenarios (Source: Cook, 2015)*

Cultural uses and values

In any discussion of impacts, it is important to also consider any benefits or services, either actual or perceived, that an invasive species may provide. This helps to identify where conflicts may arise and how they can be managed. Cultural values associated with cacti exist particularly around horticulture, food and forage. *Opuntia ficus-indica*, more commonly found in urban and peri-urban areas, is particularity valued for its fruit eaten fresh or used in preserves and cladodes cooked as vegetables. This is principally why *O. ficus-indica* is not included in the WoNS listing despite its invasive tendencies. Several other WoNS-listed species are also valued for their fruit including *O. robusta* and *O. stricta*.

In grazing areas in western and central Queensland, tree cacti such as *Opuntia tomentosa* (velvet tree pear) is often viewed as providing a greater value than it does risk. In these situations, *O. tomentosa* does not establish dense thickets, but rather establishes as large, isolated trees that provide shade to stock. New growth provides a food source particularly in drought conditions, and in turn, grazing then reduces the establishment of new infestations. It must be noted however that this species can form thick, dense patches and produces seed that is primarily spread by birds, which contributes to new populations.

Cacti are currently very popular in the nursery trade as ornamental garden plants. They have also been planted to provide property security. Cacti are currently popular in retail, with images commonly featuring on clothing and home decor, as well as personal accessories such as jewelry and even tattoos. The use of such imagery may romanticise cacti, reinforce their perceived value and suggest that they are a natural part of the Australian landscape.

Bob Chinnock

Opuntia ficus-indica is cultivated for its large fruit

Matt Sheehan

A Cylindropuntia spinosior infestation restricting grazing on a Queensland property

Awareness raising is needed to combat the spread of opuntioid cacti occurring via online sales

Identification

What do opuntioid cacti look like?

Opuntioid cacti vary in appearance, ranging from small, almost imperceptible, ground-hugging shrubs, through to tall (6–8 m) trees. They generally share the same distinctive flower – single, open, stalkless and cup-like – though these vary in shape and colour.

Plants have succulent, jointed cladodes, which are also known as pads (commonly applied to *Opuntia* species) or stem segments. These cladodes are flat, cylindrical or occasionally fan-shaped (*Cylindropuntia fulgida* var. *mamillata*) and green in colour, as they contain chlorophyll, enabling photosynthesis to occur.

Many of the opuntioid cacti growing in Australia feature cladodes with smooth, waxy surfaces (e.g. *Opuntia stricta*), although some have small bumps (papilla) (e.g. *O. microdasys*) or fine hairs (e.g. *O. tomentosa*).

It is relatively easy to identify opuntioid cacti to the genus level by appearance, usually through the shape of the cladodes. See page 19 for a summary of the key differences between the genera.

Matt Sheehan

New leaves arising from Cylindropuntia imbricata areoles

In some opuntioid cacti (e.g. *Austrocylindropuntia* and *Cylindropuntia*) cladodes are covered by tubercles, or lumps, giving the plant a ribbed appearance. Areoles appear on or near the top of tubercles.

Shauna Potter

Cylindropuntia fulgida var. mamillata tubercles showing areoles

Spines, which radiate from the areoles, can vary in number and size both between and within species (Chinnock, 2015). Not all opuntioid cacti feature spines, however the number, length, colour, angle and whether encased in a sheath or not, are all used to identify genera and species. For example, all *Cylindropuntia* spines are covered by a papery sheath, which may not be obvious. Spines can be barbed, making then difficult to remove.

True leaves are typically small and deciduous, lasting only a few weeks. An exception to this is *Austrocylindropuntia subulata*, whose leaves are persistent and up to 115 mm long (Chinnock, 2015).

Flowers are large and brightly coloured, ranging from yellow to orange, pink or red. In their country of origin many species are pollinated by insects, however some flowers are tubular and pollinated by birds. The tissue surrounding the flowers (known as the **pericarpel**) is covered with areoles and is capable of vegetative growth.

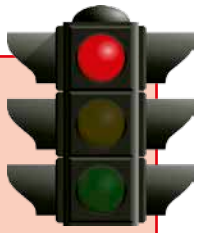
Many species produce fleshy fruit which ripens to red, purple or yellow. Several species in Australia are hybrids (e.g. *Cylindropuntia pallida* and

Shauna Potter

The striking flowers of Opuntia tomentosa, Palmer SA

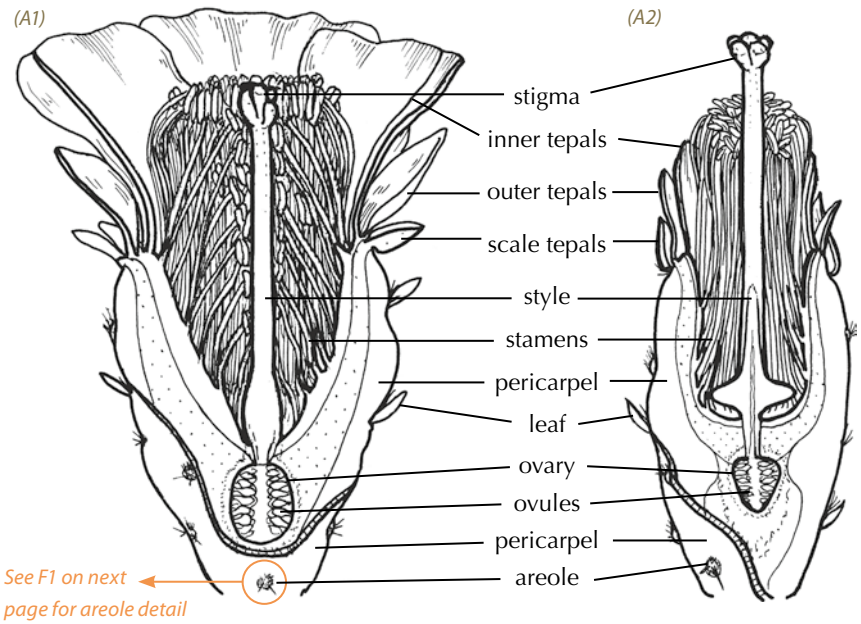
Shauna Potter

Multiple fruit and new, unopened flowers growing on the margins and faces of Opuntia robusta cladodes (pads), central Vic



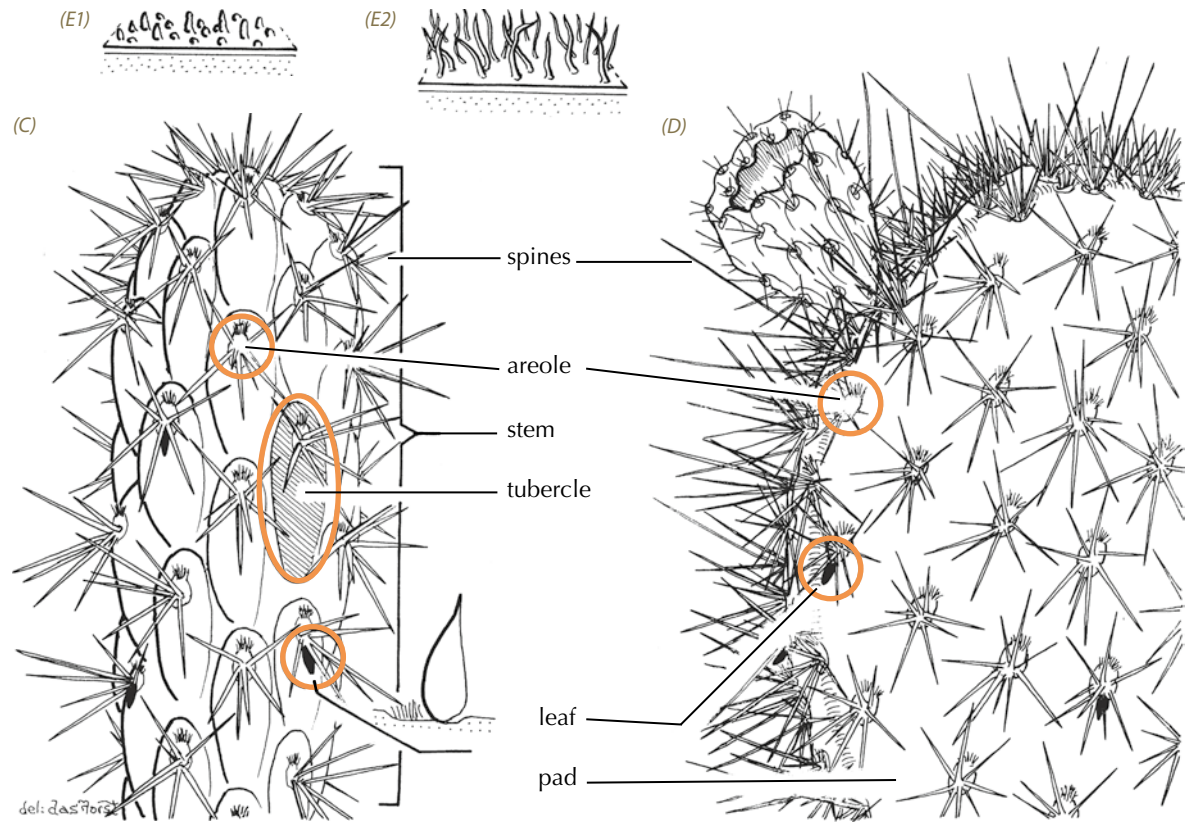
Generic and specific classification of Opuntioideae has been challenging and remains a subject of debate within the research community worldwide. This is further compounded in Australia as most species that are present have very low genetic diversity; some may well be a single clone and are not known to reproduce sexually. Many characteristics of cacti in Australia may differ from those described in the literature, where specimens are usually sourced from their native range.

Opuntia aurantiaca) whose fruit rarely develops or produces seed. Some species produce an abundance of fruit – either singularly along the margins or faces of the cladode or as chains of fruit which can develop over several years when new flowers develop on existing, unripe fruit.

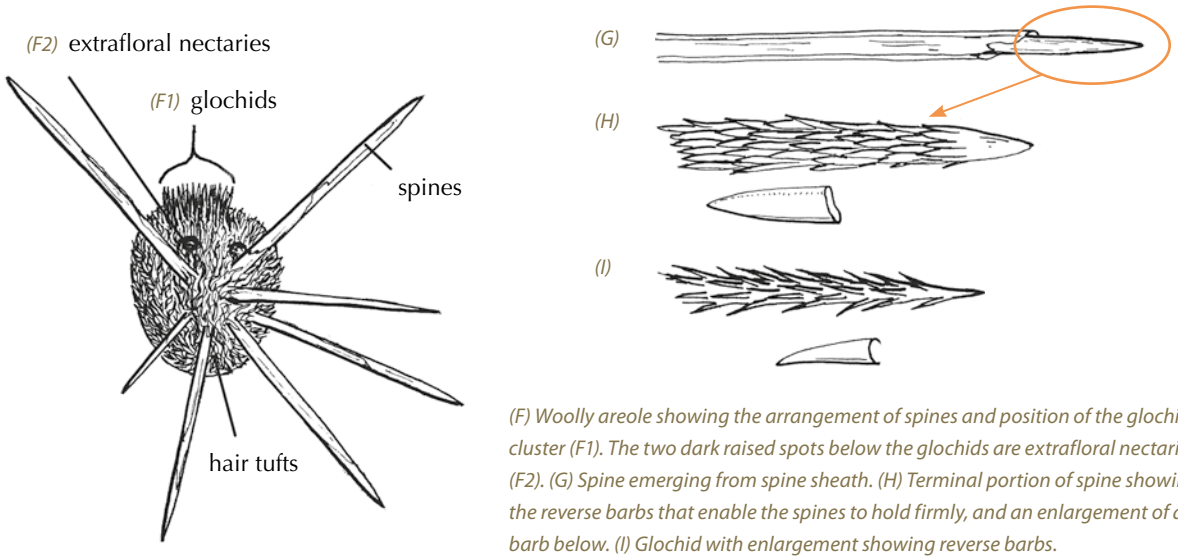


(A) Longitudinal sections through flowers showing key features: (A1) insect-pollinated Austrocylindropuntia, and (A2) bird-pollinated Opuntia (Nopalea group). (B) Side and back view of seed.

Figure 1.4 (i) **Key distinguishing features of opuntioid cacti in Australia – flowers and seeds. Drawing used courtesy of the Board of the South Australian Botanic Gardens and State Herbarium, artist G.R.M. Dashorst (adapted from Chinnock, 2015). Not to scale.**



(C) Terminal portion of a Cylindropuntia cladode. (D) Portion of an Opuntia pad with a developing fruit. (E) Surface coverings found in Opuntia: (E1) Papillae (O. microdasys, O. puberula, O. aff. microdasys), (E2) Hairs (O. leucotricha, O. tomentosa).



(F) Woolly areole showing the arrangement of spines and position of the glochid cluster (F1). The two dark raised spots below the glochids are extrafloral nectaries (F2). (G) Spine emerging from spine sheath. (H) Terminal portion of spine showing the reverse barbs that enable the spines to hold firmly, and an enlargement of a barb below. (I) Glochid with enlargement showing reverse barbs.

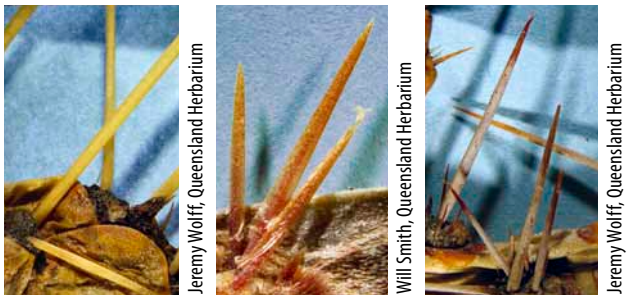
Figure 1.4 (ii) **Key distinguishing features of opuntioid cacti in Australia – cladodes, areoles, spines and glochids. Drawing used courtesy of the Board of the South Australian Botanic Gardens and State Herbarium, artist G.R.M. Dashorst (adapted from Chinnock, 2015). Not to scale.**

The three genera of opuntioid cacti of focus in this manual are *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* (see Figure 1.1, page 2). Key characteristics may assist in identification to the genus level. The illustration below provides a comparison of general form, and an indication of the different ranges in height and cladode length.

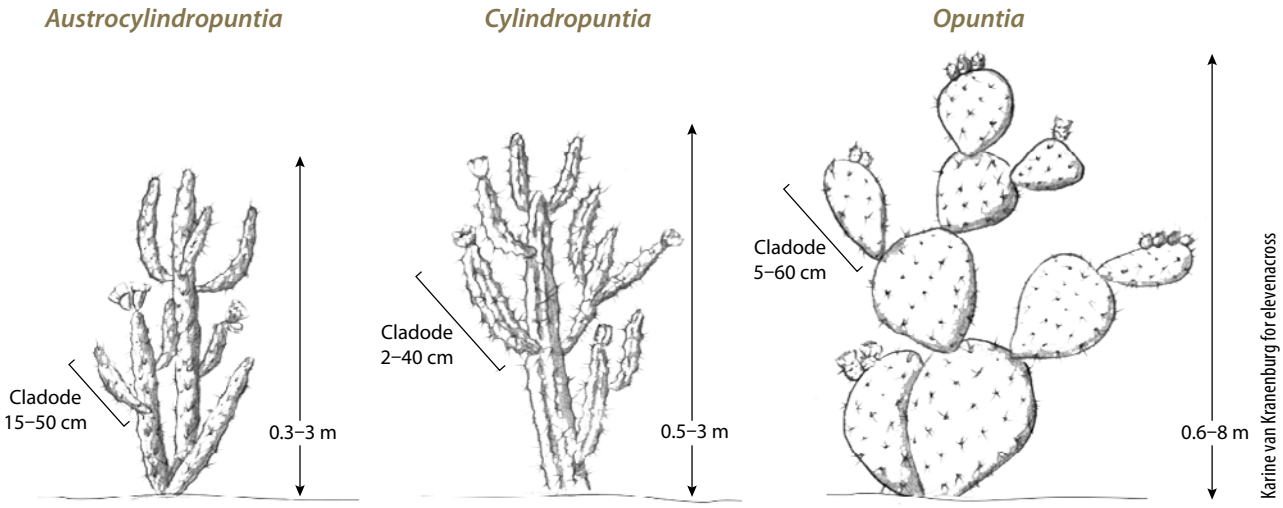
Austrocylindropuntia and *Cylindropuntia* are characterised by their cylindrical cladodes, whereas those of *Opuntia* are flattened, giving the characteristic appearance of what is often collectively referred to as 'prickly pears'. The exception is *O. aurantiaca*, whose small, elongate cladodes (to 20 cm) can appear almost cylindrical.

The prefix Austro means 'southern', and refers to a group of cacti originating in South America that resemble North American *Cylindropuntia* species. *Cylindropuntia* grow with distinct segments between growth points producing jointed cladodes, while *Austrocylindropuntia* do not (see images above right). *Cylindropuntia* species also have spines that are covered in a papery sheath (see images right), which *Austrocylindropuntia* species (and *Opuntia* species for that matter) lack. These are not always visible with the naked eye. The 'Quick guide to opuntioid cacti' on pages 21–29 provides more detailed descriptions of species.

Cladodes of Austrocylindropuntia cylindrica (above left), Cylindropuntia prolifera (top right) and Opuntia robusta (bottom)



Spines of Austrocylindropuntia subulata (left), Cylindropuntia spinosior (centre) and Opuntia monacantha (right). Papery sheaths are only present in the spines of Cylindropuntia species



Stylised illustration of the three genera of opuntioid cacti covered in this manual, comparing the different ranges in height and cladode length

Biology and threat

Identification – getting it right

Whilst identification of opuntioid cacti to genus level is relatively straightforward, identification to species level is more challenging, particularly in *Opuntia* where there are many more species involved. Environmental conditions can also lead to variation within species, further complicating the identification process. Expert advice from botanists at herbaria is often required to identify species accurately (see page 146 for contact details).

Features to look out for when identifying opuntioid cacti include:

- Cladode
  - Size
  - Shape
  - Surface: Is it hairy? Smooth? Nobbly?
  - Thickness
  - Colour
- Flower colour
- Number of spines per areole
- Fruit shape and colour

Shauna Potter

Cylindropuntia prolifera fruit forming chains, with new fruit growing from old as successive growing seasons pass, Arkaroola SA

Matt Sheehan

Distinctive magenta pink Cylindropuntia imbricata flowers

Distribution maps provide a rough guide as to whether a species is present in an area, but don't rely too heavily on this information as data can be missing and historical records may be erroneous.

If you require help identifying opuntioid cacti take good photos of:

- Plant habit;
- Cladodes (close up); and
- Flowers and/or fruit.

Provide photos and descriptions to your local herbarium for expert advice.

Incorrect identification is also compounded by the misapplication of common and/or scientific names of cacti that occur throughout Australia.

Does the species matter?

Knowing the species you want to manage can be critical when it comes to choosing a control technique, especially for biological control (see page 101).

Quick guide to opuntioid cacti

Species:	***Austrocylindropuntia cylindrica*** cane cactus	***Austrocylindropuntia subulata*** Eve's needle cactus	***Cylindropuntia fulgida* var. *mamillata*** coral cactus
Habit	Erect, branching shrub 0.3–1.5 m tall. Often forms patches several metres wide.  Shauna Potter	Branching shrub up to 3 m tall. Forms patches up to 8 m wide.  Bob Chinnock	Erect shrub 0.4–1 m tall.  Henry Rutherford
Cladode (pad/stem segment) 	Dark bluish-green, shiny. Cylindrical, 15–50 cm long, 3–4 cm diameter.  Rob Richardson	Mid green. Slender, up to 50 cm long, 4–5 cm diameter.  Bob Chinnock  Henry Rutherford	Green to grey-green. Cylindrical, often distorted, 10–22 cm long, 2–4.5 cm diameter.   Matt Sheehan
Spines 	2–6 spines per areole, approx 1 cm long. Lack papery sheath.  Rob Richardson	1–4 spines per areole, up to 7 cm long. Lack papery sheath.  Bob Chinnock	4–15 spines per areole, 0.7–2 cm long (often shorter). Cream to brown (colour variable). White to tan sheath.  Matt Sheehan
Flower 	Pink to red, cup-shaped, 2.5 cm diameter.  Bob Chinnock	Pink.  Bob Chinnock	Rarely flowers. Deep red.   Bob Chinnock
Fruit 	Egg- to urn-shaped, up to 4.5 cm long. Deep green to yellow-green. Can produce chains of fruit.  Rob Richardson	Oblong, egg- or club-shaped,up to 10 cm long. Green. Can produce chains of fruit.  Henry Rutherford	Rarely fruits. Inverse cone- or egg-shaped. Grey-green. Forms long chains of fruit.  Bob Chinnock
Reproduction	Vegetative. Seed (viability unknown).	Vegetative. Seed (viability unknown).	Vegetative. Not known to produce seed in Australia.
Notes (see Figure 4.1)	Shrub form. Easily detached cladodes.	Shrub form. Easily detached cladodes.	Shrub form. Easily detached cladodes.

Quick guide to opuntioid cacti continued/…

Species:	*Cylindropuntia imbricata* devil's rope	*Cylindropuntia kleiniae* Klein's cholla	*Cylindropuntia leptocaulis* pencil cactus
Habit	Branched shrub or small tree 1–3 m tall. Can develop a short trunk.  Bob Chinnock	Straggly shrub 0.5–2.5 m tall. Large plants form a trunk.  Shauna Potter  Bob Chinnock	Spreading shrub 0.4–1.8 m tall.  Bob Chinnock
Cladode (pad/stem segment) 	Dull grey-green. 15–40 cm long, 3.5–5 cm diameter. Large, widely-spaced tubercles give a woven, rope-like appearance.  Shauna Potter	Light grey-green. 6–26 cm long, 0.6–1.2 cm diameter.  Bob Chinnock	Green-grey to green. Very slender, 2–8 cm long, 0.3–0.5 cm diameter.  Shauna Potter
Spines 	2–12 spines per areole, 0.8–3 cm long. Trunks often covered in spines. Spines and sheath off-white to cream.  Shauna Potter	1–4 spines per areole, 2–4.5 cm long. White to brown. Tan sheath firmly attached.  Matt Sheehan	0–4 spines per areole, 0.5–1.5 cm long. Cream to pale yellow.  Bob Chinnock
Flower 	Dark pink, magenta, 3–7.5 cm diameter.  Bob Chinnock	Pink-red.  Shauna Potter	Pale to greenish-yellow.  Bob Chinnock
Fruit 	Fleshy, egg-shaped, up to 4 cm long. Greenish-yellow when ripe. Can form chains of fruit.  Bob Chinnock	Egg-shaped to cylindrical. Ripens to orange. Can form chains of fruit.  Bob Chinnock	Fleshy, egg-shaped. Yellow to red when ripe. Spineless.  Shauna Potter
Reproduction	Vegetative. Seed (viable).	Vegetative. Seed (viability unknown).	Vegetative. Seed (viability unknown).
Notes (see Figure 4.1)	Shrub and trunk form. Firmly attached cladodes.	Shrub and trunk form. Easily detached cladodes.	Shrub form. Easily detached cladodes.

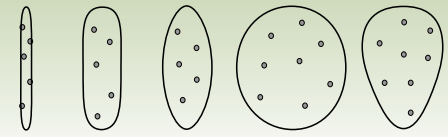
Quick guide to opuntioid cacti continued/…

Species:	***Cylindropuntia pallida* (syn. *C. rosea*)** white-spined Hudson pear	***Cylindropuntia prolifera*** jumping cholla	***Cylindropuntia spinosior*** snake cactus
Habit	Low spreading shrub usually 0.5–2 m. Up to 3 m wide. Old plants can develop trunks, but not often seen.  Bob Chinnock	Low shrub 0.4–1 m tall.  Bob Chinnock	Erect shrub to 1–3 m tall. Often forming patches several metres wide. Similar to *C. prolifera*, but different spine and fruit colour. May develop a trunk.  Matt Sheehan
Cladode (pad/stem segment) 	Grey-pale green. 4.5–26 cm long, 1.5–3.5 cm diameter. Prominent tubercles.  Henry Rutherford	Greenish-grey. 4–15 cm long, 4–5 cm diameter. Prominent tubercles.  Matt Sheehan	Mid grey-green. 10–24 cm long, 1.5–3 cm diameter. Prominent tubercles.  Bob Chinnock
Spines 	7–14 spines per areole, 1–4 cm long. White to light brown. White sheath loosely attached.  Bob Chinnock	7–11 spines per areole, 1–2 cm long. Light to dark brown, interlacing. White to tan sheath firmly attached.  Bob Chinnock	6–24 spines per areole, 0.8–1.5 cm long, interlacing. White to grey. White sheath firmly attached.  R. Bates
Flower 	Pink to purple, to 5 cm diameter.  Bob Chinnock	Rose to magenta.  Bob Chinnock	Rose-purple, 3–7.5 cm diameter.  Bob Chinnock
Fruit 	Oblong to egg-shaped, to 3 cm long. Green to yellow-green.  Bob Chinnock	Top-shaped, 2–5 cm long. Green. Can form chains of fruit.  Bob Chinnock	Fleshy, cylindrical to egg-shaped, to 4 cm long. Yellow, sometimes green.  Bob Chinnock
Reproduction	Vegetative. Sterile hybrid – seed rarely produced.	Vegetative. Not known to produce seed in Australia.	Vegetative. Seed (viability unknown).
Notes (see Figure 4.1)	Shrub form. Easily detached cladodes.	Shrub form. Easily detached cladodes.	Shrub form. Firmly attached cladodes.

Quick guide to opuntioid cacti continued/…

Species:	***Cylindropuntia tunicata*** brown-spined Hudson pear	***Opuntia aurantiaca*** tiger pear	***Opuntia elata*** Riverina pear
Habit	Low, densely branched shrub 0.3–0.6 m tall.  Bob Chinnock	Low spreading shrub to 0.5 m tall. Branches prostrate to somewhat erect. Can grow vertically in other vegetation.  Matt Sheehan	Shrubby plant with erect branches to 2 m tall.  Michael Moerkerk
Cladode (pad/stem segment) 	Pale grey-green. 10–20 cm long, 1.5–3 cm diameter. Prominent tubercles.  Shauna Potter	Green, can have a reddish tinge. Cylindrical to flattened. Up to 20 cm long.  Matt Sheehan	Glossy green, usually with a purple tinge around areoles and margins. Obovate. Often more than 2 cm thick, 5–25 cm long.  Shauna Potter
Spines 	4–7 spines per areole, 3–7 cm long. Red-brown to pale brown. Brownish sheath loosely attached.  Bob Chinnock	Usually 2–3 spines per areole, 1–3 cm long. Brownish-yellow.  Rob Richardson	Spines absent, or 1–3 short spines present at some areoles. Whitish-yellow.  Shauna Potter
Flower 	Yellowish-brown.  Bob Chinnock	Yellow, 2.5–5.5 cm diameter.  Bob Chinnock	Orange.  Bob Chinnock
Fruit 	Club- to top-shaped. Greenish-yellow to red. Spineless.  Bob Chinnock	Egg-shaped with flattened top, 2.5–3.5 cm long. Red-purple when ripe.  Rob Richardson	Club-shaped, to 6 cm long. Purplish-red.  Shauna Potter
Reproduction	Vegetative. Seed (viability unknown).	Vegetative. Not known to produce seed in Australia.	Vegetative. Seed (viability unknown).
Notes (see Figure 4.1)	Shrub form. Easily detached cladodes.	Shrub form. Easily detached cladodes.	Shrub form. Firmly attached cladodes.

Cladode shapes:



linear oblong elliptic circular obovate

Quick guide to opuntioid cacti continued/…

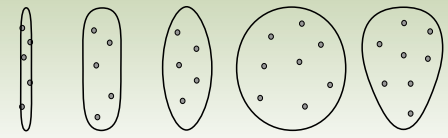
Species:	***Opuntia elatior*** Red-flower prickly pear	***Opuntia engelmannii*** Engelmann's prickly pear	***Opuntia ficus-indica**** Indian fig
Habit	Dense, branched shrub up to 5 m tall.  Bob Chinnock	Low shrub to 1.5 m tall. Forms dense patches. Can be confused with *O. robusta*, but has a low, creeping habit and the cladodes are not blue-green.  Bob Chinnock	Large shrub/small tree to 5 m tall. Usually with a trunk.  Rob Richardson
Cladode (pad/stem segment) 	Olive green. Elliptic to obovate, 10–40 cm long.  Henry Rutherford	Green. Flattened, circular to obovate, 15–20 cm long.  Greg Patrick	Dull blue-green. Flattened, obovate to oblong, 20–60 cm long.  Rob Richardson
Spines 	2–8 spines per areole, 2–4 cm long. Needle-like. Dark brown.  Henry Rutherford	1–6 spines per areole, 1–4 cm long. Yellowish.  Bob Chinnock	Mostly spineless cultivars in Australia.  Rob Richardson
Flower 	Orange-red.  Bob Chinnock	Yellow.  Bob Chinnock	Yellow.  Bob Chinnock
Fruit 	Egg-shaped. Reddish when ripe.  Henry Rutherford	Egg- to top-shaped, fleshy, to 7 cm long. Purple. Often spineless (with glochids).  Henry Rutherford	Barrel-shaped, to 10 cm long. Yellow, orange, red or purple.  Rob Richardson
Reproduction	Vegetative. Seed information not available.	Vegetative. Seed (viability unknown).	Vegetative. Seed (viable).
Notes (see Figure 4.1)	Shrub form. Firmly attached cladodes.	Shrub form. Firmly attached cladodes.	Trunk forming. Firmly attached cladodes.

* Note that, while *Opuntia ficus-indica* can be invasive, it is not a Weed of National Significance (WoNS) or a declared weed in all states and territories. Be sure to check the declaration status in your area.

Quick guide to opuntioid cacti continued/…

Species:	*Opuntia humifusa*	*Opuntia leucotricha*	*Opuntia microdasys* bunny ears
Habit	Prostrate shrub with cladodes lying on the ground, terminal cladodes up to 15 cm high when flowering.  Bob Chinnock	A multi-stemmed shrub growing to 2.5 m tall, often developing a small trunk up to 15 cm diameter.  Shauna Potter	Branched shrub, forming thickets to 1 m tall.  Bob Chinnock
Cladode (pad/stem segment) 	Deep green, often reddish-brown around margins and areoles. Nearly circular to obovate, often wrinkled, 5.5–16 cm long, 5–12 cm wide.  Bob Chinnock	Light green to grey-green, minutely pubescent. Obovate to nearly circular, 16–30 cm long, 12–26 cm wide.  Shauna Potter	Green to pale green and velvety. Circular to oblong, 6–15 cm long. Distinctive clusters of yellow glochids.  Bob Chinnock
Spines 	1–2 spines per areole, up to 3.5 cm long on margins. Glochids orange-brown.  Bob Chinnock	2–6 spines per areole, 10–18 on older cladodes, irregular curving, 1.5–4 cm long, white. Areoles brown woolly. Glochids brown.  Bob Chinnock	Spines usually absent, rarely one.  Bob Chinnock
Flower 	Yellow, with basal parts of the inner tepals turning orange in older flowers. 60–80 mm diameter.  Bob Chinnock	Yellow, 5–7 cm diameter. Outer tepals can be reddish. Flowers late spring–summer.  Bob Chinnock	Yellow, 6–8 cm diameter.  Bob Chinnock
Fruit 	Egg-shaped (narrower at base), tapering towards base, 3–5 cm long. Red-purple.  Bob Chinnock	Barrel-shaped, 2.5–3 cm long, minutely pubescent. Pale yellow.  Bob Chinnock	Fleshy, globular, to 3 cm long. Red-purple.  Bob Chinnock
Reproduction	Vegetative. Seed (viability unknown).	Vegetative. Seed information not available.	Vegetative. Not known to produce seed in Australia.
Notes (see Figure 4.1)	Shrub form. Firmly attached cladodes.	Trunk forming. Firmly attached cladodes.	Shrub form. Firmly attached cladodes.

Cladode shapes:



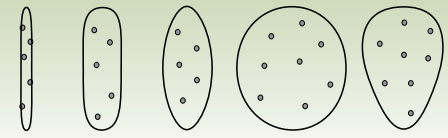
Quick guide to opuntioid cacti continued/…

Species:	*Opuntia monacantha* drooping tree pear	*Opuntia* aff. *polyacantha*	*Opuntia puberula*
Habit	Erect to drooping shrub to small tree up to 3.5 m tall, often with a well developed trunk up to 16 cm diameter.  Rob Richardson	Erect branching shrub 0.5–2 m tall.  Adrian Harvey	Erect, spreading, minutely papillate shrub 0.6–2 m tall, sometimes developing a small trunk up to 10 cm diameter.  Rob Richardson
Cladode (pad/stem segment) 	Bright green, shiny, linear to elliptic, tapering towards base, thin, 20–50 cm long, 12–18 cm wide.  Rob Richardson	Light to mid green. Elliptic to obovate, 12–22 cm long, 9.5–16 cm wide.  Bob Chinnock	Dull light to mid green, covered with minute papillae (protuberances). Elliptic to obovate, 9–22 cm long, (3.5–)5–10 cm wide. Areoles numerous.  Rob Richardson
Spines 	1–2 spines per areole (but increasing to 4–5 in older parts of the plant), 2–4 cm long. Brown to off-white.  Rob Richardson	6–14 spines per areole, variable in length, 1–5 cm long. Straw-coloured to very pale brown.  Adrian Harvey	1–3 spines per areole, 5–17 mm long, usually bent, 0.5–0.7 mm wide near base, pale yellow ageing white. Glochids yellow, red-purple.  Rob Richardson
Flower 	Yellow, outermost tepals red, 5.5–7 cm diameter.  Rob Richardson	Yellow, 6–8 cm diameter.  Bob Chinnock	Bright yellow, shiny, outer tepals reddish, old flowers sometimes aging to orangish, 5–7 cm diameter.  Rob Richardson
Fruit 	Pear-shaped tapering to a stalk-like base, 5–7 cm long. Green to reddish, spineless, often forming chains of fruit.  Rob Richardson	2.5–4 cm long. Deep red, sometimes forming chains of fruit.  Adrian Harvey	Solitary or forming small erect chains of 2–3 fruit. Egg-shaped (wider at base), tuberculate, 5–7 cm long, 2–2.5 cm diameter, minutely papillate. Red-purple.  Michael Moerkerk
Reproduction	Vegetative. Seed (viable).	Vegetative. Not known to produce seed in Australia.	Vegetative. Not known to produce seed in Australia.
Notes (see Figure 4.1)	Trunk forming. Firmly attached cladodes.	Trunk forming. Firmly attached cladodes.	Trunk forming. Firmly attached cladodes.

Quick guide to opuntioid cacti continued/…

Species:	*Opuntia robusta* wheel cactus	*Opuntia schickendantzii*	*Opuntia streptacantha* Westwood pear
Habit	Shrub with multiple stems up to 4 m tall (commonly 1–2 m).  Shauna Potter	Erect shrub 0.7–1.8 m high, trunk often well-developed, up to about 1 m high.  Bob Chinnock	Shrub to small tree up to 4.5 m tall, often forming a trunk to 20 cm diameter.  Bob Chinnock
Cladode (pad/stem segment) 	Blue-green. Flattened, circular, up to 40 cm wide.  PIRSA	Dull green, minutely papillate. Narrowly linear-elliptic to oblong, thin, 20–35 cm long, 3.5–6 cm wide. Areoles close-set, woolly. Glochids yellowish brown.  Rob Richardson	Mid green to greyish-green. Broadly obovate to nearly circular, thick, 21–48 cm long, 13–34 cm wide.  Bob Chinnock
Spines 	2–12 spines per areole, up to 5 cm long. White to pale brown or yellow.  Shauna Potter	1–3 spines per areole, straight, rigid, 4–10 mm long, spreading.  Henry Rutherford	2–8 spines per areole on terminal branches, radiating, 5–20 mm long. Whitish sometimes tipped pale yellow. Glochids not obvious.  Bob Chinnock
Flower 	Yellow, 5–8 cm diameter.  Shauna Potter	Yellow, outermost tepals sometimes tinged pink aging to orange-yellow, 4–5 cm diameter.  Bob Chinnock	Orange-yellow, 12 cm diameter.  Bob Chinnock
Fruit 	Fleshy, globular (rounded), to 8 cm long. Deep red.  Michael Moerkerk	Narrowly egg-shaped (wider at base), 2.5–3.5 cm long, to 1.5 cm diameter, tuberculate.  Ros Shepherd	Solitary, egg-shaped to oblong, to 4.5 cm long, 3.5 cm diameter. Deep red.  Bob Chinnock
Reproduction	Vegetative. Seed (viable).	Vegetative. Seed information not available.	Vegetative. Seed (viability unknown).
Notes (see Figure 4.1)	Trunk forming. Firmly attached cladodes.	Trunk forming. Firmly attached cladodes.	Trunk forming. Firmly attached cladodes.

Cladode shapes:



linear oblong elliptic circular obovate

Quick guide to opuntioid cacti continued/…

Species:	***Opuntia stricta* var. *stricta* and var. *dillenii*** common prickly pear	***Opuntia sulphurea***	***Opuntia tomentosa*** velvet tree pear
Habit	Sprawling to erect shrub up to 2 m tall. Forms thickets.  Rob Richardson	Low spreading shrub, 30–70 cm high, forming patches 1–2 m across.  Bob Chinnock	Shrubby to tree-like, up to 5 m tall. Often with a trunk.  Bob Chinnock
Cladode (pad/stem segment) 	Green to grey green. Elliptic to obovate, 10–25 cm long.  Rob Richardson	Green to greyish-green, sometimes tinged purplish. Elliptic to widely obovate, 8–32 cm long, 5–13.5 cm wide, thick. Glochids yellowish-red to brown.  Bob Chinnock	Grey-green. Flattened, elliptic to obovate, 15–30 cm long. Covered in fine hairs, giving a velvety appearance.  Bob Chinnock
Spines 	In *O. stricta* var. *stricta*, spines are absent or the occasional one may be present on a pad. In *O. stricta* var. *dillenii* there are up to 11 spines per areole, 1.5–4 cm long.  Rob Richardson	1–8 spines per areole, needle-shaped, stiff, thick, occasionally curved/twisted, 6–45 mm long. Yellowish, brownish, red or grey, but sometimes quite pale.  Bob Chinnock	Often spineless, but can have 0–4 spines per areole, 0.5–1.5 cm long. Whitish-yellow.  Bob Chinnock
Flower 	Yellow, 6 cm diameter.  Shauna Potter	Yellow, 4–7 cm diameter.  Bob Chinnock	Orange, 4–5 cm diameter.  Shauna Potter
Fruit 	Fleshy, globular to pear-shaped with flattened top to 6 cm long. Purplish-red.  Henry Rutherford	Egg-shaped, 3–4.5 cm long, 2–2.5 cm diameter, tapering to base, with a deep umbilicus (depression), often a few rigid spines in areoles around apex. Red-purple.  Bob Chinnock	Globular to egg-shaped, with flattened top up to 5 cm long. Red, covered in fine hairs giving a velvety appearance.  Bob Chinnock
Reproduction	Vegetative. Seed (viable).	Vegetative. Seed (viability unknown).	Vegetative. Seed (viable).
Notes (see Figure 4.1)	Shrub form. Firmly attached cladodes.	Shrub form. Easily detached cladodes.	Trunk forming. Firmly attached cladodes.

Quick guide to non-opuntioid cacti

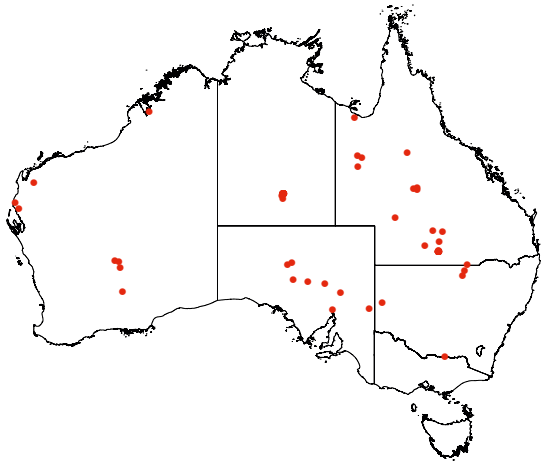
Species:	***Acanthocereus tetragonus*** sword pear	***Cereus uruguayanus*** apple fruit, willows cactus	***Harrisia martinii*** and ***H. tortuosa***	***Pereskia aculeata*** leaf cactus
Habit	 Matt Sheehan	 Matt Sheehan	 Matt Sheehan	 Queensland Herbarium
Cladode 	 Matt Sheehan	 Matt Sheehan	 Matt Sheehan	 Queensland Herbarium
Spines 	 Matt Sheehan	 Matt Sheehan	 Matt Sheehan	 Molly Murphy
Flower 	Flower buds  Matt Sheehan	Flower buds  Matt Sheehan	 Queensland Herbarium	Flower buds  Queensland Herbarium
Fruit 	 Matt Sheehan	 Matt Sheehan	 Matt Sheehan	 Molly Murphy

Biology, ecology and distribution of opuntioid cacti

Cylindropuntia fulgida var. *mamillata* Coral cactus

Origin and distribution

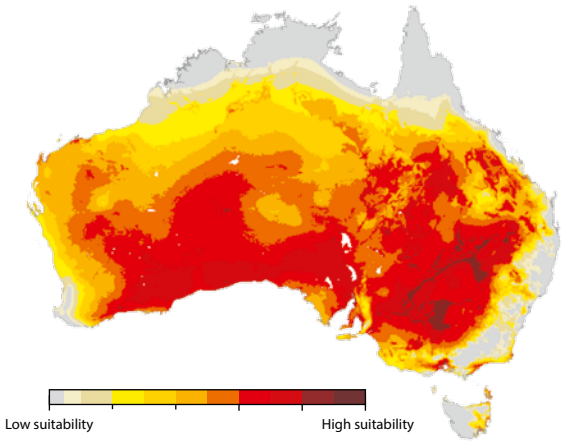
Cylindropuntia fulgida var. *mamillata* is native to south-western USA and northern Mexico. It is thought to have been introduced to Australia in the 1980s, and is recorded as naturalised in the drier inland regions, including the western parts of New South Wales (NSW) and Queensland (Qld), Western Australia (WA), South Australia (SA) and southern parts of the Northern Territory (NT).



Current distribution of Cylindropuntia fulgida var. mamillata (●)

Habitat in Australia

This species is suited to a diverse range of soil types, including but not limited to alkaline, gravel, stony and sandy soils. It thrives in a diverse range of habitats and settings, including native grassland and woodlands, riparian zones, urban areas, agricultural areas, and rangelands. It can form dense, extensive infestations that reduce land use. Habitat suitability modelling indicates this species can grow across Australia, excluding western Tasmania (Tas), east of the Great Dividing Range and north of the Gulf of Carpentaria.

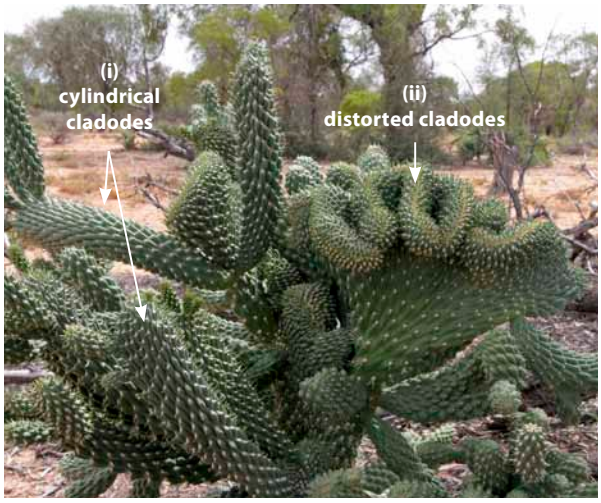


Habitat suitability for Cylindropuntia fulgida var. mamillata (Duursma et al., 2013, www.weedfutures.net)

Features to note

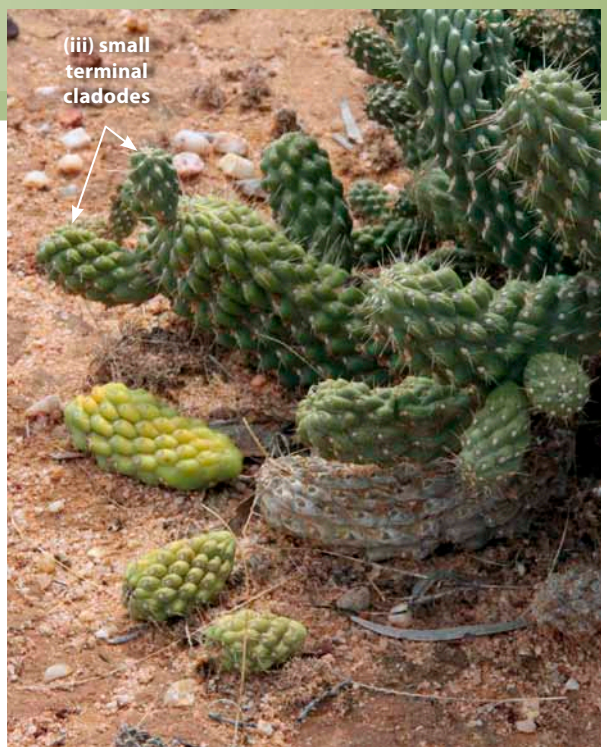
Cylindropuntia fulgida var. *mamillata* is a visually spectacular and distinctive shrub. In Australia, it grows as the monstrous form, also known as forma *monstruosa* (Chinnock, 2015).

A range of cladode forms are produced and can all occur on the same plant, from (i) cylindrical to club-shaped, (ii) distorted, wavy, boxing glove shaped, and (iii) small, loosely attached terminal cladodes (see images right and page 32). The latter are often found growing as new plants under or near to parent plants and are often very hard to detect. It rarely flowers and does not produce seed



Matt Sheehan

Different cladodes of Cylindropuntia fulgida var. mamillata: (i) cylindrical to club-shaped and (ii) distorted 'boxing glove' cladodes



Matt Sheehan

The third cladode form of Cylindropuntia fulgida var. mamillata: (iii) small terminal segment – these segments detach easily and grow beneath the parent plant or are transported

Matt Sheehan

Cladodes of Cylindropuntia fulgida var. mamillata can revert to the characteristics of C. fulgida var. fulgida, which is more heavily spined

in Australia. The easily detachable cladodes aid its spread by wildlife, stock, humans and water.

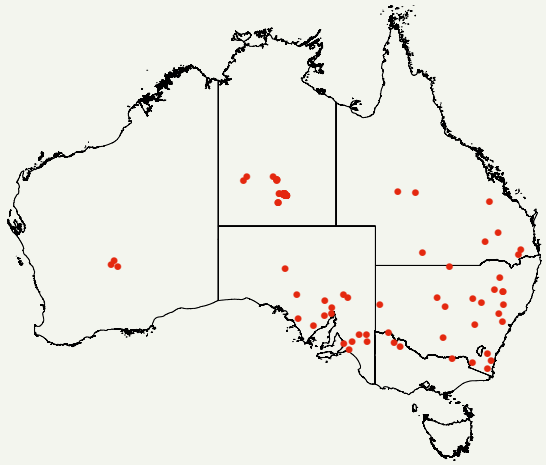
Management considerations

Control is notoriously difficult, particularly as small cladodes are extremely difficult to detect. Best results have been achieved through integrated management using a combination of biological control, foliar spraying, hand removal and exclusion fencing (see case study on page 134).

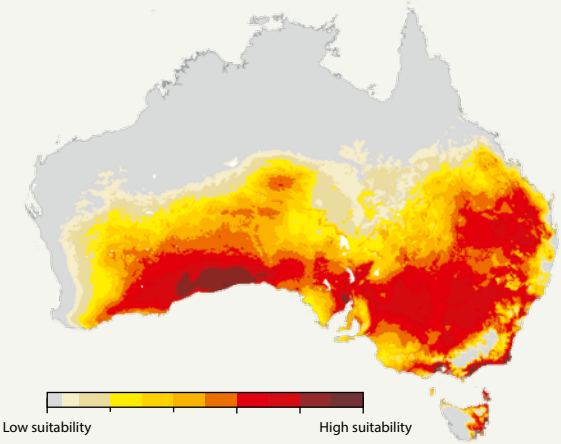
Cylindropuntia imbricata
Devil's rope

Origin and distribution

Cylindropuntia imbricata is native to south-central USA and northern Mexico, with an exotic range extending to eastern and southern Europe, northern and southern Africa and southern South America. It is thought to have been introduced to Australia in the 1930s, and is commonly found in SA, NSW and Qld. It has scattered distribution in WA, NT and Victoria (Vic) and is absent from the Australian Capital Territory (ACT) and Tas. *Cylindropuntia imbricata* still has a strong association with areas of introduction, such as abandoned homesteads.



Current distribution of Cylindropuntia imbricata (●)



Habitat suitability for Cylindropuntia imbricata (Duursma et al., 2013, www.weedfutures.net)

Matt Sheehan

Cylindropuntia imbricata often grows near abandoned homesteads

Habitat in Australia

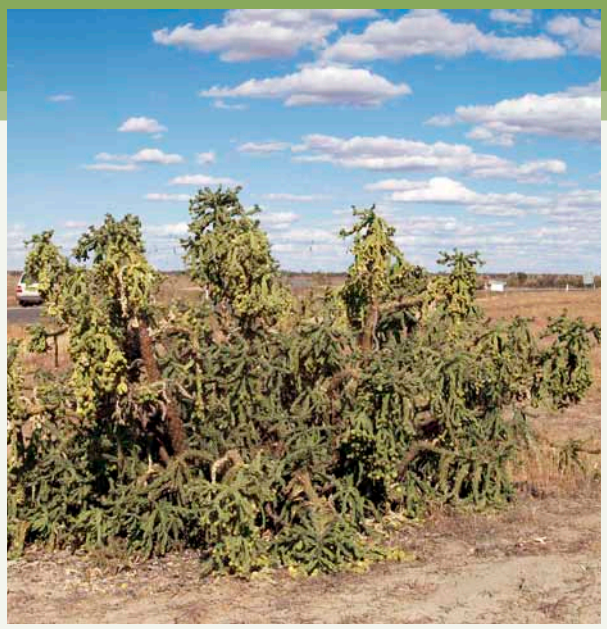
This species is mostly found in semi-arid environments and is suited to a diverse range of soil types and situations. It is found along roadsides and in disturbed sites, riparian areas, pastures, open woodlands, rangelands and grasslands. It commonly forms dense, impenetrable thickets that reduce carrying capacity and excludes native grasses and shrubs. Habitat suitability modelling indicates that it poses a potential threat to just over half of the continent, from the Tropic of Capricorn south excluding alpine areas.

Features to note

Cylindropuntia imbricata is an upright, spreading shrub or tree with a short trunk. Cladodes can be long and feature numerous lumps (tubercles), giving them a rope-like appearance. Readily spread along watercourses, *C. imbricata* also produces numerous seeds from its fruit, which grows individually or as chains.

Management considerations

Reliance on foliar spraying as the sole control method should be avoided as re-treatment is often required. An integrated management approach using biological control, foliar spraying and, in the right situation, mechanical removal, is the most effective control program. Removing 'mother plants' at homesteads is a good way of reducing the seed load.



Lesley Palmer

Matt Sheehan

Bob Chinnock

Bob Chinnock

Cylindropuntia imbricata

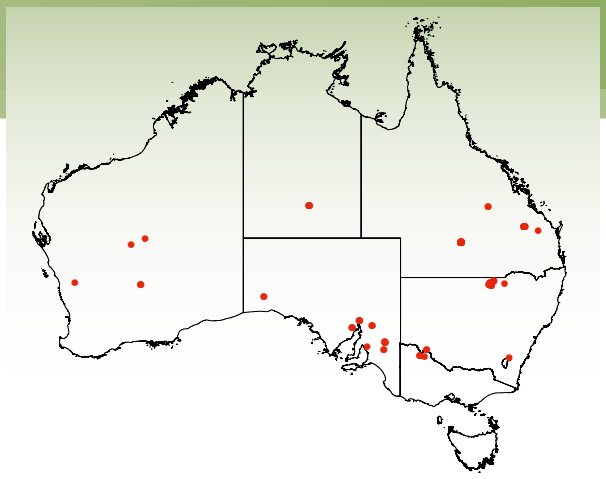
Cylindropuntia pallida (syn. *C. rosea*) White-spined Hudson pear

Cylindropuntia tunicata Brown-spined Hudson pear

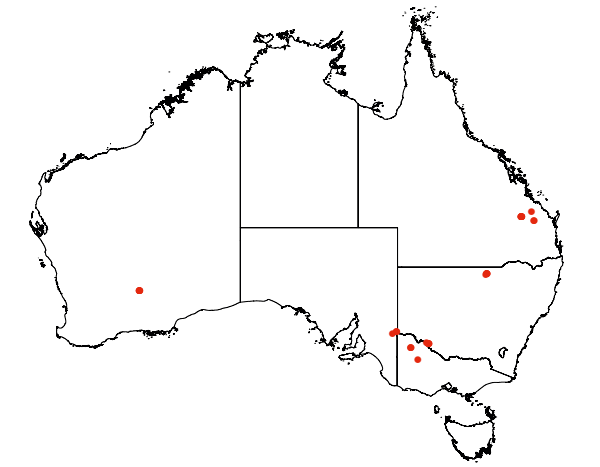
Origin and distribution

Cylindropuntia pallida and *C. tunicata* originate from Texas to northern Mexico. *Cylindropuntia pallida* is thought to be a hybrid between *C. tunicata* and another unknown parent. These species are very similar in appearance, form and impact. They commonly co-occur and are therefore considered here collectively. Spine colour, fruit and flowers are the easiest way to differentiate the two species.

Hudson pear was first detected in Australia in the Lightning Ridge area during the late 1960s. Thought to have been deliberately used by opal miners to protect their diggings from nocturnal prowlers and thieves, Hudson pear has since naturalised in inland regions of Australia, though it is not currently widespread. It is locally common in some parts of northern NSW (i.e. Lightning Ridge, Grawin, Glengarry and Cumborah) and present in the inland goldfields region of WA, western Qld, NT, SA, and the mallee region of northern Vic.



Current distribution of Cylindropuntia pallida (●)



Current distribution of Cylindropuntia tunicata (●)

Matt Sheehan

Cylindropuntia pallida (left) and C. tunicata (right) side-by-side

Habitat in Australia

Naturalised populations are believed to be relatively young (Chinnock, 2015) and are currently found growing on heavy clays, loams and sandy soils. Details are lacking on whether these species favour certain soil types. They primarily occur in the rangelands, but also occur in mallee, riparian and urban areas. Habitat suitability mapping is currently being modelled and will be available at http://weedfutures.net.

Features to note

Hudson pear reproduces vegetatively, and while both species produce seed, they are thought to be sterile in Australia. Plants produce large volumes of small cladodes (commonly referred to as segments) that either fall to the ground or remain loosely attached. As with other *Cylindropuntia* species, this feature enables their spread.

Hudson pear has particularly vicious spines that are capable of penetrating footwear and vehicle tyres.

Matt Sheehan

Matt Sheehan

Bob Chinnock

Bob Chinnock

Cylindropuntia pallida (white-spined Hudson pear)

Matt Sheehan

Matt Sheehan

Matt Sheehan

Bob Chinnock

Cylindropuntia tunicata ***(brown-spined Hudson pear)***

The spines can cause serious injury to humans, livestock and working animals such as horses and dogs, as well as native fauna. Dense infestations can displace native flora and may impact on plant biodiversity in semi-arid communities. These features, along with the ease with which it spreads, make Hudson pear one of the most concerning opuntioid cacti species from an impact and management perspective.

Management considerations

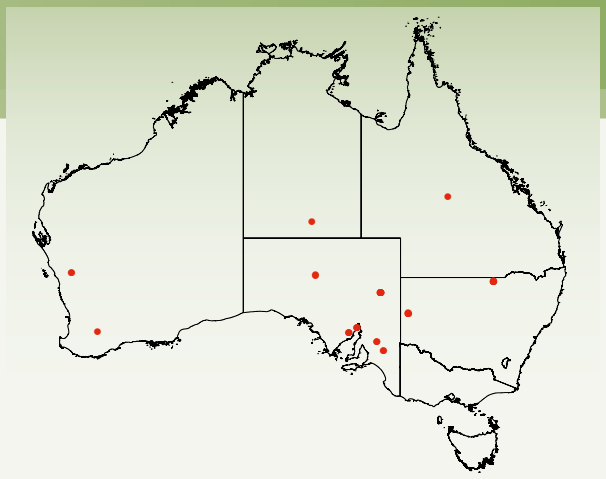
Physical removal, while successful on isolated plants, is generally not recommended because of the potential danger of serious injury. Foliar spraying is the most effective control option currently available. A biocontrol agent was approved for release for *Cylindropuntia tunicata* in October 2017. Note that dead plants remain as dangerous as live plants until they have decayed.

Cylindropuntia prolifera
Jumping cholla

Origin and distribution

Cylindropuntia prolifera has a native range from California to Baja California, Mexico (Chinnock, 2015), where it grows in coastal sage scrub, chaparral, and beach and bluff habitat.

In Australia, it is common in SA, although most populations are small. It also occurs in NSW in the Lightning Ridge area, WA, central-west Qld and Alice Springs NT.



Current distribution of Cylindropuntia prolifera (●)

Habitat in Australia

Cylindropuntia prolifera prefers semi-arid and arid rangelands and subtropical areas. Habitat suitability mapping is currently being modelled and will be available at http://weedfutures.net.

Features to note

The common name for *Cylindropuntia prolifera* is jumping cholla which comes from its ability to seemingly 'jump' off the parent plant and latch onto passers-by. It is hypothesised that this species, like many *Cylindropuntia* species, possesses mechanically weak joins and barbed spines to maximise dispersal (Bobich and Nobel, 2001). While numerous large fruit are produced, it is considered sterile in Australia (as it is not known to produce seed).

Cylindropuntia prolifera is similar to *C. spinosior*, but is easily distinguished from it by the brown to dark brown spines and green fruit.

Shauna Potter

Bob Chinnock

Shauna Potter

Cylindropuntia prolifera

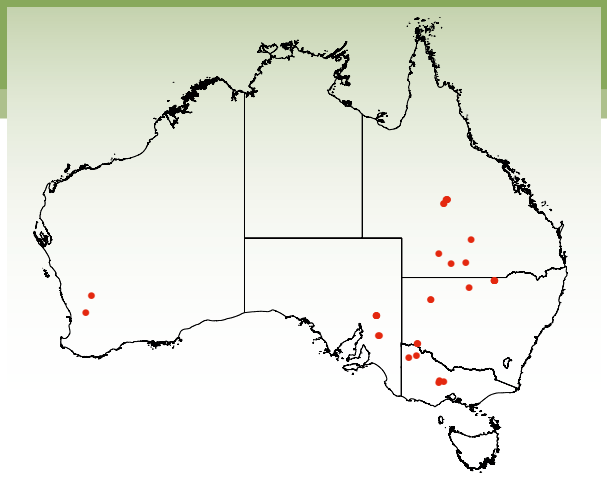
Management considerations

Spread prevention is key for *Cylindropuntia prolifera* management, and can be achieved through a combination of exclusion fencing to reduce access to vectors, combined with strict hygiene protocols when entering infested areas. Foliar spraying is currently the best control option available. A biocontrol agent was approved for release for *C. prolifera* in October 2017.

Cylindropuntia spinosior
Snake cactus

Origin and distribution

The native range of *Cylindropuntia spinosior* extends from Arizona and New Mexico to northern Mexico (Sonora and Chihuahua) (Chinnock, 2015). In Australia, it occurs in small and scattered populations in WA, SA, NSW and Vic, with some extensive populations in Qld.



Current distribution of Cylindropuntia spinosior (●)

Habitat in Australia

Cylindropuntia spinosior occurs in shrubby eucalypt woodland on red sandy and rocky soils. It is also likely to thrive in semi-arid and drier subtropical regions in a range of soil types. Habitat suitability mapping is currently being modelled and will be available at http://weedfutures.net.

Features to note

Cylindropuntia spinosior is similar to *C. prolifera* but is easily distinguished by its white to pale grey spines compared to the brown spines of *C. prolifera*.

Cylindropuntia spinosior disperses vegetatively.

Management considerations

Cylindropuntia spinosior is an aggressive, drought-tolerant plant that can be highly problematic, forming extensive, impenetrable thickets. Dense infestations can impede movement of stock, lay waste to agricultural and pastoral lands, harbour pests and drastically alter the structure and composition of native vegetation communities. It commonly grows in difficult-to-access locations, such as ridgelines, further limiting control options. Trials in western Qld have shown that fast, low-intensity grass fires benefit *C. spinosior*, and therefore fire is not recommended for use as a management tool. A biocontrol agent was approved for release for *C. spinosior* in October 2017.

Shauna Potter

Bob Chinnock

Shauna Potter

Cylindropuntia spinosior

Opuntia aurantiaca
Tiger pear

Origin and distribution

Opuntia aurantiaca is native to Paraguay, Uruguay and Argentina (Anderson, 2001), with an exotic range extending to South Africa and Australia.

The origin of *Opuntia aurantiaca* in Australia is not known, but it was first noted in NSW in 1883 and recognised as a potential problem in NSW and Qld by 1911. Many thousands of hectares were infested in southern Qld by 1932 with individual patches of over 1600 hectares. It is currently widespread in southern Qld and northern NSW, and extends to western Qld, Vic and SA.

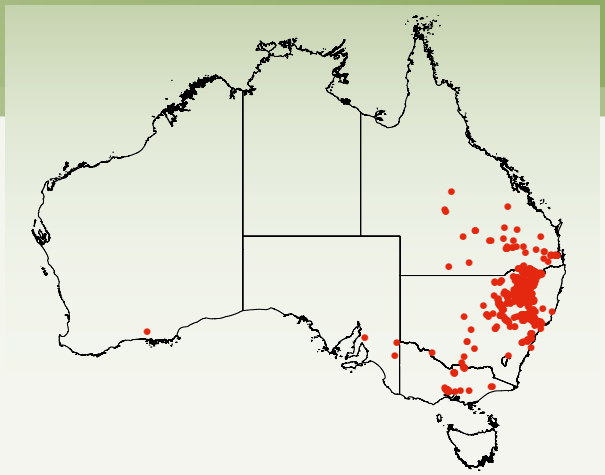
Habitat in Australia

Opuntia aurantiaca occurs in semi-arid and drier subtropical regions. It occurs on a variety of soil types and grows in open woodlands, open shrublands, pastures, riparian systems and along roadsides. Habitat suitability modelling suggests that it has a more restricted potential distribution across Australia when compared to other opuntioid cacti.

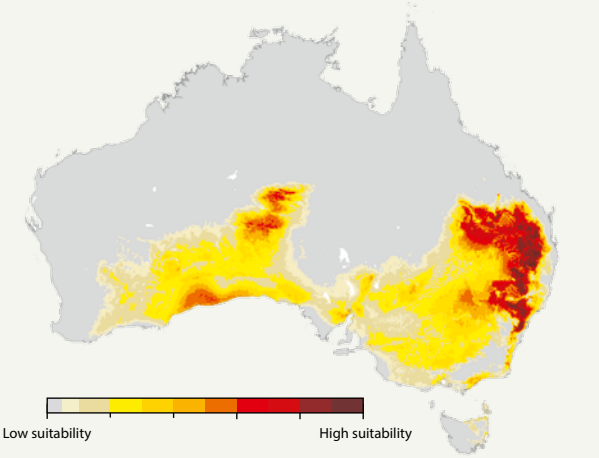
Features to note

Opuntia aurantiaca disperses vegetatively and, while it produces seed, it is thought to be sterile in Australia. The cladodes readily detach and, in addition to the usual human and animal vectors, are commonly transported by water, especially during floods. Very small cladodes can also be dispersed short distances in open areas by wind (Telford, 1984; Stajsic and Carr, 1996; Navie, 2004).

Opuntia aurantiaca is an aggressive, drought-tolerant weed that can be highly problematic, especially in NSW and Qld. It forms extensive, impenetrable thickets that can impede movement of stock, lay waste to agricultural and pastoral lands and harbour pests such as rabbits.



Current distribution of Opuntia aurantiaca (●)



Habitat suitability for Opuntia aurantiaca (Duursma et al., 2013, www.weedfutures.net)

Matt Sheehan

Matt Sheehan

Opuntia aurantiaca

Bob Chinnock

Matt Sheehan

Flowers and buds of Opuntia aurantiaca (top) and dropped cladodes (bottom)

Management considerations

Management of this species can be difficult, as it is a small, unobtrusive shrub with highly mobile cladodes. When growing in corridors such as roadsides and in riparian areas, plants are not easily seen amongst grass and ground vegetation and can be spread by animals and machinery such as slashers.

It also commonly grows amongst, and climbs up, native vegetation. Because of this, the off-target impact of chemical or physical control can be high.

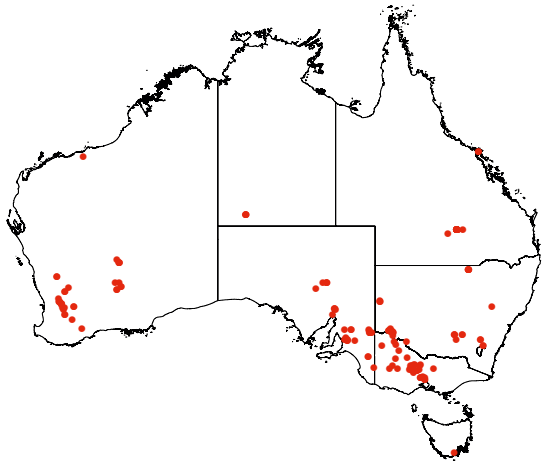
General consensus is that the control of *Opuntia aurantiaca* by the cochineal insect (*Dactylopius austrinus*) has been reasonably effective in core infestations. It is important not to become complacent when biological controls exist, as new populations, such as those recently detected in Qld, can emerge in areas where the biocontrol agent is not present.

Opuntia elata
Riverina pear

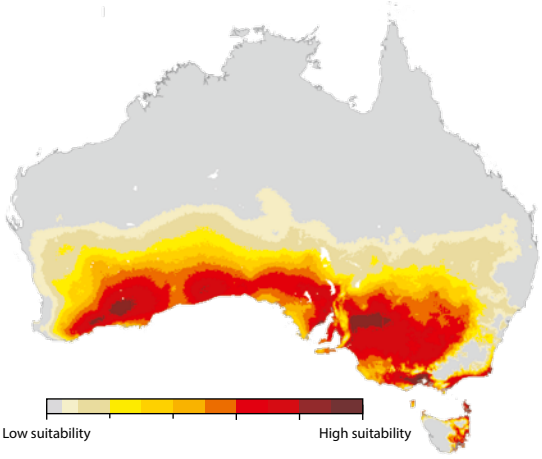
Origin and distribution

Opuntia elata is native to Argentina, Brazil, Paraguay, Bolivia and Uruguay (Hunt *et al.*, 2006), growing at elevations between 0 and 500 m above sea level (Duarte *et al.*, 2017). It is considered invasive in both Australia and the Mediterranean region of Europe.

The introduction history of *Opuntia elata* to Australia is not known, but it is thought to have been introduced in the 1960s. Naturalised populations have been recorded in all six states and the NT.



Current distribution of Opuntia elata (●)



Habitat suitability for Opuntia elata (Duursma et al., 2013, www.weedfutures.net)

Habitat in Australia

Opuntia elata is reported to prefer sandy soils, however it is likely to tolerate a range of soil types. It is found most commonly along roadsides, riparian systems (common along the Murray River), bushland, grazing areas and disturbed areas.

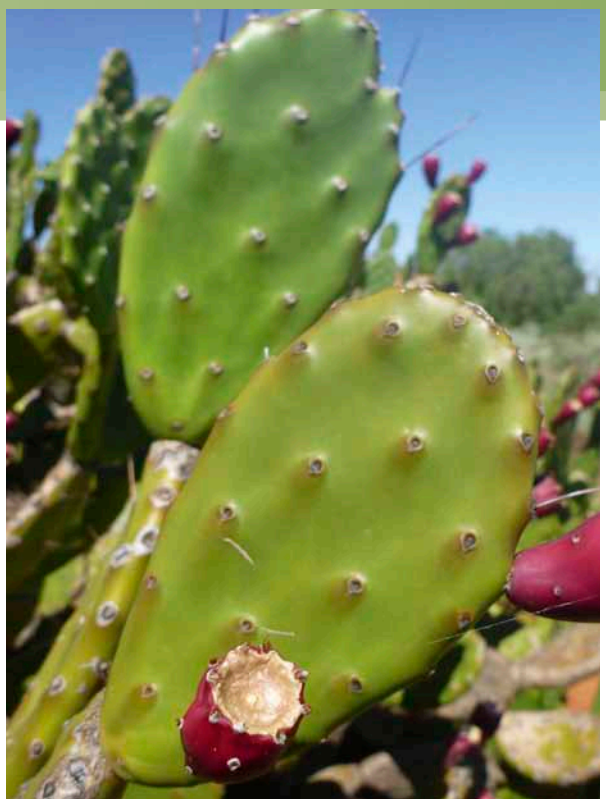
Habitat suitability modelling suggests that it is most suited to the southern third of the continent, excluding alpine areas. Contrary to modelling, populations have established north of its predicted range in western Qld and the Pilbara, WA.

Features to note

Opuntia elata has orange flowers, and commonly has purple colouration around the areoles.

Management considerations

An integrated approach to management of *Opuntia elata* is recommended, given the relatively large number of control options available. Two biological control agents are effective: *Dactylopius ceylonicus* and *Cactoblastis cactorum*. In core infestations, biological control used in conjunction with stem injection of outliers, offers an effective control program. Mechanical removal may be an option in some situations, however, note that this species often occurs within riparian zones where soil disturbance should be minimised.



Shauna Potter

Bob Chinnock

Shauna Potter

Matt Sheehan

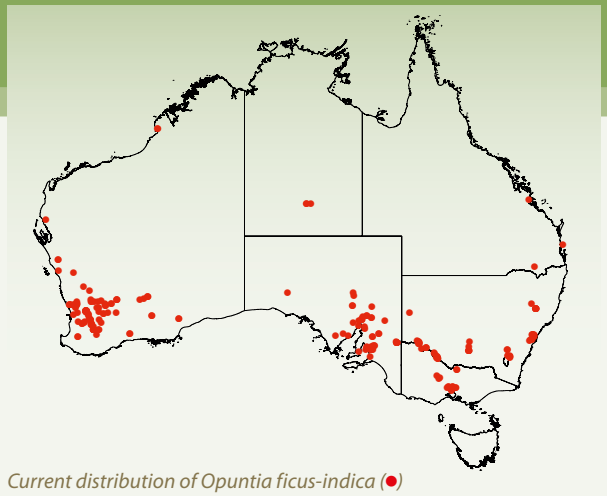
Opuntia elata

Opuntia ficus-indica
Indian fig

Origin and distribution

The native range of *Opuntia ficus-indica* is unknown due to its long history of cultivation for its edible fruit, but it is most likely from Mexico. It is now naturalised in southern Africa, Asia, southern Europe, North America, South America, West Indies, islands in the Indian and Pacific Oceans.

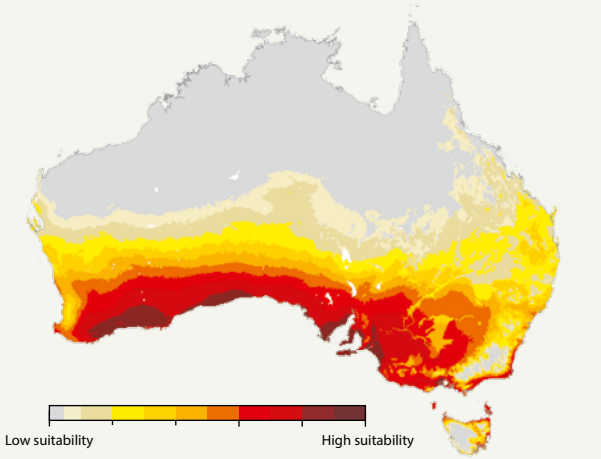
Opuntia ficus-indica is thought to have been introduced to Australia during the 1840s and is now naturalised in all states and territories excluding Tas.



Current distribution of Opuntia ficus-indica (●)

Habitat in Australia

Opuntia ficus-indica has escaped cultivation and invaded bushland, coastal vegetation/sand dunes, grasslands, scrublands and shrublands. Habitat suitability modelling suggests that it is most suited to the southern half of the continent, excluding alpine areas.



Habitat suitability for Opuntia ficus-indica (Duursma et al., 2013, www.weedfutures.net)

Features to note

Opuntia ficus-indica is often found in semi-urban and suburban areas. Infestations often occur in close proximity to where it is being grown in cultivation.

It exhibits large, elongated cladodes (pads) with few spines.

Mike Chuck

Opuntia ficus-indica

Shauna Potter

Management considerations

The fruit is valued by many as a food source, which can lead to some reluctance or resistance within the community to manage this weed.

Cactoblastis is an effective control tool for *Opuntia ficus-indica* and can be integrated with chemical or physical control. Be mindful that plants are often large, so off-target impacts of control methods such as foliar spraying may be significant and therefore may not be appropriate in some situations.

Bob Chinnock

Bob Chinnock

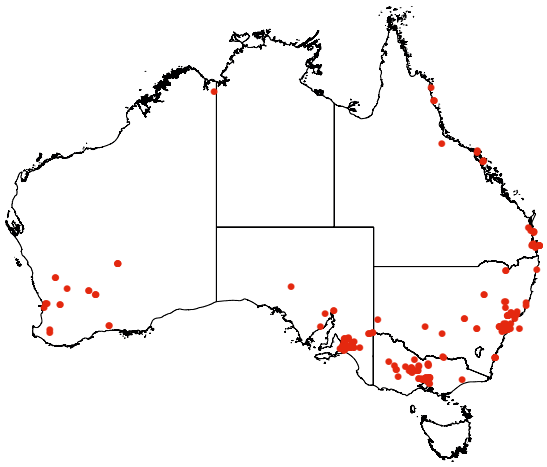
Opuntia ficus-indica

Opuntia monacantha
Drooping tree pear

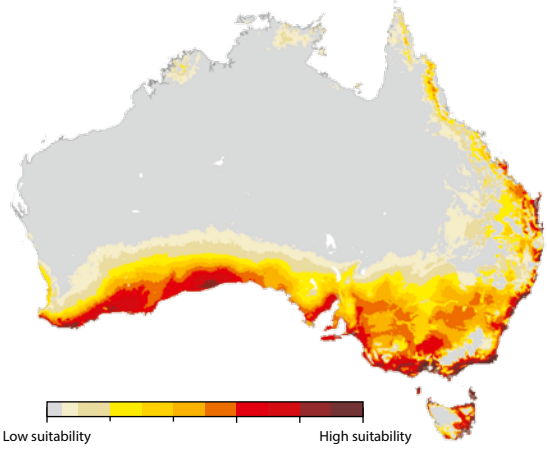
Origin and distribution

Opuntia monacantha originates from South America, with distribution throughout Brazil, Paraguay, Uruguay and Argentina (Anderson, 2001). Its invasive range includes southern Africa, Asia, Europe, Australia and islands in the Pacific and Indian Oceans.

Opuntia monacantha is thought to have been introduced to Australia by the first fleet, probably as a food plant for cochineal insects used to produce carmine (red) dyes. By the 1840s it appeared regularly in nursery



Current distribution of Opuntia monacantha (●)



Habitat suitability for Opuntia monacantha (Duursma et al., 2013, www.weedfutures.net)

catalogues throughout Australia (Parsons and Cuthbertson, 2001).

Opuntia monacantha is very widespread and relatively common in northern Qld and south-eastern SA. It also has a scattered distribution in coastal south-eastern Qld, eastern NSW, Vic, SA and south-western WA (Navie, 2004).

Habitat in Australia

Opuntia monacantha is mostly found in sub-tropical, semi-arid and warmer temperate environments. It is a weed of pastures, open woodlands, waterways, roadsides, railways, and riparian and coastal areas, often on sand. It tolerates shaded areas and higher rainfall compared to many other *Opuntia* species (Navie, 2004). Habitat suitability modelling indicates that it is largely restricted to coastal regions of southern and eastern Australia.

Features to note

Opuntia monacantha is an easily distinguishable upright shrub or small tree. Plants have an obvious drooping appearance and flattened, spiny, glossy green pads (cladodes). The yellow flowers have distinctive reddish 'stripes' on the outer 'petals'.

Opuntia monacantha produces viable seeds that are bird dispersed. It also reproduces vegetatively, by cladodes and fruit, which often grow in chains. These are readily dislodged by storms or floods and can be transported in flood waters (see case study on page 130).

Management considerations

As with many opuntioid cacti, *Opuntia monacantha* is drought-tolerant and can form dense infestations. The potential for flood waters to transport and spread cladodes and fruit should be considered when planning management of infestations in riparian areas (see case study on page 130).

Matt Sheehan

Matt Sheehan

Bob Chinnock

Opuntia monacantha

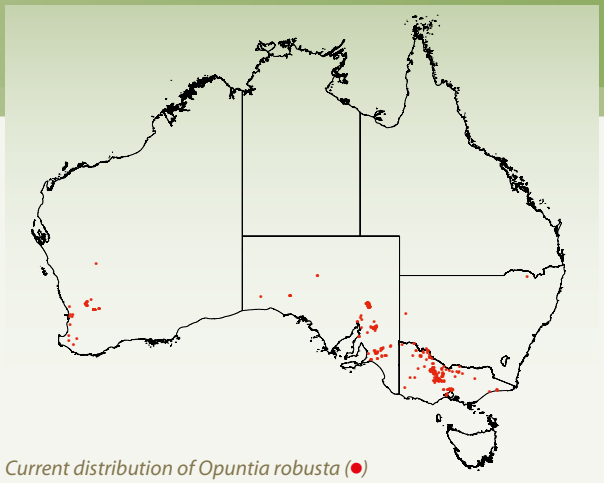
An effective biological control agent, *Dactylopius ceylonicus*, is available for this species.

Opuntia robusta
Wheel cactus

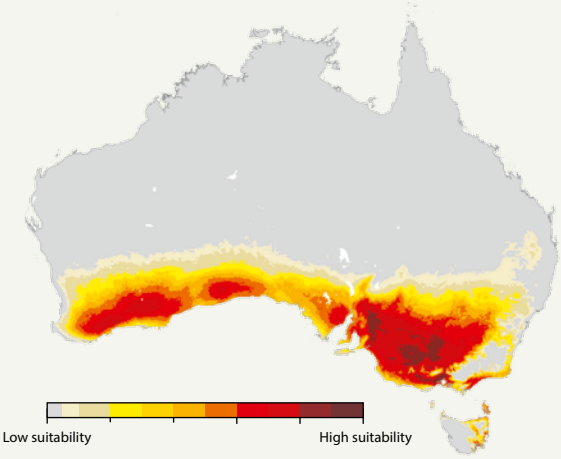
Origin and distribution

Opuntia robusta is native to northern and central Mexico, where it is rare and endangered (GRIN, 2007).

The date and method of introduction to Australia is unknown, but it was likely to have been introduced as an ornamental plant in the early 1900s and was proclaimed a weed in Vic in 1961 (Hosking *et al.*, 1988). It is widespread in SA (including the Flinders Ranges, from Pt Augusta to the mid-north and the Eastern and Murray regions) and north-central Vic. It also occurs in NSW, and coastal and inland areas of the south-west of WA.



Current distribution of Opuntia robusta (●)



Habitat suitability for Opuntia robusta (Duursma et al., 2013, www.weedfutures.net)

Habitat in Australia

Opuntia robusta is drought-tolerant and prefers arid and semi-arid areas in warm, temperate regions. It grows on a wide variety of soils and commonly invades open woodland, pasture, rocky outcrops, hills and ranges. Habitat suitability modelling indicates that it is highly suited to southern WA, southern SA, western and central Vic, and western NSW.

Features to note

Opuntia robusta can be differentiated from other similar *Opuntia* species by its round, dull grey-green, dinner plate sized pads (cladodes). A branched shrub growing up to 4 m, it produces numerous, single fruit on the margins and faces of pads.

Opuntia robusta produces viable seed and frequently occurs in dense 'halos' under and around large eucalypts where birds roost. Plants grow rapidly and can reproduce in 3–4 years from seed. Pads are large, heavy and strongly attached to each other and therefore are not carried by wildlife or stock. Instead, vegetative spread happens close to parent plants or down hill in steep country. It can also be spread in floodwaters in riparian zones. Deliberate dumping is a major vector for vegetative spread.

Management considerations

Control options for *Opuntia robusta* are limited to biological control, physical removal and stem injection. The use of biological control (*Dactylopius opuntiae*) on this species is relatively new in Australia, but it is having an impact on fruiting and overall plant health in parts of SA. Herbicide treatments, though effective, are labour intensive because infestations are typically dense and in difficult-to-access locations.

See case study on page 118 for further discussion on *Opuntia robusta* control.

Lorraine Edmunds

R.Bates

PIRSA

Opuntia robusta

Opuntia stricta
Common prickly pear

Origin and distribution

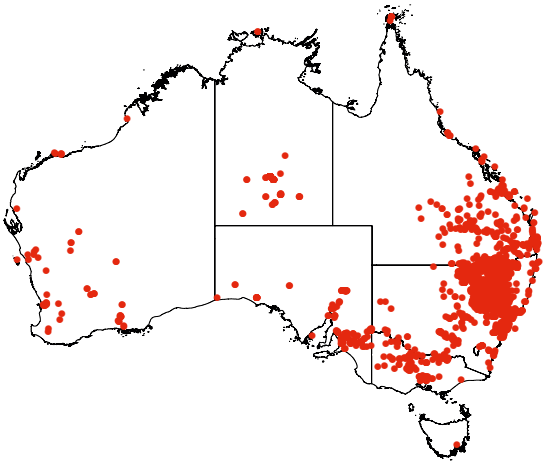
Opuntia stricta is native to the southern USA, central America, northern South America and the Caribbean (Anderson, 2001). It has become invasive throughout Western Asia, Africa, Europe, Australia and islands in the Pacific and Indian Oceans.

Opuntia stricta was brought to Australia in the early days of settlement, probably as a food plant for cochineal insects used to produce carmine (red) dyes. A potted plant was brought to Scone, NSW, in 1839 and it spread rapidly north into Qld.

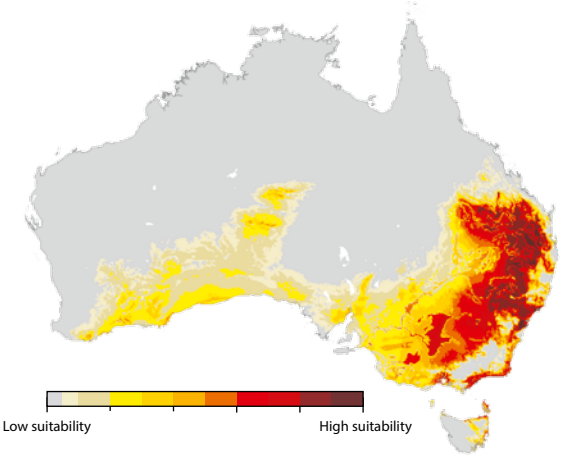
Opuntia stricta is extremely widespread throughout the eastern areas of Australia and also scattered throughout many other parts of the country. It is most abundant in central and southern Qld and northern NSW and relatively common in other parts of NSW. It is common in northern and western Vic, and from the Flinders Ranges south to the Murray Region in SA. It also occurs in the western and south-western regions of WA and in scattered locations in northern Qld and in the southern part of the NT (Navie, 2004).

Habitat in Australia

Opuntia stricta is drought-tolerant and invades lowland grassland and grassy woodlands, forests, pastures, disturbed areas and roadsides. It grows on plains, ranges, rocky steep slopes, riparian areas, beaches and off-shore islands on a great variety of soil types including heavy clays, loams, saline soils and sands (Chinnock, 2007, pers. comm.). More recently *Opuntia stricta* has started to invade cropping areas in WA.



Current distribution of Opuntia stricta (●)



Habitat suitability for Opuntia stricta (Duursma et al., 2013, www.weedfutures.net)

Rob Richardson

Rob Richardson

Opuntia stricta

Features to note

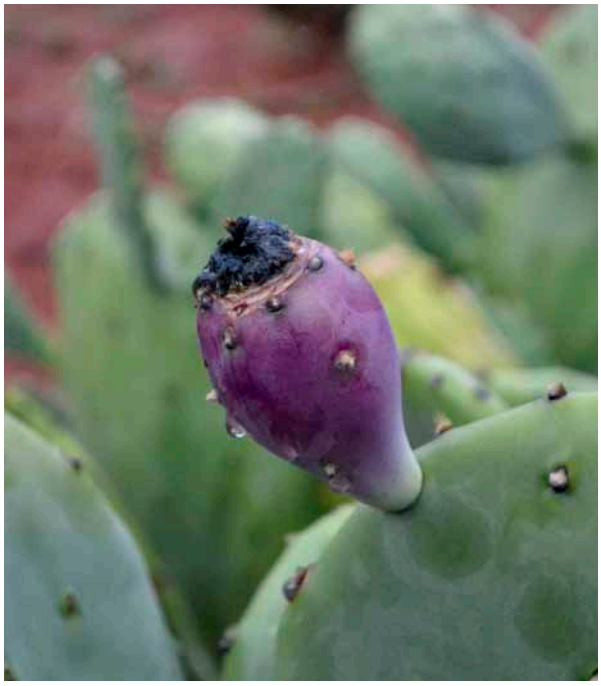
Perhaps the most infamous opuntioid cactus, *Opuntia stricta* once covered vast areas of Qld and NSW, until it was successfully controlled by biological control agents in the late 1920s. Many other opuntioid cacti species are still incorrectly referred to as prickly pear.

An upright, spreading shrub, usually growing to around 1 m in height, *Opuntia stricta* is a dull green plant with elongated pads (cladodes) and bright yellow flowers. This species spreads both by seed and vegetatively from cladodes, fallen flowers or immature fruit; these propagules easily root within a few months of contact with the soil. It can be mistaken for *O. ficus-indica*, but *O. stricta* usually has smaller cladodes.

Management considerations

Successful management of *Opuntia stricta* has been achieved both historically and today through biological control agents (cactoblastis

Shauna Potter



Henry Rutherford

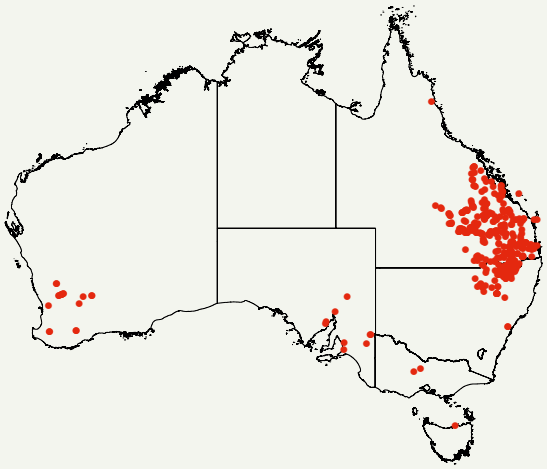
Opuntia stricta

and cochineal). Using biological control, in combination with other methods, the impacts of this species can be dramatically reduced (refer to Chapter 4 pages 109–112 for more information on the history of biological control for *Opuntia stricta*).

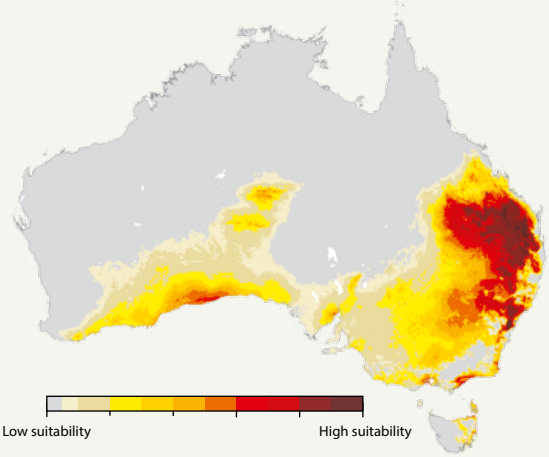
Opuntia tomentosa
Velvet tree pear

Origin and distribution

Opuntia tomentosa is a native of Mexico and Guatemala, with an exotic range extending to Western Asia, Africa, Europe, Australia and Pacific Ocean islands. The history of introduction to Australia is unknown, but it is likely to be similar to other *Opuntia* species, either introduced as an ornamental plant, hedge plant, fodder crop or as a plant host for cochineal insects (Fuller, 1998). By 1912, *Opuntia tomentosa* was common around Goondiwindi and Warwick in Qld.



Current distribution of Opuntia tomentosa (●)



Habitat suitability for Opuntia tomentosa (Duursma et al., 2013, www.weedfutures.net)

The species is widespread in central and southern Qld. It is also present in northern NSW and occurs as solitary plants or localised populations in south-eastern SA, Vic and WA.

Habitat in Australia

Mostly found in sub-tropical, semi-arid and warmer temperate environments. It is a weed of roadsides, railways, pastures, grasslands, open woodlands, rangelands, disturbed sites and waste areas.

Features to note

Opuntia tomentosa is easy to identify in the field, with its branching, tree-like shape and height of up to 5 m. The pads (cladodes) and fruit are covered in fine hairs, giving a velvety appearance to the plant. Brilliant orange flowers give rise to red, egg-shaped fruit.

Opuntia tomentosa readily reproduces from seed, as well as cladodes, fallen flowers or immature fruit; these propagules easily root within a few months of contact with the soil. Plants growing adjacent to creeks and waterways can be dispersed downstream. Discarded plants and movement of plant parts during disposal has led to new outbreaks.

Management considerations

Biological control, foliar spraying, stem injection and physical removal have all been used to good effect in the right situation and can work well as an integrated management approach. Be mindful that plants are often large, so off-target impacts of methods such as foliar spraying may be significant and therefore may not be appropriate in some situations.

Bob Chinnock

Bob Chinnock

Shauna Potter

Bob Chinnock

Opuntia tomentosa

Chapter 2

Planning

Why plan?

Good weed management is about effective land management, and planning is a critical first step. While it is tempting to 'jump straight in', it is important to plan ahead before undertaking management to ensure the best possible outcome. A well thought out plan that takes a strategic approach can:

- Make weed management tasks more achievable;
- Reduce the off-target impact of your control;
- Prevent reinvasion in the long term; and
- Save time, effort and money now and into the future.

Cacti management is a long-term exercise so it makes sense to approach tasks systematically and sequentially, just as you would for any other land management activity. Developing and following a weed management plan is important because it will help you to:

- Prioritise the use of limited resources;
- Identify the best means of control, increasing your chances of success;
- Coordinate activities with your neighbours;
- Meet your legal obligations (in states where applicable – see Chapter 6 for further information);
- Incorporate critical tasks into general property planning; and
- Undertake monitoring activities to gauge success.

Most importantly, a plan enables you to ask and answer the questions that will assist you in making the most informed management decisions. Useful questions to ask in the development of your plan can be seen in Figure 2.1.

Lee Mead

Volunteers from the Tarrangower Cactus Control Group ready to implement their strategic plan

Matt Sheehan

Monitoring the effectiveness of control techniques – a critical component in planning and improving future management

This chapter is based on the Introductory Weed Management Manual published by the Cooperative Research Centre for Australian Weed Management (2004b), which is available for internet download from http://nrmonline.nrm.gov.au/catalog/mql:582.

Some content was adapted from the *Asparagus weeds Management Manual: current management and control options for asparagus weeds (Asparagus spp.) in Australia* (OEH, 2013).

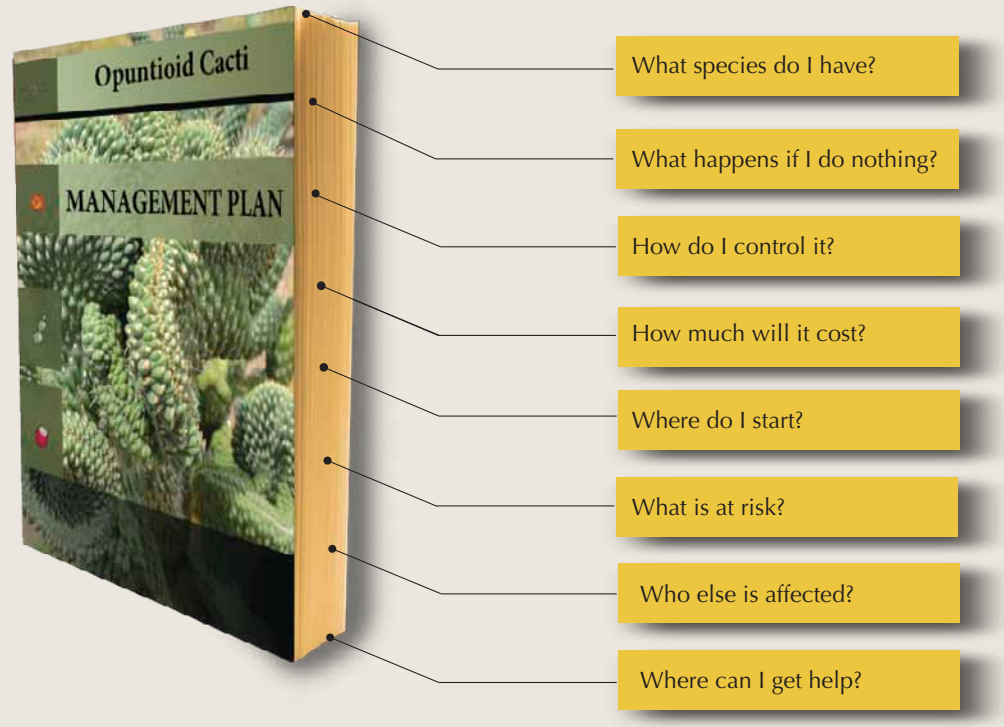


Figure 2.1 The types of questions that can be addressed through a weed management plan

Planning principles

A good plan is one that provides a clear path to your management goals, allowing for flexibility and refinement along the way. It doesn't need to be lengthy or elaborate (see 'At what scale should you plan?' on page 53 for further information), but it must take into account the long-term nature of cacti management.

Thought should also be given to why you are developing a plan. Be clear on:

- Why you want to manage cacti;
- How a plan can assist in reaching your management goals;
- What success will look like;
- How to integrate management activities into day-to-day operations; and
- Who needs to be involved.

There are no silver bullets in the cacti manager's toolkit. Ensure your plan considers important concepts like multiple treatments, adaptive management, integrated weed management and monitoring for regrowth or reinvasion. That way you will be on the path towards success.

A guide to developing and implementing a weed management plan is provided here, and includes a checklist of things to consider when developing your plan. Figure 2.2 summarises the main steps of the planning cycle. Initial assessment of the situation leads to the development of goals and priorities. These form the basis of a plan that identifies and guides on-ground management and follow-up actions. Review of outcomes allows reassessment and refinement of the plan and the management approach to ensure goals continue to be achieved long term.

Developing a management plan

The following steps provide further guidance on the content of your management plan, including examples of how you might approach and apply each step. Key points are summarised in the checklist at the end of this chapter on page 62.

Step 1. Assess the situation

Understanding the scope of works required to manage your cacti infestation is the first step in developing your plan. This involves collecting information and making decisions based on what you find.

Identify and research the target species

Identifying and understanding the species you have is critical in determining the most appropriate management option.

If you have multiple cacti species you may have to use a combination of different methods, for example biological control for one species and chemical control for another. You may also have to use multiple methods at different times in the calendar year for one species at a specific site. Be mindful that this may increase the complexity and cost of the management program.

Map infestations

A large-scale topographic map, an aerial photograph, a map from an internet mapping tool or a hand-drawn mud map are all effective ways to record infestations. A map of the area of interest is a critical component of your plan. It forms the basis for recording information for your site assessment and planning your control activities. Ideally a map should show:

- Site/property boundaries;
- Location and extent of weed infestations;
- Location and types of assets (significant environmental, agricultural and cultural sites);

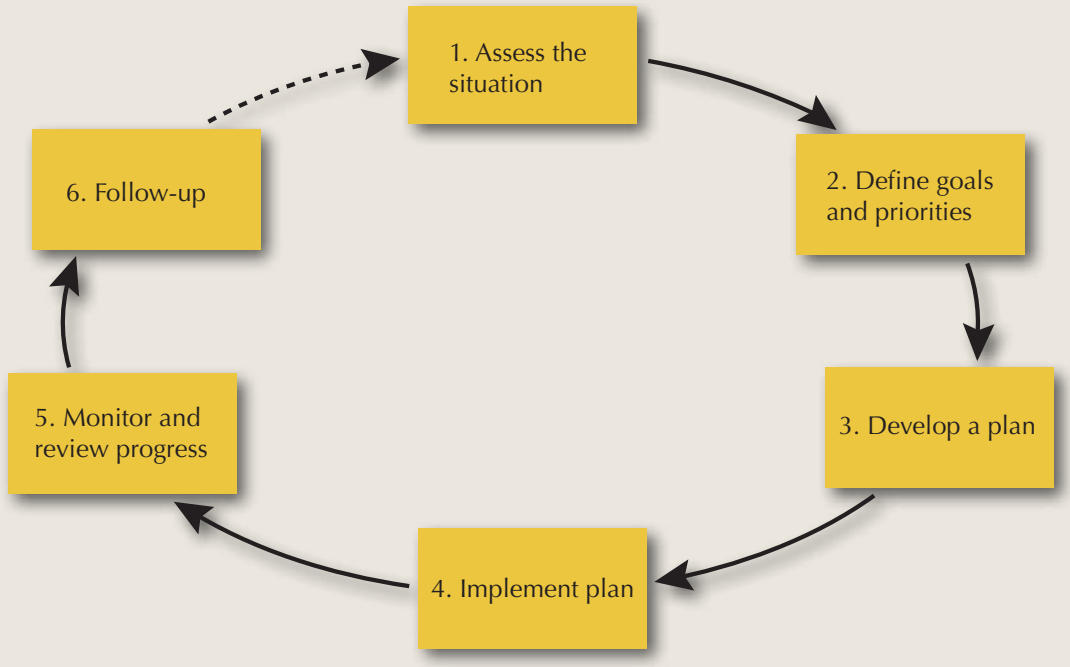
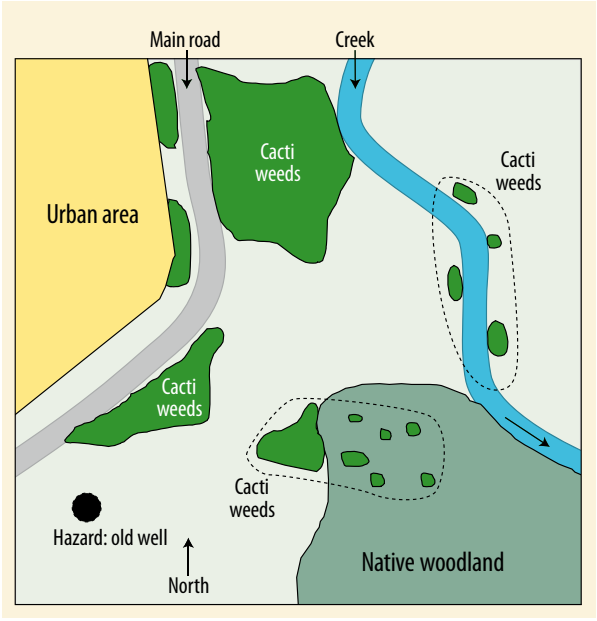


Figure 2.2 Planning cycle flowchart: Six steps to effective cacti management through the development and implementation of a weed management plan

- Old homesteads, dumping sites or other hot spots commonly associated with cacti introduction;
- Spread pathways such as water courses, stock routes, roads, etc.; and
- Changes in weed location and density over time.

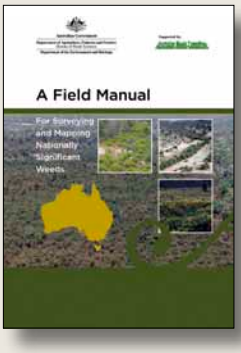


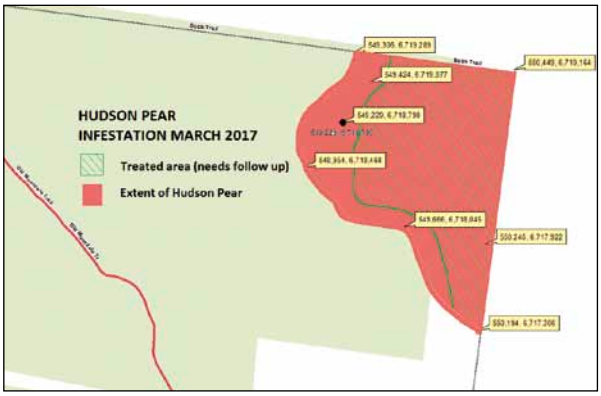
Example mud map showing cacti infestations and items of interest

Online assistance for mapping weeds

There are many mapping tools freely available online. For example, the Atlas of Living Australia (www.ala.org.au) provides a free platform for interactive map making.

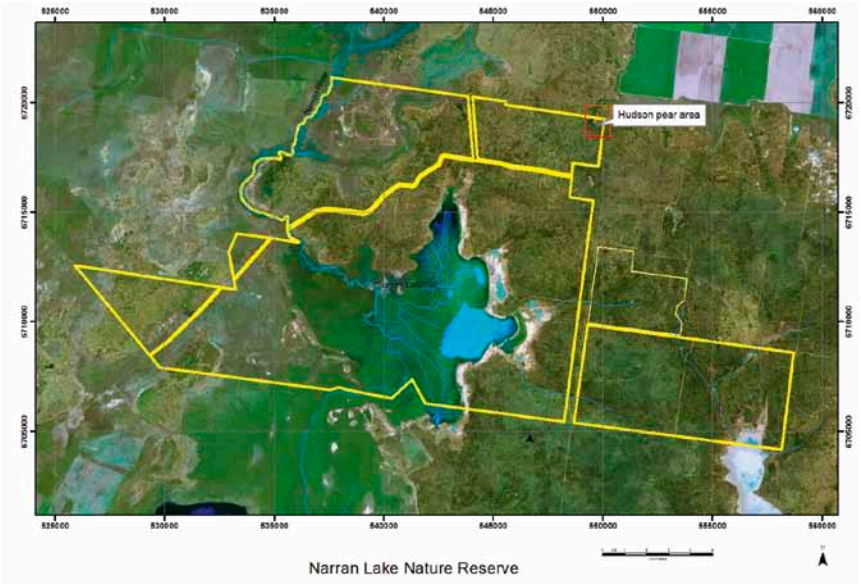
National guidelines for weed mapping are also available. *A Field Manual for Surveying and Mapping Nationally Significant Weeds* is available at http://www.weedcenter.org/management/docs/Aust_mapping.pdf (see Chapter 6 page 157)





NSW NPWS (National Parks and Wildlife Service)

Example of a map derived using GIS software, showing management information such as individual plants, infested areas and treated areas



NSW NPWS (National Parks and Wildlife Service)

Example topographic map being used to determine management areas at a landscape scale

At what scale should you plan?

Whether you plan to control a small patch or an entire region, the scale of the weed infestation will influence the type of plan you produce. Consider the following:

Property scale
This may involve a small site or a single property. A relatively simple plan – consisting of a mud map, control techniques, a calendar of control activities and monitoring prompts – should be enough to help achieve your goals. Remember that external factors may influence your success (e.g. reinvasion from neighbouring land).

Landscape scale
This could include several neighbouring properties, nearby reserves, national parks or whole catchments or floodplains. A larger scale will require a more complex plan, and may involve multiple land owners. It may be necessary to form partnerships, which may help with gaining and maintaining momentum, working together to a common goal.

(**Note** Property size varies across Australia. A property scale plan for landholders in northern Australia may be the equivalent of a landscape scale plan in southern Australia.)

Matt Sheehan

Medium (11–50% cover) infestation of Cylindropuntia fulgida var. mammilata amongst native grasses and bare soil

Matt Sheehan

Heavy (>50% cover) infestation of Cylindropuntia fulgida var. mammilata amongst native grasses and bare soil

Consider weed density

There are many methods to determine or describe weed density or the amount of an area/site that is covered by weeds. Table 2.1 provides examples of how you can describe density.

Considering weed density will help you set realistic goals and priorities (see Step 2. Define goals and priorities page 54). For example, you are unlikely to eradicate cacti if you have large, dense infestations that cover over 50% of your property.

Table 2.1 Example of density descriptions used in various density classification methods

Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
1–10% cover	Light	Rare or isolated	Occasional	Single plants and clumps	Scattered individual plants
11–50% cover	Medium	Marginal	Common	Partially accessible thickets	Scattered patches with isolated plants interspersed
51–100% cover	Heavy	Core	Abundant	Impenetrable thickets	Large, dense infestations

Weed density may also influence access to the weed and hence the control technique you select. For example, stem injection may be a suitable technique for scattered, individual plants but impractical for dense, impenetrable thickets.

See Chapter 6 page 157 or *A Field Manual for Surveying and Mapping Nationally Significant Weeds* (available at http://www.weedcenter.org/management/docs/Aust_mapping.pdf) for further guidance on estimating weed density.

Establish a baseline

Using information collected on weed distribution and density, you can establish a baseline or a reference point at the start of your management program against which you can record change and assess the effectiveness of management outcomes over time.

Identifying risk to safety and welfare

Take note of any site hazards or issues associated with safety and access (steep or uneven terrain, abandoned mine shafts, barbed wire, dumped material). Perform a safety assessment for your property and neighbouring residents if necessary.

Identify and record assets

This may include the presence of rare and threatened plants, animals or ecological communities, highly productive farming or grazing land, and cultural and heritage sites.

Determine management history

Who are the stakeholders involved and are there historical factors that may influence management (e.g. disturbance history such as floods, livestock grazing, old homesteads where cacti were planted, old mine sites where cacti were used to defend leases, old dumping sites of garden waste, etc.)? Mark these sites on your maps.

Step 2. Define goals and priorities

It is now time to set clear, realistic goals based on your site assessment. Revisit what you want to achieve with your weed management. Are you trying to prevent weed spread throughout your property or protect a significant asset?

Your objective should be time bound. It can be useful to set objectives to be achieved in the near term (1–2 years) and the medium or longer term (5–10 years or beyond).

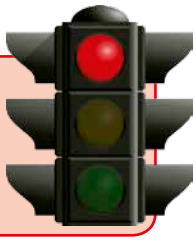
Setting goals

A useful starting point to determine your goals is to consider the level of weed invasion and assign an appropriate management objective, for example:

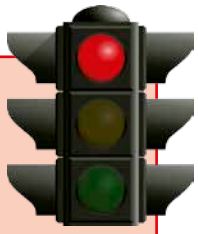
Management objective	Description
PREVENT	A management objective that prevents new weeds from arriving and/or establishing
ERADICATE	A management objective to eliminate all plants and propagules from an area, where there is limited or no potential for reinvasion
CONTAIN	A management objective that prevents the further spread and establishment of the weed beyond a predefined area (core infestation) and reduces the impact within the area where it occurs
PROTECT ASSETS	A management objective that reduces the adverse impacts of widespread weeds on high value assets by protecting and restoring those assets

See Figure 2.3 to learn how to turn a management objective into on-ground action.

PREVENTION relies on knowledge of how cacti spread. See Chapter 1 for further information.



Eradication – is it feasible?



Eradication is a term that is commonly misapplied. Successful eradication relies on the elimination of every individual of a species (including propagules, e.g. seeds and cladodes) from a defined area in which recolonisation is unlikely to occur (Panetta, 2016). This is extremely difficult to achieve and as a result eradication is a management outcome that is rarely achieved. Eradication of opuntioid cacti should only be attempted after due consideration of whether the outcome is achievable. Generally, eradication is only possible when:

- The weed is in the very early stages of establishment;
- Distribution and abundance are low across the general area;
- All infested areas are known;
- The chance of reinvasion from surrounding areas is unlikely;
- Newly emerged plants are easily detected and controlled before seeds are released;
- There is low potential for a persistent soil-stored seed bank; and
- Resources are sufficient for regular surveys and ongoing long-term management.

See page 114 for a case study of the eradication of opuntioid cacti from the Northern Territory.

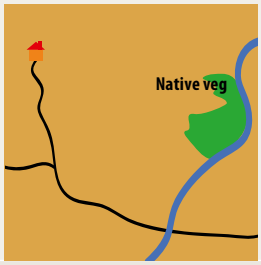
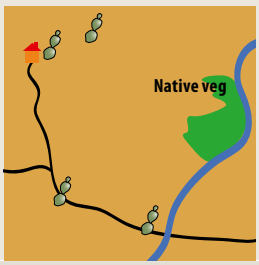
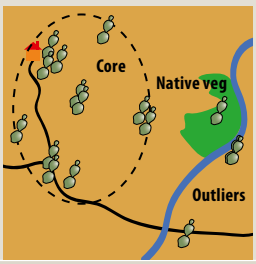
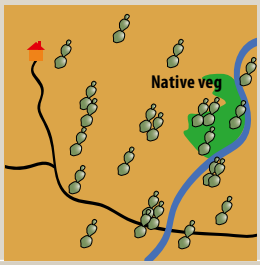
				
Stage of invasion	▪ Absent	▪ Early stages of invasion ▪ Low distribution, localised ▪ All infestations are known	▪ Scattered to widespread ▪ Extent of infestation could be greater than realised ▪ Beyond eradication, but can be contained	▪ Widespread and abundant throughout range ▪ Beyond eradication and containment
Management objectives	**PREVENT** ▪ Stop establishment	**ERADICATE** ▪ Eliminate all plants, propagules and seeds (including seed banks)	**CONTAIN** ▪ Prevent further spread ▪ Remove outlying infestations and prevent spread beyond the boundaries of core infestations	**PROTECT ASSETS** ▪ Reduce adverse effects on highly valued assets ▪ Reduce density ▪ Reduce seed production and propagule spread
Management activities	▪ Surveillance ▪ Hygiene/spread prevention ▪ Education and awareness	▪ Surveys to determine extent (delimitation) – see case study on page 126 ▪ Hygiene/spread prevention ▪ Management (chemical and/or physical)	▪ Hygiene/spread prevention ▪ Integrated management (chemical, physical, bio-control)	▪ Hygiene/spread prevention ▪ Integrated management (chemical, physical, bio-control)

Figure 2.3 **Using a weed invasion stage to determine management objectives and actions**

Prioritising sites

Site prioritisation is generally based on a risk assessment that looks at the feasibility of control (how likely are you to be able to effectively control the weed) and the risk posed by the weed (including its invasiveness, impacts and potential distribution). Prioritise which sites you focus on as follows:

PRIORITY 1	**New, small or outlying infestations** These should be eradicated where feasible to stop a seed bank from developing and reduce the likelihood of a large infestation forming. Undertake strategic surveillance of potential cacti sources or pathways, such as old homesteads and dumping sites.
PRIORITY 2	**Areas with high risk of spread** Areas such as roadsides, riverbanks or floodplains and stock routes should be targeted as a priority to limit further spread and reduce the chance of new infestations developing. Targeting point sources of infestations, such as old homesteads and dumping sites is also a strategic management priority.
PRIORITY 3	**High value assets** Where infestations are established, the priority is to reduce impact on important assets. This may include pastoral land, high value remnant grasslands or sites of community or cultural importance.

Priorities can be further assessed by examining the:

- Size of the infestation;
- Age of infestation (and approximate extent of seed bank);
- Proximity to other infestations;
- Site access; and
- Resources available.

Seek advice and input from weed management experts and neighbours to ensure that your priority setting is sound and will be supported by those around you.

What else is being done?

Align your weed management actions with your other property management plans and objectives. There may be opportunities to combine activities or plan around busy periods, ensuring important weed work is not forgotten.

Consider or investigate what others are doing to manage cacti in your area. Try to integrate or complement work occurring at the local, catchment or regional levels and seek guidance and feedback from neighbours, nearby landholders and local groups when necessary.

Am I obliged to plan?

Developing a plan is always a good idea, but in some jurisdictions it may be a legal requirement (see Chapter 6).

There may also be other factors that will influence your plan. For example, herbicide legislation, regulations regarding the use of fire, or laws protecting native vegetation may affect the management techniques available to you. Chapter 6 provides relevant contact information for weed management authorities in each state and territory.

Step 3. Develop a plan

It's time to pull together the information you have gathered in Steps 1 and 2 to develop a plan. Think of it as the who, what, where, when and why of cacti management, and then cost it by developing a budget based on the activities you have proposed.

Who is or will be involved?

If your plan includes multiple stakeholders it is important you agree on the objectives. Allocating responsibility for each action will reduce confusion and help you to monitor progress.

Also consider whether you have the skills needed for all actions. You may need to seek help from a weed professional, your neighbour or your local weed management authority.

Why are you doing it?

State the goals, aims and objectives and realistic timeframes for achieving them. What are you trying to protect? How does it complement existing plans or past works?

What are you doing? What are the actions?

Select and detail your integrated management and control techniques for the species of cacti you have. See Chapter 4 page 75 for a discussion on integrated management.

Identify other actions that might address what is causing or exacerbating the problem. For example, opuntioid cacti can be spread by humans who still plant them, transport them unintentionally with machinery or dump them in garden waste. Are there actions that can address the cause of your weed problem?

When are you doing it and for how long?

Be flexible to allow for, and take advantage of, seasonal variation. Consider the best timing of the chosen treatments based on efficacy and safety of personnel (e.g. chemical treatment works best when cacti are actively growing).

The management plan should set out treatment for at least three years, but longer if possible. The plan should also include follow-up activities (see Chapter 4 page 112 for further information) and time for monitoring.

Plan for flexibility to adapt to circumstances such as drought, fire bans, extreme weather events, or difficult access to infestations. If resources allow, incorporate the assessment and/or control of other invasive weeds at the same time.

A calendar is a simple way to keep track of planned management activities. A calendar that combines your weed management tasks with other jobs around your property will help identify conflicts and efficiencies in your property management.

Where will you do it?

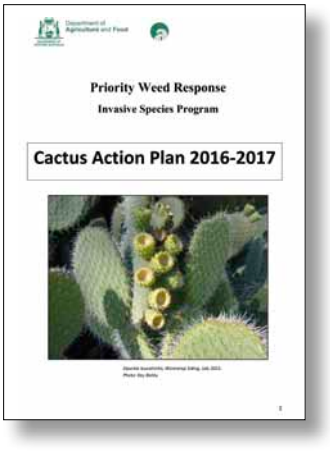
Based on the priority setting process outlined in Step 2, clearly identify in your plan where the works will be carried out. If it is a multi-year plan, you may want to identify different priorities that will be tackled at different times throughout the program. If you are taking an integrated approach, you may have several sites you are targeting at the same time but using different control techniques. To communicate where you will be working:

- Identify sites on your map;
- Be clear what the management objective is for each site (e.g. eradication, containment, asset protection); and
- Link to the calendar for when management will occur at those sites.

What are your resources?

It is critical to assess whether you have access to the skilled personnel, funds and equipment needed to complete the work.

Human resource considerations include: available skills sets; occupational health, safety and welfare (OHS&W) obligations; insurance; availability and how to avoid burn out.



Example of a management plan: WA Action Plan for Opuntia cacti

Financial considerations include the cost of weed management (consumables and equipment), the cost variation amongst control techniques, the requirement for ongoing or follow-up treatment and specialised labour if you are unable to undertake the work yourself.

How much will it cost?

This is a frequently asked question with no clear answer! The cost of cacti management can vary greatly depending on the size, density and location of the infestation, site accessibility, preferred control technique – the list goes on!

Tips for estimating the cost of weed control:

- Consider *total* management costs, including running costs, labour, equipment purchase or hire. If in remote areas you may also have to factor in travel and accommodation;
- Determine short-term and long-term budgets based on each management phase; and
- Factor in the cost of follow-up and monitoring. This is often underestimated.

How to reduce costs:

- Explore the possibility of borrowing equipment from neighbours, local councils, Landcare groups or Natural Resource Management groups;
- Decide whether a contractor is necessary or if activities can be undertaken in-house; and
- Find out if there are any financial incentives, grants, low-interest loans or labour programs available that might reduce the financial burden.

Step 4. Implement your plan

It is time to get your hands dirty! Use the plan to keep you on track, keep you motivated and remind you why you are managing cacti.

Prevent new infestations by adopting hygiene protocols during management, for example always inspect vehicles and equipment before leaving the site (see Chapter 4 page 79 for further information).

Step 5. Monitor and review progress

Monitoring is an essential component of any weed management program. Monitoring allows you to:

- Measure the success of the management program, ensuring objectives are being met;
- Decide when and how to follow-up;
- Decide if you need to adjust your management program;
- Assess the rate of native plant or pasture recovery after cacti removal;
- Identify any new weed infestations or issues that may affect the success of your program;
- Demonstrate progress to your group, financial organisations or funding body; and
- Raise awareness for group momentum and general education.

It is important to assess the success of initial management to keep track of progress and costs and adjust techniques as required for follow-up management (see Figure 2.4). To make more efficient use of time, monitoring can be incorporated into follow-up activities (see Step 6 below and Chapter 4 page 112 for a discussion on follow-up).

Monitoring approaches can include:

- Maps that document expansion/reduction of infestations against the maps you prepared at the start of the program (baseline maps);

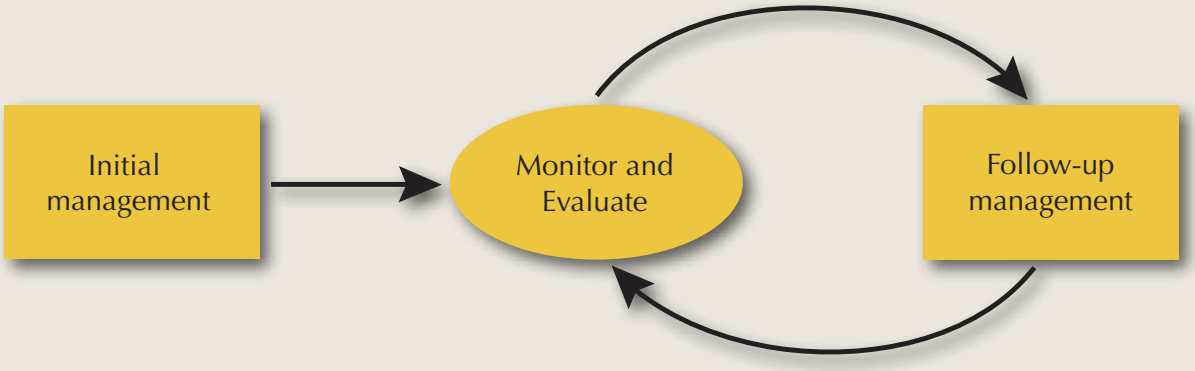


Figure 2.4 Monitoring and evaluation of the initial management program informs future follow-up treatments, improving outcomes through adaptive management

- Photo monitoring (see 'Establishing photo monitoring points' on page 60) to:
  - An easy 'visual' method of assessing progress over time;
  - Help document the size and condition of opuntioid cacti at the time of control;
- A log of activities, dates, climatic and environmental factors to help determine why some methods may have worked one year but not in another (see Chapter 6 page 156 Treatment Record Sheet);
- Assessing costs through records of expenditure and revenue;
- Records of herbicides used and their efficacy; and
- Recording failures as well as successes to ensure ongoing improvement and development of management practices.

Based on the findings of your monitoring, review your program and assess if your management activities are meeting priorities and goals. Where management outcomes were not as successful as expected, determine why and, where possible, adjust management to overcome barriers to success.

Key review questions to ask include:

Key review questions	Possible responses
Was the plan implemented? If not, why?	Lack of time, low resource availability, weather conditions
Did you achieve your outcome? If not, why?	Poor efficacy of herbicide treatment due to application error
Was the cost over or under budget?	Underestimated time required to treat infestations
Did the management program suit the situation?	Forgot to control individual plants in Priority 1 areas Herbicide used when cacti was stressed due to drought Did not survey the creek banks for new plants
Were there any positive or negative changes in the condition of the site(s) as a result of the management tasks?	Increased carrying capacity/ stocking rate in previously cacti-affected paddock Return of native species Cacti being spread into other paddocks by the movement of stock or equipment being used for control
What could you have done differently?	Involved the local community, kept better records

Establishing photo monitoring points

When set up correctly, photo monitoring can be one of the cheapest and most reliable records of change over time. It is quick, inexpensive, requires little technical skill and causes little to no disturbance of the site.

To establish photo monitoring points:

- Mark out the location where the photo will be taken with a star picket. If possible, record the location with a GPS.
- Where possible, align the photo in a north-south direction to avoid excessive sun or shadow. If not possible, record a compass bearing of the direction the camera is pointing. Try to have the sun behind you when taking photos.
- Take photos in the morning or afternoon, or on a slightly overcast day to avoid excess glare or downward shadows.
- Where possible, include distinct objects in the photo to provide a basis for comparison (e.g. a significant tree or piece of infrastructure).
- Use the same camera and settings each time.
- Take photos as frequently as needed to show changes.
- Try to take photos at the same time of year for annual comparisons.

Doug Beach

Doug Beach

Opuntia robusta (wheel cactus) control photo monitoring point at Pigeon Hill in Victoria
(i) Site in 2010 prior to management; (ii) The same site in 2014
Note the use of a tree on the left hand side as a distinct reference point

Step 6. Follow-up

The key to successful opuntioid cacti management is a commitment to an appropriate follow-up program. Follow-up is essential because:

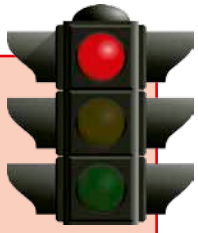
- Soil-stored seeds may continue to germinate for another 3–20 years;
- Seeds or cladodes may continue to spread in from other areas and form new plants;
- Large, dense infestations may take many years to contain; and
- Cacti are difficult to kill so it is common for treated cacti to reshoot.

You will need to determine the frequency of your follow-up, noting that many chemical treatments take a long time (3–8 months) to completely kill opuntioid cacti. Six-monthly follow-up is a good starting point, and as the program continues and you start to reduce the number of cacti, you may be able to reduce the frequency to annually for at least 10 years. The most important consideration is that your follow-up is implemented at a frequency that is likely to impact new seed production and reduce propagule spread.

See Chapter 4 page 112 for further discussion on follow-up.

Matt Sheehan

Re-establishment of Opuntia robusta (wheel cactus) following unsuccessful mechanical control



WHACK IT ONCE AND WALK AWAY?

We know cactus is hard to kill – that is in part why it is a successful weed in Australia. While research is underway to improve management success, the methods currently available to us require ***FOLLOW-UP***, ***FOLLOW-UP*** and more ***FOLLOW-UP***.

Matt Sheehan

Seedling germination following mechanical removal of Opuntia tomentosa (velvet pear), Goomalling WA

Management Plan Checklist

Step		Further information
1. Assess the situation		
☑	**Identify and research the target species**	Chapter 1 'Biology' and Chapter 4 'Managing cacti'
☑	**Determine the extent (distribution and density)** by mapping infestations and estimating density (Establish a baseline)	Chapter 6 'Further information' *A Field Manual for Surveying and Mapping Nationally Significant Weeds*
☑	**Identify any risks to safety and welfare**	Chapter 3 'Safety and welfare'
☑	**Identify and record assets**	
☑	**Determine land use and/or management history**	
	Remember to identify the scale of your plan (e.g. property scale or landscape scale)	
2. Define goals and priorities		
☑	**Set goals** (Prevention, eradication, containment or asset protection)	
☑	**Prioritise sites** ▪ New, small or outlying infestations ▪ Areas with high risk of spread ▪ High value assets	
☑	**Find out what else is being done?** Other plans, strategies	Contact your local weed management authority Chapter 6 'Further information'
☑	**Know your management obligations** Are there any legal obligations in your state and territory and what is involved?	Chapter 6 'Further information'
☑	**What are your resources?**	Chapter 4 'Managing cacti'
3. Develop a plan		
☑	**Who** is or will be involved? **Why** are you doing it? **What** are you doing? What are the actions? **When** are you doing it and for how long? **Where** will you do it?	*Introductory Weed Management Manual*
4. Implement your plan		
☑	**Implement your plan**	Chapter 4 'Managing cacti'
☑	**Develop and implement hygiene protocols** to prevent spread	Chapter 4 'Managing cacti'
5. Monitor and review progress		
☑	**Establish a monitoring and evaluation program**	
☑	**Is your management adhering to your priorities and goals?**	
6. Follow-up		
☑	**Have you allowed for adequate follow-up?**	Chapter 4 'Managing cacti'

Chapter 3

Safety and welfare

Safety and welfare should be foremost in the minds of those managing opuntioid cacti. These species are literally a prickly problem! All species are covered with glochids (fine barbed bristles) and most have spines of varying number and length (see Chapter 1). These two features alone call for careful consideration of the wellbeing of:

- People handling cacti (during surveys, control and collection of material);
- People exposed to cacti through outdoor activity (e.g. bushwalking);
- Farmers/pastoralists through agricultural work; and
- Animals, both livestock and wildlife.

In addition to physical injury is the psychological impact that can be associated with cacti management – either through loss of livelihood (reduced income and property values), or the challenging nature of long-term management.

This chapter outlines the safety and welfare risks associated with managing opuntioid cacti; strategies to prevent or manage such risks; and the tools that will help keep you comfortable and safe when handling these prickly pests.

Henry Rutherford

Cylindropuntia pallida spines attached to a forearm, Coolgardie WA

Risks to human health

Physical

The most common problem associated with cacti is injury from spines and glochids. Spines play a significant role in cacti dispersal, with sharp spines that are perfectly designed to lodge in the skin, clothing and footwear of passers-by.

Spines are usually found on cladodes (stem segments), but can also protrude from the peri-carpel (flowering fruiting body) (Chinnock, 2015).

In *Cylindropuntia* species, spines are covered in a papery sheath, which can remain lodged in the skin even after the spine has been removed. Spines can also be barbed, making removal difficult and painful, sometimes leading to localised irritation and infection.

Henry Rutherford

Cylindropuntia pallida spines easily penetrating leather boots, Coolgardie WA

Spine injury can also be indirect. Spines (and glochids) can contaminate the fleece of sheep, for example, piercing the skin of shearers' hands made soft by regular contact with lanolin.

All opuntioid cacti have glochids – numerous fine, barbed, hair-like bristles that are easily detachable. Glochids are more insidious in that they can be difficult to see, or appear benign to the casual observer. As with spines, glochids penetrate the skin, causing irritation (and sometimes inflammatory conditions such as dermatitis) until they are removed or dislodged.

ShawnaCoronado.com

Glochids pierce the skin, causing irritation, pain and swelling

Will Smith, Queensland Herbarium

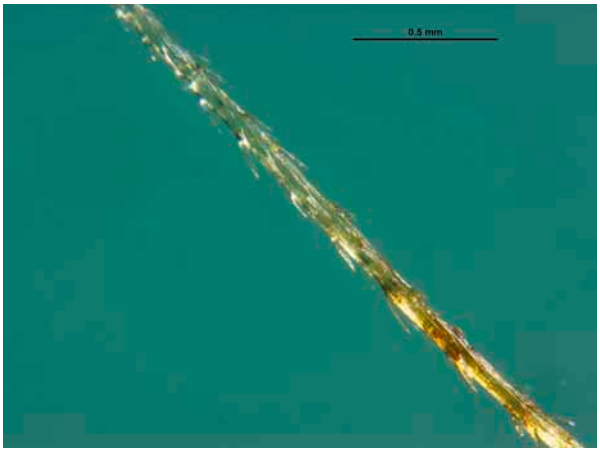
Opuntia microdasys glochids

Eyes are particularly at risk and glochid damage can range from inflammation and conjunctivitis to scratches and ulcers. If left untreated these injuries can lead to eye disease. Some of these conditions are accompanied by intense pain (Odat, 2014). It is possible for glochids to become airborne (Horn *et al.*, 2003), hence it is also possible that they may be inhaled, with potential to cause irritation and more serious conditions to the nostrils, nasal passages, throat and lungs.

If the fruit of *Opuntia ficus-indica* are not properly prepared prior to eating, the ingestion of glochids can irritate the lips, tongue and gums.

Whilst minor injury may arise from incidental exposure to cacti, the real risk occurs when undertaking cacti management. The type or severity of risk may vary depending on the control technique used, but can be reduced through planning and effective use of personal protection equipment (PPE) and other tools (refer to Chapter 4 for further information).

As well as injury from the cacti themselves, is the additional risk that comes from working in remote locations and/or harsh conditions. Working in remote locations can extend the time taken to respond to cacti or other work-related injury. Ways to reduce this risk are provided in Table 3.2 page 70.



Will Smith, Queensland Herbarium

Magnified image of a single glochid of Opuntia microdasys showing reverse barbs

Psychological

Less obvious than physical risk, but of great importance, is the potential impact on the welfare of those involved in cacti management.

Working in isolated, remote areas means support services may be difficult to access.

The long-term nature of effective cacti management is often taxing, both financially and emotionally, and can come at the expense of other work or leisure activities.

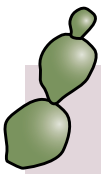
Ineffective management has the potential to reduce livelihood through reduced carrying capacity of stock or reduction in cropping area. The presence of infestations can also reduce land value as industry and the community see cacti as a liability.

Preventing burnout through planning

It is difficult to separate the psychological issues from the physical impacts of cacti management as they are important factors that contribute to the success or failure of a control program.

Some of these impacts can be prevented or reduced by developing a management plan that sets achievable goals, realistic timeframes and identifies resources required (see Chapter 2).

Planning helps you break a big task into smaller parts.



More information on the impacts of cacti can be found in Chapter 1.

If cacti management is getting the better of you:

STOP. REASSESS. REACH OUT. ACCESS SUPPORT.

Beyond Blue: www.beyondblue.org.au
1300 224 636

Lifeline Australia: www.lifeline.org.au
13 11 14

Aussie Farmer's Foundation:
www.aussiefarmersfoundation.org.au

Shauna Potter

Opuntia robusta reinvading grazing land previously cleared, Buckrabanyule Vic

Risks to wildlife and stock

Animals are at risk of all the injuries and conditions mentioned above for humans. In addition, given their typically smaller size, animals can, and do, die from cacti injuries. Cacti spines can trap and impale reptiles, birds and mammals (see images on the following page).

Spines can become lodged in the mouths, coats, paws and hooves of wildlife and stock. Injuries can be serious enough that animals are maimed, sometimes losing their mobility and ability to eat. Problems can be perpetuated by the spread of cacti along pathways such as stock routes, roadsides, water courses and animal tracks. Constant movement along such pathways leads to further spread and an increased chance of future injury.

Safety and welfare

Dan McCudden

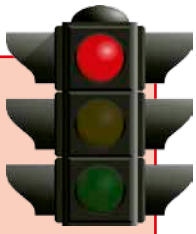
Small birds, reptiles and mammals are easily injured by cacti – here the wing of a small bird is pierced by the spines of Opuntia aurantiaca, Augathella Qld

Bren Lay

Kingfisher caught in Cylindropuntia prolifera, Flinders Ranges SA

Bren Lay

Cylindropuntia prolifera cladodes growing through a dead euro, Arkaroola SA



Spines and spread: a vicious cycle

In some species, particularly *Cylindropuntia*, the presence of spines is one of the key mechanisms of spread. When cacti attach themselves to fur, skin, clothing or vehicles, the cladodes break off the parent plant and can be carried some distance before being dislodged.

These cladodes are then capable of taking root and forming new plants, thus creating new infestations. In the case of spread by wildlife this cycle can continue unchecked, with new plants scattered throughout the bush (refer to Chapter 1 'How opuntioid cacti spread' page 6 and Chapter 4 'Weed hygiene' page 78).

Elizabeth Clark

Exclusion fence

Injury to wildlife, stock and humans can be minimised by the construction of a physical barrier around cacti infestations. For example, exclusion fencing is an effective spread prevention tool and is worth considering when developing your integrated management plan (see Chapter 2).

Safe use of equipment

Some control techniques involve the use of specialist equipment or heavy machinery (see Chapter 4). It is important to assess the risks associated with using these techniques and ensure people are adequately skilled and trained to reduce the chance of injury. Appropriate personal protective equipment (PPE) should always be worn when managing cacti. Refer to Tables 3.2 and 3.3 on pages 70–72 for further information.

Safe management of opuntioid cacti

The primary safety and welfare focus of any management program is to avoid injury. The best way to achieve this is to undertake a risk assessment prior to any control activity.

Hazard or risk?

- A **hazard** is something that can cause harm, for example chemicals, uneven terrain, a chainsaw, etc.
- A **risk** is the likelihood (high, medium, low) of a hazard causing someone harm.

There are four key steps to follow when undertaking a risk assessment:

1. Identify hazards and risks.
2. Assess the impact of potential risks.
3. Develop strategies that prevent or minimise exposure to risks.
4. Review risks and associated controls for currency and effectiveness (e.g. Safe Work Australia, Work Safe Victoria).

Further details of these steps are provided in Figure 3.1 below.

Figure 3.1 The risk assessment cycle and guiding questions for the identification and reduction of risk

Safety and welfare

A common approach in quantifying risk is to use a risk assessment matrix. This allows the risk to be categorised based on the likelihood of occurrence and the severity of the impact. An example of a simple matrix is provided in Table 3.1 below.

Details on where you can find further information on safety, welfare and risk assessment are included in Chapter 6.

Lee Mead

Cactus warrior volunteers in Victoria – high visibility clothing is very useful for control operations involving groups working over large distances

Table 3.1 Basic risk assessment matrix to identify the level of risk

Likelihood of occurrence	Severity of impact: Not significant	Minor	Moderate	Major	Severe
Almost certain	MEDIUM	HIGH	VERY HIGH	VERY HIGH	VERY HIGH
Likely	MEDIUM	HIGH	HIGH	VERY HIGH	VERY HIGH
Possible	LOW	MEDIUM	HIGH	HIGH	VERY HIGH
Unlikely	LOW	LOW	MEDIUM	MEDIUM	HIGH
Rare	LOW	LOW	LOW	LOW	MEDIUM

Henry Rutherford

Thick leather gloves, pliers, knife and long-handled tongs – the use of these will reduce the likelihood of injury

Andy Vinter

An example of personal protective equipment (PPE) for foliar spraying of cacti

Key points to prevent injury from cacti

- Plan your travel route to avoid infestations. Stay on roads and tracks.
- Avoid working on windy days, or work up wind of infestations.
- Watch where you are stepping to avoid standing on or brushing against plants.
- Wear personal protective equipment (PPE) to prevent spine and glochid (fine barbed bristle) injury to skin and eyes. Consider:
  - Goggles/glasses
  - Long sleeves and pants
  - Thick fabrics
  - Leather gloves
  - Leather safety boots.
- Use long-handled tongs and a knife if collecting cacti specimens or for manual removal.
- Before squatting or bending down, always check trousers and boots to ensure you are not carrying spines that will pierce your thighs or buttocks.
- Avoid placing bags and backpacks on the ground as cladodes can attach to them by spines.
- Store any cacti pieces (specimens) in heavy duty containers with lids.

Frank Bernhardt

Controlling Opuntia robusta in the Flinders Rangers SA, can be challenging and requires specialised equipment and skilled operators

The '70's' hair comb

A simple technique used to remove spiny *Cylindropuntia* cladodes from clothing, backpacks and other material is the '70's' hair comb. The comb is scraped between the cladode and the item it has attached to, releasing the spines without the need to handle the cacti. A video demonstration can be viewed at https://www.youtube.com/watch?v=xZUJK_vycYU

Establishing ways to 'control the risk' of injury is an important part of the planning process. The *Avoid – Manage – Treat* approach provides cacti managers with strategies to prevent, reduce and respond to injuries that may arise from cacti management.

A range of potential hazards have been identified in Table 3.2 on pages 70–71. The risk category assigned to these hazards will depend on the individual situation and will be determined by your own risk assessment. The response type (*Avoid – Manage – Treat*) should help maintain acceptable safety and welfare standards.

A good range of tools and equipment will assist in keeping you safe in the field. Basic examples have been included in Table 3.3 on page 72.

Table 3.2 Potential hazards and how to avoid, manage and treat injury

Hazard	Potential outcome	Avoid by…
Injury from spines	Puncture wound Infection of wound Shock (in extreme cases)	See 'Key points to prevent injury from cacti' page 69 Using appropriate control techniques
Injury from glochids (fine barbed bristles)	Skin irritation Damage to eyes Irritation to lips, tongue, throat, nasal passages	Working in calm conditions or upwind of infestations See 'Key points to prevent injury from cacti' page 69
Adverse weather	Heat exhaustion Sunburn Dehydration	Checking weather forecasts Planning Working in cooler conditions or at cooler time of day (e.g. avoiding the hot middle of the day)
Difficult terrain (trip hazards)	Sprained ankles Broken bones Cladode rolling/falling onto you	Generally difficult to avoid. Refer to 'Manage by…' column
Remote location	Delayed access to medical aid Diminished essential supplies	Generally difficult to avoid. Refer to 'Manage by…' column
Chemical handling hazard	Skin or eye irritation Breathing difficulties	Chemical handling training Maintaining equipment
Vehicle/machinery accident	E.g. rolling quad bike Fatigue from long drives	Training in the use of equipment and vehicles (e.g. 4WD or quad bikes) Planning your field trip Allowing for rest breaks
Disorientation	Getting lost Separated from vehicle, supplies and communication	Planning your field trip Working with others Adequate food and water
Working alone	Inability to seek aid due to injury Disorientation (see above)	Working with others Establishing and following working alone procedures (including SITREPs and agreed call-in times etc.) Maintaining equipment
Injuries from falling cacti limbs (e.g. tree pears)	E.g. fractures, head injuries	Using appropriate control method Maintaining equipment Working with others
Injury from wildlife	Snake bite Insect bite (e.g. ticks)	Generally difficult to avoid. Refer to 'Manage by…' column

Manage by…	Treat by…
Adequate PPE (e.g. leather gloves, eye protection, long-sleeved shirts, long pants, leather boots)	See 'First aid for cacti injuries' page 73
Adequate PPE (e.g. leather gloves, eye protection, dust masks, long-sleeved shirts, long pants, leather boots)	See 'First aid for cacti injuries' page 73
Adequate PPE (e.g. sunscreen, wide brimmed hats, long-sleeved shirts, long pants) Ample fluids Taking regular breaks	First aid Rehydration drinks (e.g. hydrolyte)
Adequate PPE (e.g. sturdy footwear, long pants, walking poles, use of personnel with adequate fitness and experience working in areas with difficult terrain)	First aid Bandages, strapping
Working in pairs or groups Use of personnel with adequate fitness and experience working in remote locations Carrying satellite phone or other device	First aid Medical assistance
Adequate PPE (e.g. rubber gloves, eye protection, respiration masks, long-sleeved shirts, long pants, boots)	Following label/MSDS directions First aid Medical assistance
Working in pairs or groups Switching operators regularly to avoid fatigue	First aid Medical assistance
Navigational aids (e.g. maps, GPS) Communication tools (e.g. phones, EPIRBs, UHF radio) Carrying basic supplies when away from vehicle (e.g. food, water, first aid)	Enacting pre-existing search and rescue plans Notifying emergency services
Adequate PPE Communication tools (e.g. phones, EPIRBs, UHF radio)	Notifying emergency services Enacting pre-existing search and rescue plans
Adequate PPE (e.g. helmets, high visability clothing)	First aid Medical attention
Adequate PPE (e.g. gloves, long-sleeved shirts, long pants, sturdy footwear) Insect repellant	Snake bite kit First aid Medical attention

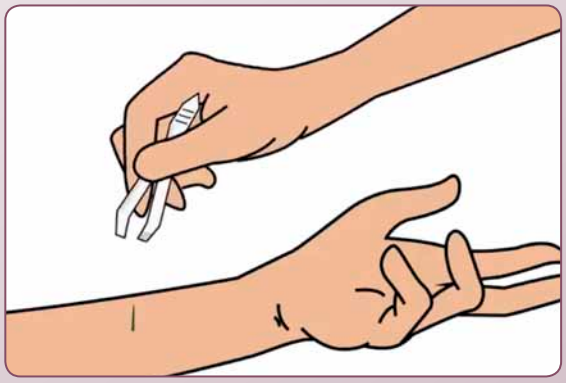
Table 3.3 Basic tools and equipment for safe opuntioid cacti management

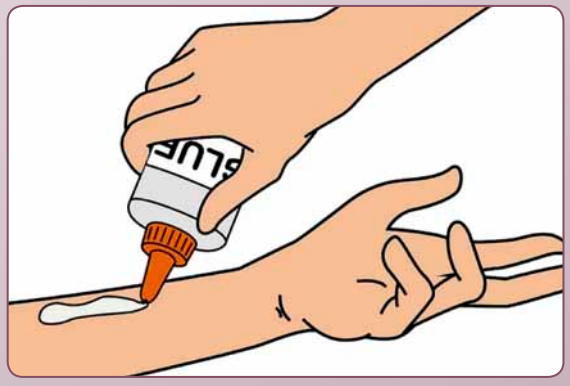
	Tools and equipment	Description
	Gloves ▶ rigger's gloves ▶ rubber gloves	Used to prevent/minimise spine injuries ▶ Not to be used as PPE when spraying with chemicals ▶ For chemical handling
	Leather safety boots	Provide ankle support and reduce penetration of spines
	Personal protective equipment (PPE)	Long-sleeved, high vis shirts Long pants Gaitors Wide-brimmed hat Helmet Dust mask (to prevent inhalation of glochids) Respirators (for chemical handling) Goggles (to prevent glochids entering eyes) Sunscreen Sunglasses
	Snake bite kit	Especially useful in summer and remote areas
	First aid kit	Including insect repellant, eye flush, tweezers, magnifying glass, PVA glue, gause and duct tape for removing spines and glochids, antihistamines
	Food and water	Consider electrolyte drinks
	Pliers	For removing spines from clothing, shoes and skin
	Long-handled tongs	For handling cacti material (cladodes, fruit)
	Hair comb	Long-handled, wide-toothed hair comb for removing cladodes from clothing, etc.
	Saw (handheld or electric)	For collecting live material, or gaining access to stems/trunks of plant
	Mattock	Long-handled for grubbing individual plants
	Heavy duty containers/bins with lids	For collecting live material or temporary transport and disposal of cacti
	Navigation aids	Maps, hand held GPS, compass, smartphone
	Vehicle recovery gear	E.g. winch, shovels, spare tyres
	Fuel	Allow enough for contingency
	Communication aids	E.g. phones, EPIRBs, sat phones, UHF radio

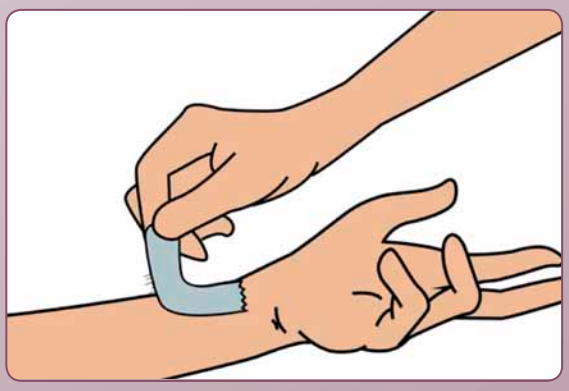
Treating opuntioid cacti injuries

First aid for cacti injuries

- Carry pliers, tweezers and a hair comb at all times and use them to remove spines and glochids (fine barbed bristles).
- Remove spines and glochids as soon as possible to prevent further irritation. Spines will start to swell when they enter flesh, making it harder to remove them.
- To remove spines:
  - Hold the spine with tweezers or forceps close to the skin and pull out in the same direction the spine entered the skin; or
  - Run a hair comb between cladode and point of contact (e.g. leg) – it will 'pop' off.
  - Remove the spine sheath if it has detached from the spine when being pulled out.
  - Treat as soon as possible with antiseptic.
- **Do not attempt to remove glochids with your mouth!** They will transfer to your lips, tongue and cheek insides, causing severe discomfort. To remove glochids:
  - Use tweezers to remove as many as possible; then
  - Coat the skin with non-toxic household glue (polyvinal acetate – PVA) and wrap the injury in gauze. Once dry, peel away the glue and any remaining glochids (Martinez, 1987).
  - Duct tape can also be used. Apply to skin, then pull off quickly, as you would a band aid.
- Antihistamines may reduce irritation and discomfort (Healio, 2011).
- Monitor wounds regularly in case of a reaction. Seek medical advice promptly if required.







Illustrations courtesy wikiHow.com from the article http://www.wikihow.com/Remove-Cactus-Needles

Safety and welfare

Safety

All weed control activities involve risk, so personal safety must be prioritised. Regulations regarding the safe use of herbicides and machinery must be followed and personal protective equipment (PPE) such as gloves, respiratory equipment, eye and ear protection worn as appropriate.

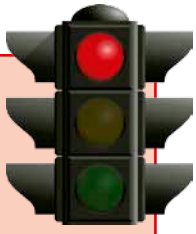
Training may also be required for handling herbicides and operating machinery (see Chapter 4).

National model work health and safety laws (including Acts of Parliament, Regulations and Codes of Practice) have been adopted by all jurisdictions except Victoria and Western Australia. Other states have updated their own workplace safety structures accordingly. Check with your state or territory for the latest information.

Guidance, information and fact sheets for working with volunteers are available from Safe Work Australia at www.safeworkaustralia.gov.au, and relevant authority websites in each state.

A risk management tool called *Running the Risk?* is available from Volunteering Australia at volunteeringaustralia.org/wp-content/files_mf/1377053059VAManagersrunningtherisk.pdf.

Contact your local council or natural resource management agency for current information about safety and weed management.

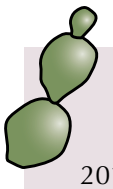


The information provided in this chapter aims to further support cacti management in the field. It does not replace your workplace and legal requirements.

Your workplace or volunteer organisation will already have several Occupational Health and Safety (OH&S) policies and guidelines in place to help maintain good safety and welfare.

Andy Vinter

Conservation land management students geared up for foliar spraying, Alice Springs NT



Parts of this chapter are based on the *Broom management manual* (OEH, 2014) and *Safe work procedure: Working near invasive cacti* (Blood and James, 2017).

Chapter 4

Managing cacti

Choosing a control method

As described in Chapter 1, opuntioid cacti, though sharing some commonalities, are a very diverse group of plants. Characteristics such as growth form can vary significantly across species. All opuntioid cacti have jointed cladodes, but they can vary from plants with ribbed, cylindrical cladodes that readily detach from one another (e.g. *Cylindropuntia prolifera*) to ones with round, flat, fleshy, firmly attached cladodes (*Opuntia robusta*). Even species within the same genus can be quite different, from small, sprawling shrubs (*O. aurantiaca*) to 5 m tall trees (*O. tomentosa*).

Growth form and cladode type (shape and detachability) are the two main characteristics that will help you identify appropriate control methods for the species you are managing. Subsequent considerations, such as the density of the infestation and site considerations like accessibility, soil type and conservation value, will enable you to select the most appropriate control method for your situation.

There is no single, correct control method – you may have to employ multiple methods, either over time or for different sites or species. Figure 4.1 on pages 76–77 sets out a decision support tool that allows you to use plant and situational characteristics to systematically select from the range of control options available to you.

What is best practice management?

Best practice management is the use of control methods that, through experience and research, have been found to be the most effective and practical means of achieving a management objective (such as reducing the impact of cacti). As best practice control methods for opuntioid cacti are evolving, it is important to note that the methods described here are only as good as our current knowledge. There are still opportunities to improve efficacy of control for opuntioid cacti in Australia. Documenting and sharing the methods and outcomes of your control programs will contribute to the available knowledge base and highlight areas that need further research.

Integrated weed management

Often the most successful and cost-effective approach to controlling weeds is to combine or integrate several control methods over time (termed 'integrated weed management'). A variety of methods can be used to target vulnerable aspects of a weed, its life cycle or its environment. For example, dense, core infestations of mature *Opuntia robusta* (wheel cactus) may be controlled principally by biological control, while outliers and any new outbreaks outside of the core may be controlled by a combination of chemical control (stem injection) and hand removal. This integrated approach can reduce the impact of the core infestation, while also containing the infestation by minimising spread. Integrated control can:

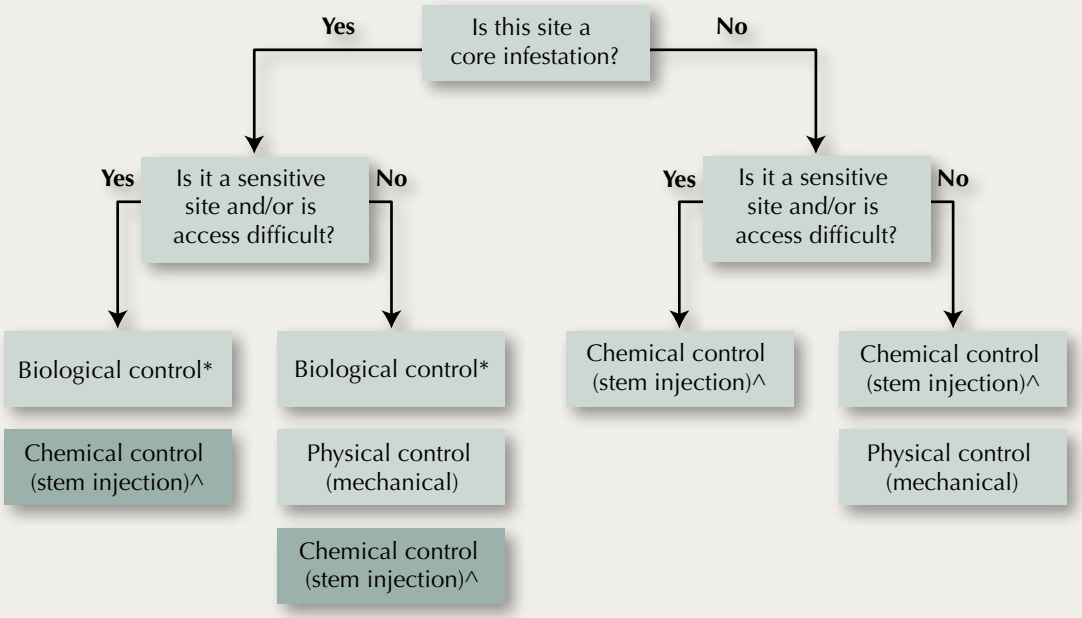
- Reduce the impact of control on the surrounding desirable vegetation;
- Reduce the chance that weeds will adapt to a given control method (e.g. build up resistance to a herbicide); and
- Achieve successful weed management using limited resources in the most effective way.

This chapter describes current, known control methods for opuntioid cacti, and gives suggestions on how to integrate methods for your situation to get the best result in the long term.

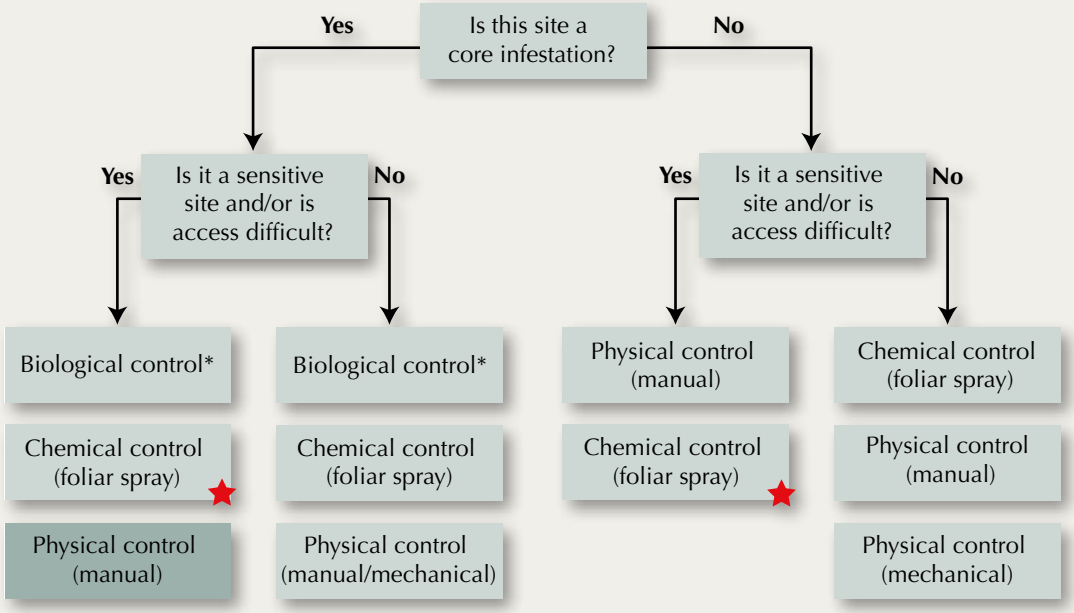
Decision support tool for selecting appropriate control options

(i) Large cacti with trunks or tree-like form (examples include *Opuntia monacantha* and *O. tomentosa*)

NOTE: *These methods are recommended, in part due to the size these cacti species can grow to at maturity. Control methods such as foliar spraying may be appropriate in some situations (e.g. for juvenile plants of the same species).*

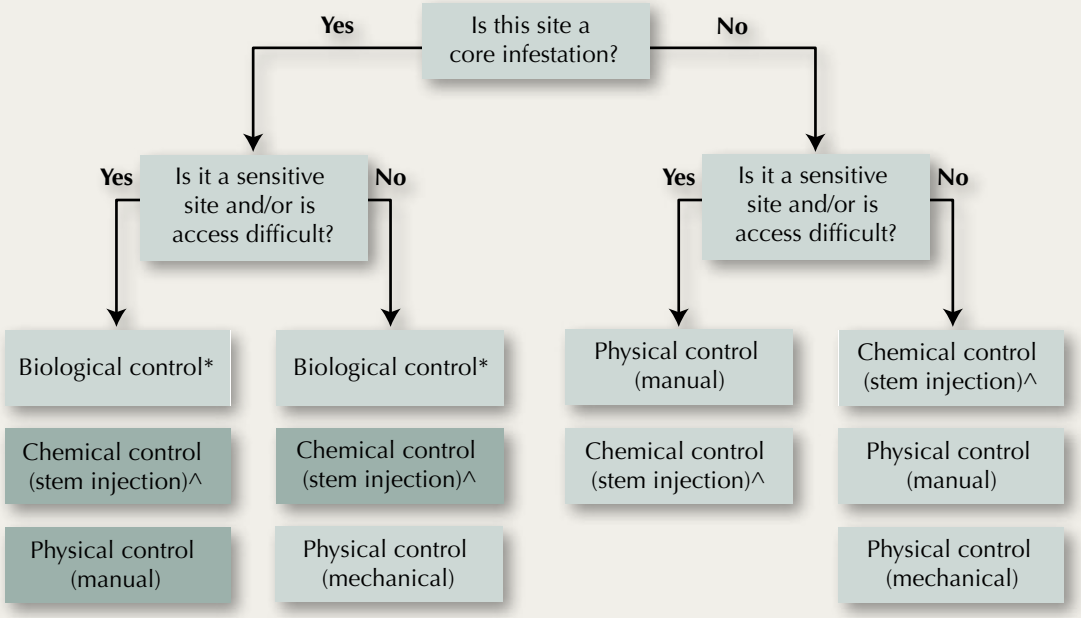


(ii) Shrub-forming cacti with easily detachable cladodes (pads) (examples include *Cylindropuntia fulgida* var. *mamillata*, *C. pallida*, *C. prolifera*, *Opuntia aurantiaca*)



(iii) Shrub-forming cacti with firmly attached cladodes (pads) (examples include *Cylindropuntia imbricata*, *Opuntia elata*, *O. robusta*, *O. stricta*)

NOTE: *Other control methods (e.g. foliar spraying) may be appropriate in some situations for juvenile plants of these species.*



Effective control technique, but time consuming and labour-intensive when used in core infestations. In some instances it may be the best option available.

* Biological control only available for some species. Refer to Table 4.3 on page 104 for further information.

^ Stem injection consists of pad injection for fleshy pads (e.g. *Opuntia robusta*) and drill and fill for woody stems (e.g. *Cylindropuntia imbricata* or *O. tomentosa*).

★ Further consideration of the site's sensitivity should be undertaken before choosing this control technique.

Figure 4.1 Decision support tool for selecting appropriate control options for (i) cacti with trunk or a tree-like form, (ii) shrub-forming cacti with easily detachable cladodes, and (iii) shrub-forming cacti with firmly attached cladodes (refer to quick guide notes on pages 21–29 for link to species details)

General tips for successful weed control

Prevention is cheaper than control

- Ensure vehicles, machinery, livestock and produce do not carry weed seeds or propagules (vegetative material that is capable of reproduction);
- Report sales of declared plants to your local weeds officer or weed authority.

Find weeds early

- Get to know plants in your area/on your property and quickly identify and deal with new threats.

Prevent weed spread

- Take measures to contain weed infestations and prevent further weed dispersal.

Plan your control approach

- Obtain information about managing your target weed;
- Map infestations;
- Treat weeds when they are young;
- Use the recommended control method;
- Minimise damage to non-target plants;
- Establish and promote competing vegetation.

Undertake follow-up control

- Continue follow-up treatments over several years. Some plants may have been missed, some may not have died and new seedlings may emerge.

Adapted from the *Weed Control Handbook for Declared Plants in South Australia* (NRM Biosecurity, 2017).

Weed hygiene

The most efficient and effective weed control strategy is prevention. Chapter 1 outlines how easily opuntioid cacti are spread, either by people, animals or water. These plants were born to roam!

When choosing a control method, and prior to starting a control program, it is important to plan how to prevent the target weed (and other weeds) being spread further across the site or off-site. Ironically, one of the best opportunities for weed spread comes about through our attempts to manage them, either during reconnaissance trips, control or monitoring. For this reason, it is important to consider how weeds spread and to put in place some routine protocols that will minimise the risk when in the field.

An essential activity is cleaning vehicles and machinery before moving them to a different area. This helps prevent the spread of weeds to other parts of the property, adjoining land, and along transport corridors such as roads.

The following hygiene protocol will guide you through key considerations for preventing weed spread during reconnaissance, control works and monitoring, as well as day-to-day property management activities.

Tips for reducing the risk of spread

- Avoid driving off-road in areas known to contain declared weeds or areas that present a risk of vehicle or machinery contamination.
- Ensure clothing and footwear is free of soil and weed material before stepping into vehicles.
- Avoid driving or working in contaminated areas in wet or dewy conditions.
- Clean vehicles and machinery suspected of carrying soil or weed material before moving to another site.
- Begin work in clean areas or in areas with the least amount of infestation and work towards infested or high-density areas.
- Keep roads, laneways and buffer zones free of weeds.
- For physical removal, secure load when transporting cacti to disposal area.

Hygiene protocol

1. Consider the risks of spread

What species of cacti are you dealing with?	Does it have cladodes that are easily detached? Does it seed? Is it fruiting when you are managing it?
What is the density?	The higher the density, the greater the likelihood of contact and spread.
What is your mode of transport around the site during control and monitoring (vehicle, quad bike, on foot)?	Driving through infestations increases the likelihood of spread (e.g. *Cylindropuntia pallida* attaches to tyres, mud containing seed adheres to vehicles and boots).
What are other weeds or pathogens on the property or in surrounding areas that could be spread?	In managing cacti, other weeds or pathogens can be either brought in or taken from the site. Adopting general hygiene measures reduces this risk.

2. Develop a protocol to reduce the likelihood of weed spread while carrying out your control program

Enter a site clean 	You may be using a shared vehicle and may not know where it has been or what it is carrying. Conduct visual inspections and, if available, use a wash- or brush-down facility. Also ensure boots, clothing and equipment are free of weed seeds and other propagules before entering the site.
Establish a clean-down/ inspection point	Using a property map, determine the edge of the infested area and establish an inspection point. This will help prevent spread to clean areas. If possible, choose an open, clear site that is less likely to be frequented by stock or wildlife. Ensure the site is away from watercourses and drains and consider the site's run-off. This will help prevent the spread of weeds. Ensure the site can be easily identified, as it will need to be monitored for outbreaks in the following seasons. Use a fence post, distinguishing landmark or GPS coordinate to identify the site.

3. Carry out inspection

Vehicles

Thoroughly inspect tyres and undercarriage of vehicles (including quad bikes) and machinery for cladodes.

- Use a mirror on a stick for inspecting under vehicles.
- Use reverse camera on mobile phone to inspect wheel arches.
- Note that spines may be left behind when removing cladodes from tyres. Pliers aid in the removal of spines.

Equipment

Check clothing and boots (including soles) and equipment (bags, cameras, spray gear, etc.) for spines and cladodes. Remove with tweezers, tongs, gloves or a 70's hair comb (see Chapter 3).

If footwear is contaminated with soil, brush down with a scrubbing brush.

As an added precaution against pathogens, spray with 70% methylated spirits, quaternary ammonium disinfectant or a prepared solution such as 'Phytoclean Sanitiser'.

Control methods

Physical control

Under the right circumstances physical control, either by manual (hand) or mechanical (machinery) removal, can be a feasible and cost-effective management method for all opuntioid cacti species. Manual removal can be very effective for small plants and scattered infestations, while mechanical removal can be effective for large, dense, impenetrable stands.

Physical control can also be an option in situations where control using herbicides is not desirable, practical or possible (e.g. in or adjacent to residential areas or organic properties). Figure 4.2 provides a simplified decision support tool to determine the situations in which physical control might be appropriate.

Physical control, given its labour-intensive nature, is commonly integrated with other control methods in a management program, either at:

- The beginning, in the case of mechanical clearance, to reduce a large infestation; or
- The end, in the case of manual removal, when other primary control methods have removed the bulk of plants and regular follow-up of seedlings is required.

Like all methods a commitment to follow-up is critical.

Refer to the case study on page 122 for practical applications of mechanical control.

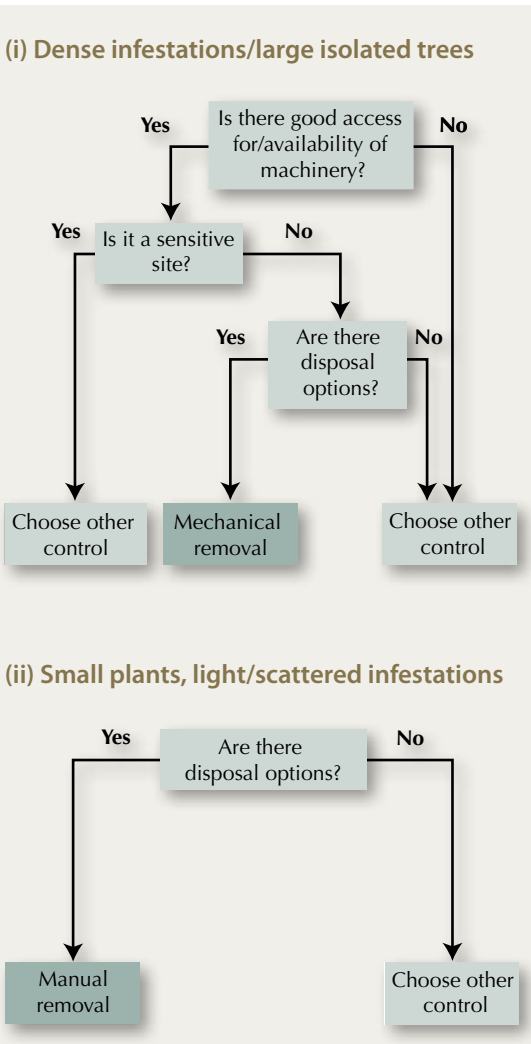
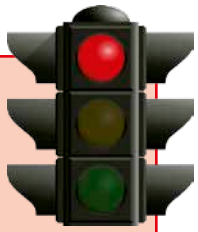


Figure 4.2 Decision support tool for determining situations in which physical control might be appropriate



Where are we going to put it?

The first thing to determine when considering physical removal is what to do with the biomass (plant material).

- Is there a deep burial facility close by where disposal will be permitted?
- Are there other burial or disposal options?
- Do you have equipment to bury on site?
- Cacti plants can establish from any fragments of cladodes or fruiting bodies (pericarpels). Care should be taken to ensure fragments are not dropped during transport.

See pages 84–87 for more information.

Andy Vinter

Cacti collected in sealable plastic buckets or tubs – makes removal from the field easier and reduces the likelihood of spread

Manual removal (hand-pulling)

Hand-pulling small and medium-sized cactus is a very effective form of control, particularly in new or expanding infestations. Remember though that *collection and removal* of vegetative matter is needed to prevent regrowth, and it is currently considered best practice to dispose of cacti in an approved deep burial facility (refer to 'Disposal' page 86)

Applying the method

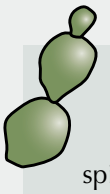
Due to the spiny nature of cacti, removal is aided by the use of a 'heritage garden hoe' or other gardening implements such as a lopper, as well as tongs to collect small plants and cladodes from the ground. In some species, the spines of small, young plants are often absent or sparse at the very base of the stem. These plants may be removed with a gloved hand. Some species such as *Cylindropuntia fulgida* var. *mamillata* (coral cactus) have very small cladodes that can be easily missed. Follow-up may be required to manage seedbank or regrowth.

Many cacti, such as *Opuntia aurantiaca* (tiger pear) and *Cylindropuntia* species, drop cladodes very readily. Using tongs, place plants in plastic buckets or bins with lids (see image above). Work from the outside toward the parent plant. This will reduce the liklihood of trampling on or spreading propagules. Collecting cladodes that may have been dislodged during plant removal will reduce the risk of regrowth or spread.

Hand removal of large mature plants such as *Opuntia robusta* (wheel cactus) or tree cacti is not recommended as they are extremely heavy. An option that will reduce seed spread is to leave plants in place but remove fruit using tongs and a knife, disposing of it in a deep burial facility.

Lee Mead

Heritage garden hoe – a useful tool for the manual removal of cacti



As part of the Hudson pear eradication program in northern Victoria, the spines of Hudson pear are removed by burning them with a drip torch, commonly used during planned burn programs. This approach, used under the appropriate conditions and following standard operating procedures, can reduce the hazards of hand removal.

Bec James, DEWLP

Treating Cylindropuntia pallida with fire to remove spines for safer hand removal, Ouyen State Forest Vic

Managing cacti

Timing

While hand removal can be carried out year round, be mindful that some species (e.g. *Opuntia microdasys*, *O. robusta* and *O. stricta*) have airborne glochids that are thought to be more easily dislodged and mobile during dry conditions. Use personal protective equipment such as glasses and a mask or respirator to protect eyes and the respiratory system.

Hand-pulling works best when soils are moist to minimise effort and maximise likelihood of removing the entire plant.

Manual removal

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Whole plant removed ▪ No chemicals and minimal equipment required ▪ Suitable control method for organic certified properties ▪ Suitable control method in all soil types and most terrain ▪ Causes negligible soil disturbance or impact to desirable vegetation ▪ Highly effective	▪ Time consuming and labour intensive ▪ Not practical for extensive infestations of mature plants	▪ **Inappropriate disposal may lead to new populations off site** ▪ **Follow-up required for seedlings or cladode regrowth** ▪ **Appropriate personal protective equipment must be worn to avoid spine/glochid injury**	Year round	▪ Chemical control ▪ Biological control * Manual control is ideal for removing outliers around core infestations that are being managed by other means

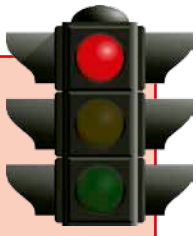
Mechanical removal (machinery)

Mechanical removal using machinery is usually most suitable for the control of dense and extensive infestations. This method is a cost-effective way of removing biomass and increases accessibility for other follow-up control methods. It can also be used to remove large mature plants that do not respond to other methods.

Mechanical removal of cacti with heavy machinery (such as front-end loaders and excavators) may cause high levels of disturbance to the soil and desirable vegetation, increase soil compaction or contribute to soil erosion if used on sloped areas. Careful planning and research will identify situations where mechanical control is appropriate and a well coordinated and executed control program will reduce or mitigate off-target impacts.

Heavy infestations of cacti commonly occur in areas that are highly modified or disturbed. These may include mining sites, gravel extraction sites and dumping sites, where conservation and cultural values may have already been compromised. These are situations where mechanical removal using machinery is worth considering.

Two methods of mechanical removal using machinery are described here.



Seek advice

Any land manager considering mechanical removal of cacti should seek advice from their local council and state or territory government to ensure laws or regulations regarding land clearance, vegetation conservation, cultural heritage and movement of declared weeds are adhered to.

Large-scale clearing/pushing

Applying the method

This method uses heavy machinery, such as a front-end loader or tractor with a grapple arm, to push or pluck cacti out of the ground. Plants can also be dumped directly into trailers or trucks for disposal off site. Depending on the situation and site sensitivity, it is sometimes considered appropriate to remove topsoil to reduce the seed bank and ensure vegetative matter is removed. Regardless, it is advisable that mechanical removal by this means is immediately followed by a combination of mechanical (e.g. grader) and manual (hand pulling/collection) control to collect any vegetative matter left behind. See the case study on page 122 for an example of large scale clearing/pushing.

Timing

This method can be undertaken year round, however it is best conducted in dry conditions to simplify clean-down procedures and reduce the likelihood of spread (or causing greater soil disturbance at the site). Note, however, that some species (for example *Opuntia microdasys*, *O. robusta* and *O. stricta*) have airborne glochids that are thought to be more easily dislodged and mobile during dry conditions. Use personal protective equipment such as glasses and a mask or respirator to protect eyes and the respiratory system.

Kim Eckert

Heavy machinery being used to remove infestations at highly modified or disturbed sites

For seeding species, adult plants should be treated before fruiting, as this will help reduce the seed bank.

Large-scale mechanical clearing

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Quick removal of infestations ▪ Can be cost-effective for extensive infestations ▪ Reduces volume of herbicide required for follow-up ▪ Useful where there are multiple species of cacti co-occurring that would require different chemical controls or biocontrol agents ▪ Suitable control method for organic certified properties	▪ Can cause significant disturbance to soil ▪ May cause off-target impact to desirable species or cultural heritage values ▪ Vehicle/machinery hygiene risk from cacti and other weeds and pathogens ▪ Not suitable for some soil types or terrain (e.g. shallow soils and rocky areas) or where there are limited options for disposal ▪ Disturbance can promote the establishment of other weeds	▪ **Inappropriate disposal may lead to new populations off-site** ▪ **Plants can grow from any fragments that are left on the ground or dropped during transport** ▪ **Monitoring and follow-up activities need to be carried out long term at both the removal and the disposal site**	Year round	▪ Chemical control (follow-up) ▪ Hand-pulling (follow-up)

Kevin Teague, Yorke Peninsula NRM Board

Kevin Teague, Yorke Peninsula NRM Board

Kevin Teague, Yorke Peninsula NRM Board

(i) and (ii) Mechanical control using a grapple arm to 'pluck' Opuntia robusta from the ground; (iii) site in Kellerberrin WA following in situ burial of O. robusta

In situ burial

In situ burial is useful for infestations of medium density or isolated stands of large mature plants where soils are deep.

If works are not well considered or executed, the treatment could make the problem worse. For example, any fragments of cladodes or fruit left on the surface or shallow buried can continue to grow, giving rise to new infestations that may be more dense than the original infestations. If there are multiple burial sites, follow-up management can be time consuming. Burial 1 m below the surface is currently considered best practice and required to prevent regrowth (see 'Pit burial – tips and traps' on page 87).

Applying the method

Using an excavator, holes are dug beside plants and the plants are pushed into the hole and buried to a depth of at least 1 m below the surface.

Timing

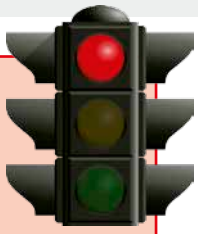
In situ burial can be carried out year round, however it is best conducted in dry conditions to simplify clean-down procedures and reduce likelihood of spread or causing greater soil disturbance at the site. Note, however, that some species (for example *Opuntia microdasys*, *O. robusta* and *O. stricta*) have airborne glochids that are thought to be more easily dislodged and mobile during dry conditions. Use personal protective equipment such as glasses and a mask or respirator to protect eyes and the respiratory system.

***In situ* burial**

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Quick removal of infestations ▪ Relatively low soil disturbance compared with large-scale clearing/pushing ▪ Reduced volume of herbicide required for follow-up ▪ Monitoring and follow-up only required at the infestation site ▪ Less off-target impact to desirable species or cultural heritage values compared to clearing/pushing ▪ Suitable control method for organic certified properties	▪ Vehicle/machinery hygiene risk from cacti and other weeds and pathogens ▪ Not suitable for some soil types or terrain (e.g. shallow soils and rocky areas)	▪ **Follow-up required for seedlings and cladodes**	Year round	▪ Chemical control (follow-up) ▪ Hand-pulling (follow-up)

Physical barriers/exclusion

Stopping the spread of cacti is the only way to prevent the establishment of new infestations or the expansion of existing infestations. An effective management tool to reduce vegetative spread (spread of cladodes) is to erect physical barriers such as fences. This restricts entry to heavily infested areas by wildlife, stock, vehicles and other vectors most commonly associated with vegetative spread. This approach has the added benefit of reducing the risk of injury, particularly to wildlife and stock. Physical barriers, integrated with biological control (if available) of core infestations and chemical control or hand removal of outliers, can be an effective combination to reduce the density and the impact of cacti (see the case study on page 134). Note that physical barriers and exclusion are not effective for seed-dispersed cacti, where birds are the major vector of spread.



Is mulching an option for cacti control?

'Best practice' control methods are only as good as our current knowledge. There are some methods currently in use, the effectiveness of which is uncertain, either because results have been inconclusive, or because there has not been sufficient monitoring or trialling of those methods. Mulching is one such method where the jury remains out.

- All opuntioid cacti give rise to new plants from areoles. Under the right conditions, new plants could develop from mulched fragments containing intact areoles or from seed. Anecdotal evidence suggests this is the case for some species.
- While mulching reduces biomass and allows for follow-up management, in the absence of conclusive evidence about the viability of mulched cacti material, it is not considered best practice management. If this method is used, mulched material should be deep buried.

Disposal

The first question when considering physical removal should be about how the biomass is to be disposed of, remembering that the principal method of opuntioid cacti reproduction in Australia is by vegetative means. Also remember that, under the right conditions, any fragments of cladodes or fruit can give rise to new plants for at least 5 years. If there is no place to safely dispose of cacti, mechanical removal should not be considered.

Matt Sheehan

A new plant of Opuntia elata formed from a cladode left on the ground following physical removal

Deep burial

Deep burial is the safest form of disposal. It is considered best practice to ensure that all vegetative matter is permanently buried to no less than 1 m below the soil surface. The best option is to bury cacti in an approved deep burial facility such as a municipal waste disposal site. Obtain permission for cacti disposal from the facility manager and discuss disposal requirements.

Matt Sheehan

A purpose-built cacti disposal pit – this should be deep enough to ensure that buried cacti are covered with at least 1 m of soil

On-site or off-site burial?

Depending on soil type, depth and cultural and environmental values of the site, on-site burial may be an option. A clear advantage of on-site burial is that you do not need to transport vegetative matter or dispose of it in a new location, so there is no risk of a new infestation establishing. It also means that monitoring, surveillance and follow-up activities only have to be carried out at the removal site, if equipment and vehicle hygiene protocols are followed.

Advantages of on-site burial
▪ Less risk of off-site spread ▪ Monitoring surveillance and follow up all at one site
Advantages of off-site burial
▪ Often purpose-built facilities are available and may be more cost-effective ▪ Existing burial facilities are monitored

Other disposal methods

Burning

Burning can be a useful method for the disposal of cacti on a small scale. Remember that cacti are succulents and contain large amounts of water, therefore complete combustion can be difficult. The use of fire requires a three stage process:

1. Dry out cacti over summer – loosely pile and intersperse with more flammable materials, such as branches and stumps from other plant species.
2. Burn cacti in a high intensity bonfire.
3. Monitor the site after the burn for a minimum of 5 years and undertake follow-up control as required.

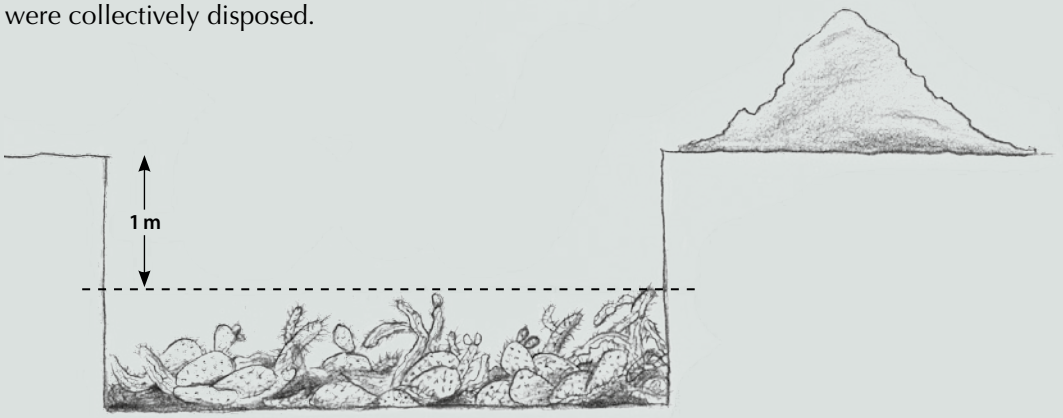
You should consult your local fire service for advice and to seek any permission that may be required to undertake this activity.

Matt Sheehan

This purpose-dug cacti disposal pit in Goomalling, WA remained opened for several months, resulting in it partially filling with water and cacti fragments re-sprouting

Pit burial – tips and traps

Subject to relevant permits, it may be preferable to construct a purpose-dug pit for the disposal of cacti. This has been undertaken by cacti managers in WA, where plants from large infestations and gardens were collectively disposed.

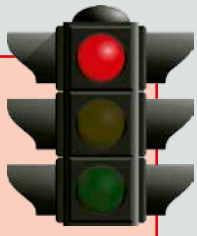


Karine van Kranenburg for elevenacross

Sketch of a purpose-dug pit – it is considered best practice to ensure that all vegetative matter is buried to no less than 1 m below the soil surface

Plan for pit burial

- Seek permits and plan well in advance of physical control.
- Coordinate cactus removal and ensure there is enough material to justify pit burial.
- Plan pit digging during a period when rain is least likely, and dig just before delivery of cacti.
- Close pit immediately after cacti are deposited to reduce the likelihood of re-sprouting or filling with water.
- Clearly map and mark pits to assist with locating the pit for future surveillance.



CAUTION!

Pits that are open for extended periods are susceptible to filling with water following heavy rains. Cacti float and there is a danger of them escaping the pit.

Also, cacti exposed to light will continue to grow.

If the pit must remain open, consider covering the cacti with black plastic, foliar spraying with an appropriate herbicide, or back-filling from one end only.

Managing cacti

Chemical control

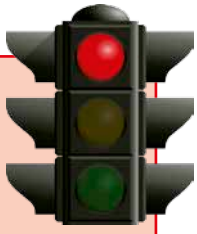
When used as part of an integrated management plan, chemicals (herbicides) can be an effective way of controlling cacti. Herbicide applications can be used for infestations of all scales. To avoid off-target damage, care must be taken when applying herbicide in areas of native vegetation. Herbicide application on cacti is only effective when correct application methods and appropriate herbicides are used. Choosing herbicides and methods requires consideration of the species of cacti you are dealing with. Not only are herbicides more effective when applied to plants that are actively growing, many of those registered for use on cacti can only be legally used on actively growing plants. This can be difficult to define in cacti and can vary from year to year. A good rule of thumb is to avoid chemical control if the cacti are showing signs of stress, such as yellowing, wilting or die back. Methods used on cacti include:

- Stem injection (includes pad injection and drill and fill);
- Foliar spraying; and
- Basal barking and cut stump – not recommended as best practice.

Herbicide labels and legislation

The Australian Pesticides and Veterinary Medicines Authority (APVMA) controls and regulates all agricultural chemical products (which includes herbicides) from importation and manufacture to the point of retail sale. The APVMA approves the use of a herbicide to control a weed and sets the product label recommendations. The use of agricultural chemical products is regulated by relevant state and territory departments (see Chapter 6 for details).

Each registered product has a label providing instructions on safety, use and disposal as well as identifying the active constituents and other ingredients of the product. Labels also outline the pests, crops and situations where the herbicide may be applied. In certain situations, the APVMA may issue a minor use permit for use of a herbicide in a situation not specified on the label. Permits need to be applied for and will have specific conditions and expiry dates that must be adhered to.



STOP AND THINK!

Be aware of legislation in your state regarding herbicide use. For example, some herbicides are restricted in certain states or in specific areas of the state. For up-to-date registration details and current permits visit the Australian Pesticides and Veterinary Medicines Authority (APVMA) website: www.apvma.gov.au and refer to weed control contacts in your state (see page 150).

Following label or permit instructions ensures that herbicides are used effectively and do not have a negative impact on the environment, health, safety and trade. It is an offence to use unregistered pesticides unless you have a permit. To search for registered and permitted products visit the APVMA on line database at https://portal.apvma.gov.au/home.

The use of herbicides in a manner that varies from the label instructions is called off-label use. Limited off-label use may be allowed by state or territory regulatory authorities if an APVMA off-label permit is obtained.

Also, some jurisdictions permit the use of products that are either registered, or approved for use under a permit, in another state or territory, provided all other label directions are followed.

It is critical to check with the relevant department regarding off-label use.

The information in this guide is not necessarily comprehensive and does not imply any recommendation of a specific herbicide.

Individual site requirements and the species you are controlling must be considered when choosing a herbicide.

Other herbicides containing these active ingredients, but not mentioned in this manual, may also be registered for use on cacti.

Safety and training

Personal protective equipment (such as protective clothing, eye or face shields, and respiratory protection) must be used in accordance with the recommendations stated on the herbicide label or permit. Herbicide use training is highly recommended and is required for people using herbicides as part of their job or business. Training is recommended for community groups and may be required if working on public land. Depending on the rules of your state or territory, there may be other mandatory training and licensing requirements. Contact your Agriculture Department for details. Training courses are available in each state and territory.

By law, you must read the label (or have it read to you) before using any herbicide product. Always follow the label instructions. The same applies for off-label permits.

Registered herbicides

Products registered for control of opuntioid cacti contain the active ingredients picloram, triclopyr, monosodium methyl arsonate (MSMA), amitrole or glyphosate. Some products contain two of these active ingredients (see Tables 4.1 and 4.2). Labels for different products specify application in water or in diesel. The application of these chemicals is species specific. The characteristics of the most commonly used herbicides are described below. The decision support tools in Figure 4.1 (pages 76–77) provide guidance for the selection of the most appropriate herbicide application method based on the situation and species. The case studies in Chapter 5 provide examples of where managers have considered their specific situation before applying herbicides.

Glyphosate is a non-selective herbicide used on many annual and perennial broadleaf weeds and grasses. It is not residual, meaning it only kills existing plants and is deactivated on contact with the soil. Glyphosate is absorbed by the leaves and stems and is translocated throughout the plant. Glyphosate inhibits an enzyme required for the production of amino acids used in protein synthesis for plant growth. The speed of entry and action of glyphosate depends on the species and where, when and how it is applied. For opuntioid cacti control, glyphosate is generally only used for stem injection (pad injection and drill and fill) on *Opuntia* species such as *Opuntia robusta* (wheel cactus). It can take 3–4 weeks to see the visible impacts of glyphosate on cacti through stem injection, and up to 2 months to kill (may be longer in cool or cloudy weather). Only healthy and actively growing plants should be treated, as translocation is dependent upon the sugar transport system (phloem) when the plant is active. Other factors such as plant stress and extreme weather can affect glyphosate uptake in plants.

Picloram is a selective herbicide targeted for use on broadleaf plants. It affects the synthesis of proteins and disrupts cell growth. It is absorbed through the roots and cut stems and translocates throughout the plant. It is slow acting; signs of damage may take over 2 months and total death may take from 6 months to two growing seasons after application. Picloram is highly residual and can remain active within the soil for more than a year and within the plant for up to 2 years. Picloram can have a significant off-target impact on native broadleaf species, and its use, both in liquid and granular form, can lead to unacceptable levels of off-target damage to canopy trees and other vegetation.

Triclopyr is a systemic foliar-applied herbicide used to control a range of broadleaf weeds. It does not have a long residual activity in the soil. Half-life estimates for triclopyr range between 30 and 90 days. Once absorbed, it is rapidly transported throughout the plant, disrupting plant cell growth.

Monosodium methyl arsenate (MSMA) is an organo-arsenical (arsenic-based) herbicide. The mode of action for organo-arsenicals is unknown, but it is believed to work on the target species in various ways to kill the plant (refer to https://www.croplife.org.au/wp-content/uploads/2016/08/2017-Herbicide-Resistance-Management-Strategies-.pdf). It can be used on *Opuntia* species for stem injection/drill and fill and foliar spraying in some juristictions (see Tables 4.1 and 4.2). It is fast acting and has high efficacy.

MSMA is a Schedule 7 poison. It is available only to specialised or authorised users who have accreditation. Special regulations restricting its availability, possession, storage or use may apply. Check with weed authorities in your state or territory to ensure that you are fully aware of your legal obligations in relation to this herbicide.

Amitrole is a non-selective systemic herbicide used to control a range of grasses and broadleaf weeds. It is classed as one of the Group Q herbicides, which are bleachers, inhibiting carotenoid biosynthesis in the target species.

Herbicide adjuvants

An adjuvant is any substance added to a herbicide to improve its effectiveness or application characteristics. The most commonly used adjuvants are carriers, surfactants (also known as wetters), penetrants and dyes. Only ever use adjuvants that are compatible with the herbicide chosen; these will be listed on the herbicide label.

Carriers are substances used to 'carry' or deliver the herbicide, most commonly water, but in the case of cacti control, diesel may be used with some herbicides such as Access™. Some jurisdictions also permit the replacement of diesel with more environmentally friendly carriers such as BIOSAFE, although its efficacy on cacti is untested.

Surfactants/wetter/spreaders enhance adhesion to and spreading of spray droplets on target surfaces by reducing the surface tension of the pesticide formulation and improving coverage. Using a wetting agent is very important in cacti control as good cover is essential to reduce reshooting. Refer to the label for the most appropriate wetter for your chosen chemical and application method.

Penetrants allow active ingredients to more easily enter vascular tissue, thus allowing movement of the herbicide throughout the plant. As well as being a carrier, diesel also acts as a penetrant in some registered and permitted mixes for cacti, increasing efficacy and reducing the likelihood of resprouting. Diesel a less desirable carrier for operators and for the environment, due to possible off-target damage and petrochemical residue in the soil leading to long-term site contamination issues. It also is very damaging to spray equipment.

Dyes are commonly used for spot spraying herbicides to detect missed spots and to avoid double spraying.

Herbicides for use on cacti

Herbicides listed in Table 4.1 are currently registered for use on cacti in stated situations, while those listed in Table 4.2 are permitted under minor use permits. Before using any herbicide, always read the label carefully. All herbicides must be applied strictly in accordance with the label directions or the conditions in the APVMA permit.

Tables 4.1 and 4.2 were developed in June 2017. Use them as a guide, but do not rely on them entirely. Check the permit or label before application to ensure it is still valid to use a product. Commercial products listed here are examples only, and many other products containing these active ingredients may be registered, visit www.apvma.gov.au/permits/search.php. To search registered chemical products, visit https://portal.apvma.gov.au/pubcris.

Please note that Tables 4.1 and 4.2 are not a full list of herbicides or applications for use on opuntioid cacti, and therefore information provided in these tables should be used as a guide only. Registered uses change periodically, so seek further advice from APVMA or your local weed authority before commencing any chemical control.

Table 4.1 Registered herbicides for use on opuntioid cacti

Jurisdiction	Application method	Active ingredient	Commercial products *See additional information at PUBCRIS*	Rate	Situation as per label *See additional information at PUBCRIS*	Species suitability	Comments
All states	Foliar spray	triclopyr as butoxyethyl ester (600 g/L)	Garlon 600	3 L/100 L water	Timber production, Commercial / Industrial / Public / Non-agricultural land, Rights-of-way, Pastures	*Opuntia* spp. including *stricta*, *aurantiaca*	Apply as a thorough foliar spray.
		triclopyr as butoxyethyl ester (600 g/L)	Garlon 600	0.8 L/60 L diesel	Timber production, Commercial / Industrial / Public / Non-agricultural land, Rights-of-way, Pastures	*Opuntia* spp. including *stricta*, *aurantiaca*, *monacantha*	Apply as a thorough foliar spray*
		triclopyr as butoxyethyl ester (750 g/L)	Safari 750 EC	2.4 L/100 L	Timber production, Commercial / Industrial / Public / Non-agricultural land, Rights-of-way, Pastures	*Opuntia* spp. including *stricta*, *aurantiaca*	Apply as a thorough foliar spray.
		triclopyr as butoxyethyl ester (750 g/L)	Safari 750 EC	0.8 L/75 L diesel	Timber production, Commercial / Industrial / Public land, Rights-of-way, Pastures	*Opuntia* spp. including *stricta*, *aurantiaca*, *monacantha*	Apply as a thorough foliar spray*
		picloram as potassium salt (240 g/L)	Stuka Flexi	0.21 L/100 L + 0.25 L/100 L triclopyr (600 g/L)	Agricultural land (Non-crop), Timber production, Commercial / Industrial / Public, Rights-of-way, Pastures	*Opuntia* spp. including *stricta*, *aurantiaca*	Apply as a thorough foliar spray. Regrowth may occur, so a follow-up application may be necessary.
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxy-propylamine salt (100 g/L) + aminopyralid as hexyloxypropylamine salt (8 g/L)	Grazon Extra	0.5 L/100 L	Timber production, Commercial / Industrial / Public / Non-agricultural land, Rights-of-way, Pastures	*Opuntia* spp. including *robusta*, *stricta*, *monacantha*	Apply as a thorough foliar spray. Regrowth may occur, so a follow-up application may be necessary.
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxy-propylamine salt (100 g/L)	Apparent Woody	0.5 L/100 L	Timber production, Commercial / Industrial / Public land / Non-agricultural land, Rights-of-way, Pastures	*Opuntia* spp. including *stricta*, *monacantha*	Apply as a thorough foliar spray. Regrowth may occur, so a follow-up application may be necessary.
		picloram as isooctyl/ ethylhexyl (120 g/L) + triclopyr as butoxyethyl ester (240 g/L)	Access	1 L/60 L diesel	Agricultural Land (Non-crop), Timber production, Commercial / Industrial / Public land, Rights-of-way, Pastures	Cacti including *O. stricta*, *Harrisia* spp., prickly pears, snake cactus, tiger pear, tree pear	Apply as an overall spray, wetting all areas of the plant to ground level. DO NOT allow mixture to contact non-target species.*

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Table 4.1 continued/…

Jurisdiction	Application method	Active ingredient	Commercial products *See additional information at PUBCRIS*	Rate	Situation as per label *See additional information at PUBCRIS*	Species suitability	Comments
Queensland	Injection (mature)	amitrole (250 g/L) + ammonium thiocyanate (220 g/L)	Amitrole T	1 mL neat per injection cut	Land – around buildings, Commercial / Industrial / Public / Non-agricultural land, Rights-of-way	Tree pears (*Opuntia* spp.)	Injection in cuts at 3 cm spacings around lower trunk of mature plants. Tree pears may take up to 12 months to die. Respraying may be necessary in some cases.
	Foliar spray	amitrole (250 g/L) + ammonium thiocyanate (220 g/L)	Amitrole T	1 L/25 L water	Land – around buildings, Commercial / Industrial / Public / Non-agricultural land, Rights-of-way	Tree pears (*Opuntia* spp.)	Apply foliar spray liberally to small plants and regrowth. Tree pears may take up to 12 months to die. Respraying may be necessary in some cases. Tall plants may be lopped before spraying. Apply the spray liberally over the entire plant and on adjacent soil.
South Australia	Foliar spray	MSMA (720 g/L)^	Gauntlet, Daconate 720	1.1 L/40 L water	Pest-infested areas	*Opuntia stricta*, *imbricata*, *monacantha*, *ficus-indica*, *robusta*	Apply in summer using a power sprayer when air temperature is above 30°C. Thoroughly cover all pad surfaces. Respray any regrowth that may occur.
		MSMA (800 g/L)^	Daconate, Militate	1 L/40 L water	Land – around buildings, Non-agricultural land, Rights-of-way	*Opuntia stricta*, *imbricata*, *monacantha* (syn. *O. vulgaris*), *ficus-indica*, *robusta*, *leucotricha*, *phaeocantha*	Apply in summer using a power sprayer when air temperature is above 30°C. Thoroughly cover all pad surfaces. Respray any regrowth that may occur.

* The application method listed on label for these herbicides is 'basal bark/cut stump', however the critical comments on the label specify applying as a thorough foliar spray. The critical comments have been interpreted as the most appropriate application method for cacti.

^ Monosodium methyl arsenate (MSMA) is a Schedule 7 poison. It is available only to specialised or authorised users who have the skills and accreditation necessary to handle it safely. Special regulations restricting its availability, possession, storage or use may apply. Check with weed authorities in your state or territory to ensure that you are fully aware of your legal obligations in relation to these herbicides.

Table 4.2 Herbicides permitted for use on cacti off-label under minor use permits

Jurisdiction	Application method	Active ingredient	Commercial products *See additional information at PUBCRIS*	Rate	Situation as per label *See additional information at PUBCRIS*	Species suitability	Label of permit (APVMA) requirements as at July 2017	Comments
New South Wales	Foliar spray	metsulfuron-methyl (600 g/kg) glyphosate (360 g/L)	Metsa 600 Herbicide Raystar Glyphosate 360 IPA SL Herbicide	1–2 g met, 20 mL glyphosate/10 L water	Natural ecosystems – non agricultural	prickly pear (*Opuntia* spp.)	PER12363 Exp. 31 Mar, 2021	This permit applies to spot spraying from unmanned aircraft only.
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxypropylamine salt (100 g/L)	Grazon DS	0.5 L/100 L + 0.5% v/v Uptake Spraying Oil	Agricultural land – non-crop, Bushland, Rights-of-way, Pastures	All species Cactaceae family	PER14442 Exp. June 30, 2018	
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxypropylamine salt (100 g/L) + aminopyralid as hexyloxypropylamine salt (8 g/L)	Grazon Extra	0.5 L/100 L + 0.5% v/v Uptake Spraying Oil	Agricultural land – non-crop, Bushland, Rights-of-way, Pastures	All species Cactaceae family	PER14442 Exp. June 30, 2018	
		triclopyr as butoxyethyl ester (600 g/L)	Garlon 600	1 L/75 L diesel or 3 L/100 L water or 50 mL in 10 L of water + 50 mL Uptake Spraying Oil	Agricultural land – non-crop, Bushland, Rights-of-way, Pastures	All species Cactaceae family	PER14442 Exp. June 30, 2018	
Victoria	Stem injection	MSMA (800 g/L)	Daconate	4 mL/m plant height/stem branch	Agricultural land – non-crop, Bushland, Non-agricultural land	Wheel cactus	PER14787 Exp. 30 June, 2020	
Queensland	Basal bark/cut stump	triclopyr as butoxyethyl ester (240 g/L) + picloram as IOE (120 g/L)	Access	1 L/60 L diesel	Commercial / Industrial, Rights-of-way, Pastures	Coral cactus	PER13812 Exp. 30 June, 2022	Paint stump immediately after cutting or spray basal bark.
South Australia	Stem injection	triclopyr as butoxyethyl ester (600 g/L)	Garlon 600	Apply undiluted (stem injection)	Native Forests, Bushland, Recreation land, Rights-of-way	Prickly pears (*Opuntia* spp.)	PER12932 Exp. 31 Aug, 2021	
		glyphosate (450 g/L)	Roundup CT	Undiluted	Conservation areas, bushland and other non-crop areas	*Austrocylindropuntia* spp. *Cylindropuntia* spp. *Opuntia* spp.	PER 13371 Exp 31 Mar, 2022	While actively growing, inject a measured dose of herbicide into the cladodes with a drenching needle.
	Drill and fill	triclopyr as butoxyethyl ester (600 g/L)	Garlon 600	Undiluted	Native vegetation, rangeland, pasture and other non-crop areas	*Austrocylindropuntia* spp. *Cylindropuntia* spp. *Opuntia* spp.	PER 12932 Exp. 31 Aug, 2021	While actively growing, use cordless drill to make holes around the base into the sapwood. Inject herbicide immediately.

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Table 4.2 continued/…

Jurisdiction	App. method	Active ingredient	Commercial products	Rate	Situation as per label *See additional information at PUBCRIS*	Species suitability	Permit no. (as at July 2017)
Western Australia	Not specified – refer to label and seek advice from DPIRD	picloram as triethanolamine salt (20 g/kg)	Tordon Granules	Apply up to maximum registered label rates and in accordance with Department of Primary Industries and Regional Development (WA) advice for control of Declared Plants.	Crop and non crop areas as specified for WA on the approved label, for the control of declared plants specified under the *Agriculture and Related Resources Protection Act 1976*	Not specified – covered under 'Declared Plants'	PER13236 Exp. 31 Dec, 2022
		triclopyr as butoxyethyl ester (600 g/L or 750 g/L)	Garlon 600, Safari 750	As above		Not specified – covered under 'Declared Plants'	PER13236
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxypropylamine salt (100 g/L) + aminopyralid as hexyloxypropylamine salt (8 g/L)	Grazon Extra	As above		Not specified – covered under 'Declared Plants'	PER13236
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxypropylamine salt (100 g/L)	Apparent Woody	As above		Not specified – covered under 'Declared Plants'	PER13236
		triclopyr as butoxyethyl ester (240 g/L) + picloram as IOE (120 g/L)	Access	As above		Not specified – covered under 'Declared Plants'	PER13236
		MSMA (800 g/L)	Daconate	As above		Not specified – covered under 'Declared Plants'	PER13236
	Foliar spray	triclopyr as butoxyethyl ester (600 g/L)	Garlon 600	1 L/100 L + wetting agent or spray oil	Agricultural land – non-crop, Commercial and industrial areas, Wetlands, Bushland and forests	Not specified – covered under 'Environmental weeds'. Cacti is considered as 'Woody weeds', 'woody weeds and trees' and 'perennial broadleaf weeds'	PER13333 Exp. 31 Mar, 2022
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxypropylamine salt (100 g/L) + aminopyralid as hexyloxypropylamine salt (8 g/L)	Grazon Extra	1 L/100 L + wetting agent or spray oil	Agricultural land – non-crop, Commercial and industrial areas, Wetlands, Bushland and forests	As above	PER13333
		triclopyr as butoxyethyl ester (300 g/L) + picloram as hexyloxypropylamine salt (100 g/L)	Grazon DS	1 L/100 L + wetting agent or spray oil	Agricultural land – non-crop, Commercial and industrial areas, Wetlands, Bushland and forests	As above	PER13333
		MSMA (720 g/L–800 g/L)	Daconate or Imtrade MSMA	1.1/40 L water (720 g/L) or 1/40 L water (800 g/L)	Agricultural land – non-crop, Commercial and industrial areas, Wetlands, Bushland and forests	Opuntioid cacti (declared pest cacti)	PER13333
	Drill/injection	glyphosate (formulation not specified)		2 mL/hole or cut	Agricultural land – non-crop, Commercial and industrial areas, Wetlands, Bushland and forests	Not specified – covered under 'Environmental weeds'. Cacti is considered as 'Woody weeds', 'woody weeds and trees' and 'perennial broadleaf weeds'	PER13333
	Paint stump or basal bark	glyphosate (formulation not specified)		Undiluted to 1 L/5 L water	Agricultural land – non-crop, Commercial and industrial areas, Wetlands, Bushland and forests	As above	PER13333
		triclopyr as butoxyethyl ester (240 g/L) + picloram as IOE (120 g/L)	Access	1 L/60 L diesel	Agricultural land – non-crop, Commercial and industrial areas, wetlands, Bushland and forests	As above	PER13333

Application methods

Foliar spraying

Foliar spraying is the use of herbicide diluted with water (or other carriers such as diesel) at a specific rate and application to the leaves and stems of a plant in the form of a fine spray. A range of other chemicals may be added (e.g. penetrants, surfactants, wetting agents and dyes), depending on label recommendations. These chemicals can greatly assist with the uptake of the active ingredient.

Applying the method

- Effective foliar spraying of cacti requires that all cladodes (including undersides) are wet with herbicide to the point of drip.
- Foliar spray application techniques used to control opuntioid cacti include:
  - Backpack/knapsack – for low pressure spraying and used for spot spraying large or small infestations;
  - Hand held spray bottles – for small areas, small plants or around native vegetation; and
  - Vehicle-based sprayers – for high pressure spraying using a hose and handgun.

The most appropriate foliar spray application for your situation will depend on the plant size and growth form, density of infestation, habitat, site specifications and the availability of resources, including trained contractors. The application rate, volume and concentration of herbicide will vary with the application used (refer to label or permit).

Foliar spraying is currently used* on:

Austrocylindropuntia spp.	*Opuntia engelmannii*	*Opuntia puberula*
Cylindropuntia spp.	*Opuntia leucotricha*	*Opuntia stricta*
Opuntia aurantiaca	*Opuntia monacantha*	*Opuntia tomentosa*
Opuntia ficus-indica	*Opuntia polycantha*	*Cereus* spp.

STOP AND THINK!

Site-specific management: Minimising spray drift and off-target damage

- Foliar spraying can have a significant impact on non-target vegetation:
  - Other shrubs and ground covers can be affected by spray drift.
  - Some herbicides are residual in the soil and are absorbed by roots. Canopy trees can be killed if cacti co-occurring within their root zone are sprayed.
- Think about your situation and consider off-target damage.
- Do not use root-absorbed herbicides such as picloram under the canopy of desirable vegetation.
- Only use foliar spraying on small to medium cacti and ensure wind speeds are low.
- Causing spray drift is considered an offense in some states and territories.

Matt Sheehan

Canopy trees dying as a result of foliar spraying of Opuntia stricta with picloram

** Note that this is a guide only based on practitioner experience, how firmly the cladodes are attached to the plant, and the plant's size and shape. Other methods may be more appropriate depending on the maturity (size) of the individual plant. Ensure the application method, species and situation is registered or permitted for use in your state or territory by checking the APVMA website or chatting to your local weed officer.*

Foliar spraying

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Efficiency ▪ Can cover large areas	▪ Potential for spray drift and off-target damage ▪ 100% of the plant must be wetted with herbicide ▪ Re-sprouting is very common, requiring follow-up ▪ Human health risks If used incorrectly	▪ **Follow-up control is required to treat regrowth, cladodes and seedlings** ▪ **Personal protective equipment required**	Refer to label – Herbicides should not be applied where plant is under stress or during hot, dry conditions, apart from MSMA (see label)	▪ Physical control ▪ Other chemical control ▪ Biological control

Stem injection (pad injection/drill and fill)

Stem injection is an effective method for controlling *Opuntia* species whose cladodes are firmly attached to each other, are shrub-forming with a branching and open form, or are tree/trunk-forming. As described in Chapter 1, the modified stems of opuntioid cacti are referred to as **cladodes** and are variable in form both within and between genera. For simplicity, when thinking of cacti, it is easiest to think of anything protruding from the ground as a stem regardless of form. The form will determine the most appropriate method of stem injection.

In some *Opuntia* species, the cladodes are large, thick, fleshy and flat, and because of their appearances are often referred to as 'pads' or 'wheels'. An example of such a cactus is *Opuntia robusta* (wheel cactus). Stem injection can be administered directly by inserting an injector needle into the pads. This is commonly referred to as **pad injection.** Other species, such as *O. monacantha* and *O. tomentosa*, while also having fleshy pads, can develop woody sections between pads that look more like true stems. Pads may also be tough and fibrous and not easily penetrated with an injecting needle. In these species, stem injection can be administered by first drilling a hole and then injecting with herbicide. This is referred to as **drill and fill.** Both methods of stem injection will be described here, allowing you to choose the most suitable method for your cacti.

You say 'cladode', I say 'stem segment', they say 'pad'

In Australia, the stems of opuntioid cacti are known by several names – stem segments, cladodes or pads. The term pad is commonly applied to *Opuntia* species.

Both stem methods involve using a drenching needle to inject herbicide directly into the 'pads' or via holes drilled at multiple locations on the plant. While effective, it can be time consuming and labour intensive, so it is best suited to small or scattered infestations, or for the management of outliers around core infestations in conjunction with other methods such as biological control. However, for some species such as *Opuntia robusta* (wheel cactus), where there are limited alternative control options, pad injection is routinely used in large dense infestations.

Glyphosate is registered for use with this application method throughout Australia, and is used as a herbicide of choice when control is being carried out by volunteers. Amitrole is registered for use in Queensland. Additionally, MSMA is listed on a minor use permit in Victoria and triclopyr (Garlon

600) in South Australia. Refer to Tables 4.1 and 4.2 for registered and/or permitted herbicide options.

Stem injection kills cacti where they stand, therefore only plants that can be safely left to die and rot should be treated this way. If the cactus plant is to be felled post-control, allow it to die completely before felling to avoid re-sprouting from cladodes that come in contact with the ground.

Applying the methods

Pad injection – for fleshy pads (e.g. *O. robusta*)

The number of injections per plant will differ depending on the shape and height of each plant. It is worth taking a moment to stand back and look at the plant to work out how best to tackle it. Refer to labels for recommended rates and the amount of chemical required per length of stem. A good guide is to aim to inject every second or third pad to ensure that there is enough herbicide to circulate throughout the plant.

1. Starting from the outermost (top) pad on a branch, inject every 2–3 pads back down toward the base, ensuring every branch is treated. Note that it may not be possible to inject pads near the base of plants as older pads can become woody and may damage the injector – drill and fill could be used on these if required.
2. The key to successful plant kill is using the correct injecting technique. The injector is inserted into the cladode (pad), ideally from the top edge, alternatively from the side on an oblique angle. Insert the injector 5–10 cm into the pad towards the centre and then retract about half way to make a pocket for the herbicide. Making this pocket is very important as without it the herbicide may shoot out of the pad when the herbicide is injected or when the injector is removed.
3. Deliver a dose of herbicide into the pad and repeat for remaining pads. Marking treated plants with spray paint can help keep track of plants that have been controlled.

Aimee Heath and Kym Haebick

Equipment for stem injection, including Daconate herbicide, stem injection kit, drill, plastic gloves and face shield

Drill and fill – for woody stems/pads or trunk forming cacti

This method is effective for trunk-forming cacti or as an alternative to pad injection for branching open cacti such as *Opuntia robusta* (wheel cactus).

Perri Carter

Lee Mead

Pad injection using a Velpar Spot Gun with a drenching nozzle (top) and 47 cm spear nozzle (bottom)

1. Using a battery-powered drill and a 12 mm bit, drill into the stem or trunk or the base of each branch above the ground surface or at major junctions, to a depth of 50–70 mm on a downward angle. The drill hole must be large enough so that the injecting needle fits in, and deep enough to hold the dose of herbicide.
2. Immediately inject the dose of herbicide.

Timing

This method can be applied year round. Stem injection in Victoria is completed over the winter months, while in South Australia it is usually undertaken during the warmer months. Summer application is likely to work quicker and possibly result in higher efficacy; however, summer conditions can present health and safety risks to operators. Also, pads often wilt in hot weather, making them more difficult to inject and more prone to splitting.

Stem injection is currently used* on:

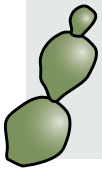
C. imbricata	*Opuntia leucotricha*	*Opuntia schickendantzii*
Opuntia elata	*Opuntia monacantha*	*Opuntia streptocantha*
Opuntia elatatior	*Opuntia polycantha*	*Opuntia stricta*
Opuntia engelmannii	*Opuntia puberula*	*Opuntia tomentosa*
Opuntia ficus-indica	*Opuntia robusta*	*Cereus* spp.

Pad injection – the South Australian approach

The Blinman Parachilna Pest Plant Control Group (BPPPCG) have controlled thousands of *Opuntia robusta* plants in the Flinders Ranges of South Australia. Volunteers and contractors have had good success with the following method:

- Count the number of pads per plant;
- Divide pad number by 4 to determine number of injections per plant;
- Deliver required number of 4 mL injections evenly throughout the plant, ensuring each branch is injected in a multi-branched plant;
- Injections are pre-set at 4 mL of herbicide using a Velpar spot gun style injector.

This method is based on a rate of 1 mL of herbicide per pad, delivered in 4 mL doses (hence dividing total number of pads by 4). Using this formula a plant with 28 pads would require 7 injections in total.



** Note that this is a guide only based on practitioner experience, the plant's size and shape. Other methods may be more appropriate depending on the maturity (size) of the individual plant. Ensure the application method is registered or permitted for use in your state or territory with the species and situation you are managing by checking the APVMA website or chatting to your local weed officer.*

Stem injection (pad injection and drill and fill)

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Suits isolated, small infestations or difficult-to-access sites ▪ High efficacy and minimal off-target damage ▪ Low volumes of herbicide required ▪ Glyphosate suitable for volunteers with appropriate training	▪ Time consuming ▪ The number of pads requiring treatment is subjective ▪ Works for large, dense infestations, but is labour intensive	▪ **Requires specialised equipment (e.g. a Velpar injector kit)** ▪ **Use of MSMA requires accreditation – not suitable for volunteers**	Year round	Biological control (where available)

Important injecting tip

Ensure that the injector does not pierce the wall of the pad, as the dose will be lost.

TCCG

Other methods

Other chemical treatments for cacti include basal bark paint or spray and cut stump.

While the basal bark and cut stump application methods are on label for some herbicides, they are rarely used on opuntioid cacti, and therefore the efficacy of these methods are unknown.

Basal bark and cut stump are not recommended as best practice control methods on opuntioid cacti.

Comparing *Opuntia robusta* (wheel cactus) control methods

Opuntia robusta forms extensive, thick monocultures in difficult-to-access, rocky ridges in central Victoria. Restricted site access and lack of other suitable control methods for *O. robusta* have resulted in the Tarrangower Cactus Control Group (TCCG) using pad injection or drill and fill as their control methods*. The TCCG conducted trials to compare the efficacy and cost of glyphosate pad injection to MSMA drill and fill. They found that MSMA drill and fill is cheaper, quicker and faster acting with greater efficacy than glyphosate pad injection.

* Elsewhere in Australia, other methods, such as mechanical or biological control, may also be effective for managing *O. robusta*.

	Glyphosate (inject each pad)	**MSMA (Daconate) (drill hole in stem and inject)**
Approx. time per injection	3 seconds	9 seconds
Mean no. injections per plant	84.5	13.8
Mean time injecting per plant	4.9 min	2.1 min
Cost of chemical	0.7 cents/mL	1.7 cents/mL
Mean volume chemical per plant	113 mL	55 mL
Approx. cost of chemical per plant	79 cents	94 cents
Approx. time taken to kill plant	> 54 days	20 days
Follow-up	Re-injection very likely	Unlikely
Withholding period	No	Yes – 5 weeks

Managing cacti

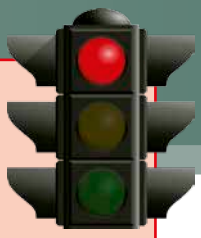
Fire management

Cacti and their responses to fire are not well understood in Australia. It is likely that some opuntioid and non-opuntioid cacti species are more susceptible to fire than others. However, all cacti are succulents (containing lots of moist tissue) and, as a rule, it takes considerable heat energy to burn and completely destroy plants. Trials of burning *Cylindropuntia spinosior* (snake cactus) and field observations of *Opuntia stricta* (common prickly pear) following wild fire have shown that these species are not killed by fire, and in fact they recover with great vigour.

In 2011, burning was trialled as a control method on a dense infestation of *Cylindropuntia spinosior* (snake cactus) in western Queensland. While the cactus burned, it was not killed, and within 6 months, most of the cactus plants had reshot from the base. It is likely the spinifex-dominated open woodland did not provide the fuel load to allow the fire to reach the intensity required to kill the cactus.

Shauna Potter

Cylindropuntia spinosior regrowth following controlled burn



Be prepared

If you plan to burn an area, permission may be required. Contact your local fire authority for advice.

The use of fire as a management tool requires careful consideration and planning. Appropriate safety measures should be put in place.

It has also been speculated that winds that accompany intense fire events may act as a spread vector, transporting small cladodes of shrub cacti, such as the easily detachable cladodes of *Cylindropuntia fulgida* var. *mamillata* (coral catcus).

Based on this, fire as a sole control method for any cacti species is not recommended.

However, fire has a role to play in an integrated management setting where other methods may be used opportunistically following fire events. Fire reduces the biomass of both cactus and surrounding vegetation, increasing visibility and accessibility. Cacti re-establishes more quickly than other vegetation, allowing a window of time for chemical or manual control.

Fire can also be used as part of a follow-up management strategy with other control methods (e.g. chemical control), cleaning up the area by removing dead plants, reducing risk that spines pose to humans, livestock and wildlife, and to improve access for follow-up chemical treatment.

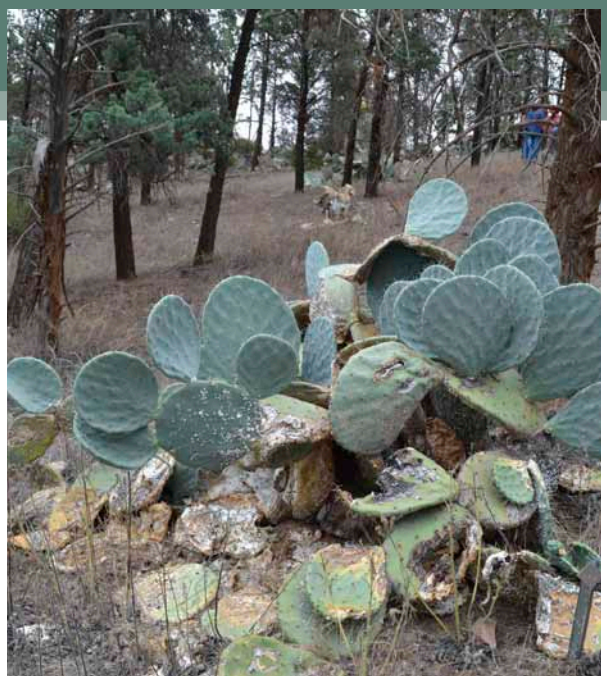
Fire management

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Good for clearing large area of infestation to reduce biomass and provide access ▪ Wildfire or fuel reduction burns can allow for opportunistic control with other methods ▪ Hot fire will destroy seed and very small plants	▪ May not kill cacti and may result in vigorous regrowth following fire ▪ Updrafts may disperse small cladodes	▪ **Many unknowns**	Opportunistically link with wild fire and fuel reduction burning	▪ Chemical control ▪ Physical control

Biological control

The science of **biological control** (or biocontrol) can be defined as the study and utilisation of natural enemies such as parasitoids, predators, herbivores and pathogens for the regulation of host population densities. These natural enemies are referred to as biological control agents.

There are several approaches used in the global practice of weed biological control, but when dealing with opuntioid cacti the one most commonly used in Australia is that of 'classical biological control'. This refers to the introduction of host-specific natural enemies, from the native range of the weed, into areas where their host plant has become a weed. The aim is to reduce the density (and resulting impact) of the weed to a level that is acceptable, and maintain the weed density at that level (Figure 4.3).



Shauna Potter

Opuntia robusta plants collapsing under the impact of cochineal

Frank Bernhardt

Cactoblastis larvae hard at work

One of the key points to note in this definition of classical biological control is the use of the terms 'reduce and maintain density levels'. This means that biological control should not be regarded as a 'silver bullet'. It is not an eradication tool and should always be used in conjunction with other control techniques, such as herbicides and physical control, in an integrated manner.

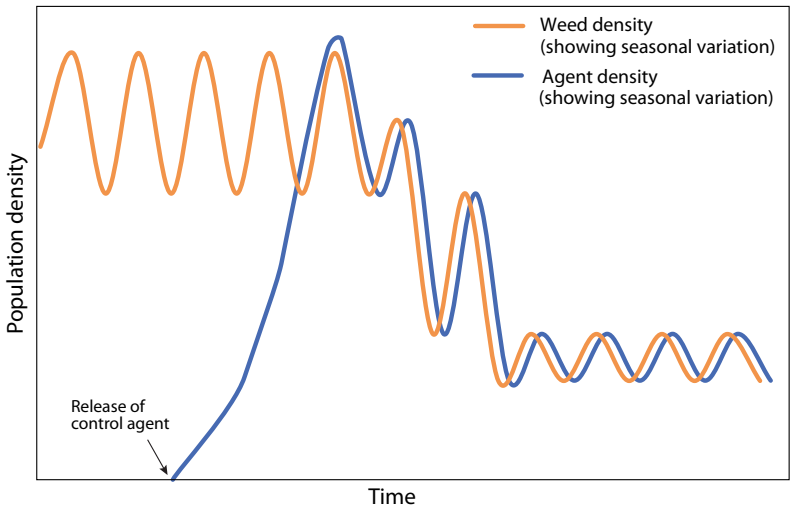


Figure 4.3 Changes in the population density of a weed before and after the establishment of biological control agents

Lorraine Edmunds

Opuntia robusta heavily infested with cochineal

The approval process for biological control agents in Australia

To be considered suitable for use in a biological control program, an agent must be **host specific**. That is, it must have an extremely limited host range that includes the target weed and possibly a few closely related species. The agent must not attack non-target species such as crops, ornamentals and other beneficial plants or native species. Fortunately, in Australia, there are no native cactus species and most opuntioid cacti are declared noxious so host specificity testing is a relatively simple process.

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

Use of biological control agents on cacti in Australia

A number of agents have been introduced into Australia for the biological control of opuntioid cacti, but the only ones that have a significant impact on cacti populations are *Cactoblastis cactorum* (a stem-boring moth) and several *Dactylopius* species (cochineal insects).

An excellent summary of the agents introduced into Australia for cacti control is: Hosking J.R., McFadyen, R.E. and Murray, N.D. (1988) Distribution and biological control of cactus species in eastern Australia. *Plant Protection Quarterly* 3, 115-123.

Cactoblastis

Cactoblastis (*Cactoblastis cactorum*) is a moth that, in its larvae stage, feeds on the fleshy interior of cacti cladodes. It is especially effective on *Opuntia stricta* (common prickly pear), although it feeds on a range of opuntioid cacti. The exploration for, and subsequent release of, cactoblastis in Australia in 1926 is covered in a case study at the end of this section (see page 109).

Impact of cactoblastis biocontrol

The damage is done by the bright orange and black larvae (caterpillars), which feed inside the prickly pear cladodes.

Eggs are laid in sticks that mimic spines, each containing 50 to 100 eggs, attached to the cactus pad surface. The hatching larvae feed in a group inside the pad, leaving a small hole to push out the frass (debris). At first the damage isn't very obvious, but as the larvae grow they destroy the whole pad and then move into new ones. The glutinous frass drips to the ground and this, plus the dried-out empty pads, is the most obvious sign of their presence.

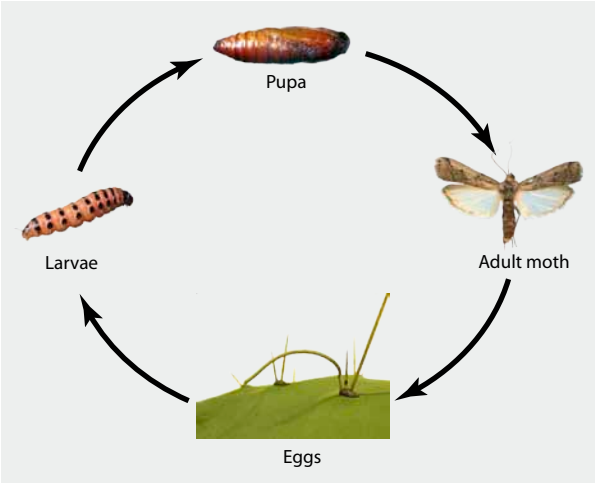
Full-grown larvae leave the pads and spin silk cocoons in the leaf litter on the ground. Adult moths emerge three to four weeks later, and the cycle starts again. In most regions there are two well-synchronised generations each year, a short summer generation and a long winter one. In warmer regions there may be three generations and only one in colder areas.

Lorraine Edmunds

Egg stick

Lorraine Edmunds

Larvae around a frass hole



Cactoblastis life cycle

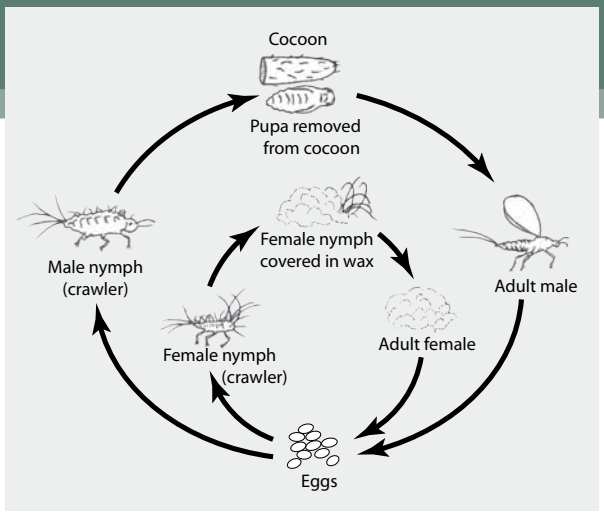
Cactoblastis continues to be an extremely successful agent for controlling certain cactus species. It is effective in most situations, although less so in cooler areas or very dry locations. Cactoblastis moths are strong fliers that are capable of dispersal over large distances.

Dactylopius

Dactylopius is a genus of scale insect, commonly referred to as cochineal, a name that also specifically refers to the best-known species, *Dactylopius coccus*. Cochineal is an insect of economic and historical importance as a main source of the red dye carmine. Cochineal is also important because several species have been used as biological control agents for cacti in many countries throughout the world.

Life cycle

All *Dactylopius* species have adult females that are sessile (fixed in one place; immobile) and remain attached to cladodes of their host plants where they feed. Adult males are small, weak fliers that do not feed. The only method of dispersal for cochineal is by the movement of first instar nymphs, often referred to as 'crawlers'. They climb to the extremities of plants where they are picked up by wind currents and spread to neighbouring host



Dactylopius life cycle (adapted from Moran and Cobby, 1979)

plants, so dispersal is relatively localised. Crawlers are very small and are vulnerable to being washed from plants by heavy rain before they are able to disperse or attach. Heavy rain and cold weather can inhibit the effectiveness of cochineal, which thrive under drier conditions.

Adult and immature female cochineal insects remain permanently attached to their host plant by their sucking mouthparts. They feed by sucking sap from the plant. This can cause discolouration and eventually death of the plant. It is not certain if the damage is caused by the feeding itself (removal of plant sap), or whether the insects also inject damaging toxins.

Commencing a biological control program on cacti

Before commencing a biological control program for opuntioid cacti, it is important to consult with a specialist from the agriculture department (or equivalent) in your state or territory or your local weeds officer. They will be best placed to advise on requirements, whether the project is likely to be successful and where to source the correct agents.

Remember:

- If cacti are dense or are present over a large (core) and/or inaccessible area, biological control is an excellent, cost-effective and long-term option.
- If there is only a small, scattered population of plants, control is best through use of herbicides or physical means.

Dactylopius host specificity

There are a number of *Dactylopius* species and **biotypes**, each of which are very selective about which host cacti they will feed on. For effective biocontrol, you must have the correct *Dactylopius* for your cacti, but note that currently there are not agents available for all opuntioid cacti (see Table 4.3 below).

Four species of *Dactylopius* have been introduced into Australia. These are *D. austrinus* for *Opuntia aurantiaca* (tiger pear) in 1933, *D. ceylonicus* for *O. monacantha* (drooping tree pear) in 1914, *D. opuntiae* for *O. stricta* (common prickly pear) in 1921 and *D. tomentosus* for *Cylindropuntia imbricata* (rope pear) in 1925. An additional biotype of *D. tomentosus* was introduced for *C. fulgida* var. *mamillata* (coral cactus) in 2016. In 2017, biotypyes were released for all other *Cylindropuntia* species.

A full list of cacti and their agents is provided in Table 4.3 below.

It is advisable to talk to the agriculture department (or equivalent) in your state or territory or your local weeds officer, about how to obtain the relevant cochineal (refer to contact information in Chapter 6 on page 147). This will ensure that you have obtained the correct biotype for the cacti species you are targeting.

What is a 'biotype'?

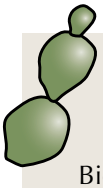
A morphologically indistinguishable form of a species that can interbreed, but can only be recognised by their distinct:

- Host preference for feeding or oviposition (egg laying); and
- Survival and development on different hosts.

Table 4.3 A list of biological control agents (*Dactylopius* and *Cactoblastis*) released and/or established on opuntioid cacti in Australia

Cactus species	Biocontrol agents
Cylindropuntia fulgida var. *mamillata*	*D. tomentosus* (South African biotype)
Cylindropuntia imbricata	*D. tomentosus* (*imbricata* biotype)
*Cylindropuntia kleiniae**	*D. tomentosus* (*Cylindropuntia* sp. biotype)
*Cylindropuntia leptocaulis**	*D. tomentosus* (Cylindropuntia sp. biotype)
*Cylindropuntia spinosior**	*D. tomentosus* ('*bigelovii*' biotype)
*Cylindropuntia tunicata**	*D. tomentosus* ('*acanthocarpa* × *echinocarpa*' biotype)
Opuntia aurantiaca	*D. austrinus* and *C. cactorum*
Opuntia humifusa	*C. cactorum*
Opuntia dillenii	*C. cactorum*
Opuntia elata	*D. ceylonicus* and *C. cactorum*
Opuntia elatior	*D. opuntiae* and *C. cactorum*
Opuntia ficus-indica	*D. opuntiae* and *C. cactorum*
Opuntia monacantha	*D. ceylonicus* and *C. cactorum*
Opuntia robusta	*D. opuntiae* and *C. cactorum*
Opuntia streptacantha	*D. opuntiae* and *C. cactorum*
Opuntia stricta	*D. opuntiae* and *C. cactorum*
Opuntia tomentosa	*D. opuntiae* and *C. cactorum*

* Biocontrol agents for these species were approved for release in October 2017. There will be a lag time of several months before field releases can be made and agents establish in the field.



Where can I get biological control agents?

Biocontrol agents generally occur throughout most areas impacted by opuntioid cacti, however some areas, such as Western Australia, are in the early stages of biocontrol. To find out where and how to source agents for your weed management program you can:

- Check the Biocontrol Hub (see page 107) to see whether agents are already in your area; and
- Contact your local weed authority or weeds officer for assistance.

Establishing and redistributing cactoblastis

Cactoblastis is easy to establish and redistribute. Unlike cochineal, there is no need to rear (breed up) populations. Cactoblastis is widespread amongst populations of their host plants, particularly in the eastern states. Cactoblastis moths are strong flyers and are capable of finding isolated plants or populations, so further releases are usually not needed. Situations where redistribution may speed up natural spread include:

- Following a series of unsuitable seasons that may have impacted on cactoblastis populations;
- Establishing a new population in a remote area that cactoblastis has not yet reached.

Cactoblastis harvest and redistribution method

Method 1: Egg stick

Moving egg sticks involves pasting the egg sticks to a small piece of paper and pinning the paper to the new plant. As this is very time consuming, an alternative approach is to place cladodes with egg sticks attached into new plants. Larvae will then hatch, bore into the unaffected cladodes and commence feeding.

Method 2: Larvae

An easier method of transferring cactoblastis is to move cladodes already infested with larvae. Cut off infested cladodes and store them in boxes out of direct sunlight for transport to the release site. These should be placed among cladodes of the target plants either attached to cladodes, wedged in or at the base of plants. Ants can be a problem using this technique as they can gain access to, and prey on, the larvae through the cut or broken ends of the cladodes.

Lorraine Edmunds

One method trialled for translocating cactoblastis larvae, Emu Creek SA

Establishing and redistributing cochineal

Because of their dispersal mechanism, cochineal insects are less likely to find isolated plants or populations, so human intervention may sometimes be required. These species all look similar to the naked eye so it is **important to use the correct cochineal species for each cacti species**. Refer to Table 4.3 page 104 for guidance.

Cochineal redistribution method

Moving cladodes infested with adult females (obvious by the white, waxy coating) is the most successful redistribution method.

Harvest:

Collect infested cladodes from existing populations using tongs and a knife. Ensure the cacti species you are collecting from is the same as the species you wish to introduce the agent to. Plastic tubs with lids are ideal for collecting and transporting cladodes. Do not leave agents in tubs in direct sunlight or hot cars or buildings. It may be necessary to increase the number of collected agents prior to mass release. See Table 4.4 for a rearing protocol.

Redistribution:

There are many methods for releasing agents:

- Pinning infected pads to host pads with kebab skewers;
- Wedging infected pads in the junctions of stems;
- Placing infected pads within and beneath recipient plant.

Andrew McConnachie

Placing infected cladodes on Cylindropuntia fulgida var. mamillata at an infestation in Tibooburra NSW

All methods are considered equally effective, however pinning cladodes is time consuming. If you only have a very limited supply of cladodes containing cochineal, you may consider pinning them to ensure they don't fall to the ground.

A few tips to assist with cochineal redistribution:

- Cladodes infested with cochineal should be placed among cladodes of the target population where they are protected and out of direct sunlight.
- Because of cochineal's method of dispersal (wind) infested cladodes should be placed on the up-wind side of the cactus infestation, thus allowing crawlers to naturally disperse into the dense part of the weed population.
- Strategically placing infested cladodes amongst a large, dense field population will also augment (increase) redistribution by allowing crawlers to more quickly reach and establish on neighbouring plants (see case study page 109).
- Establishment may be assisted if some larger plants (especially with the bigger *Opuntia* and *Cylindropuntia* species) are cut down and piled up prior to release, but not too deep as lower cladodes may start to rot.
- Do not place infected cladodes on plants showing high ant activity.

NOTE: cochineal also infects fruit, but infested fruit should not be redistributed, as they may contain viable seed.

Cochineal rearing protocol

Rearing cochineal is easy, and hard to get wrong! Table 4.4 below provides a guide based on the approach used for *Dactylopius opuntiae* on *Opuntia stricta* in Western Australia.

Table 4.4 Guide to rearing cochineal

Optimal rearing temperature	Dormant below 16°C, mortality increases above 30°C. 25–30°C is considered a comfortable temperature.
Housing	A dry protected room; or warm glasshouse in the winter, transferring outside or to a shade house as the weather warms up.
Equipment	► Shelving ► Plant trays, metal trays or plastic tubs ► Large serrated knife for harvesting cacti pads ► Heavy duty gloves ► Tongs for handling cacti pads ► Mask or respirator to avoid inhalation of airborne glochids ► Safety glasses or a face shield
Harvesting 	Harvest infected cladodes (and fruit) from known populations or nursery sites using tongs and a serrated knife. Collect in a tub. ***Tip:*** Each time you collect pads, harvest extra plant material and store it in a cool place until you need it. **Note** – you may require a permit to transport and/or keep opuntioid cacti. Contact your local weed authority for more information.
Feeding 	Place 1–2 infested cactus cladodes within a tray of clean pads. When the new pads are infested, each infested pad can be added to a new tray of fresh plant material. Trays can be stacked to allow crawling nymphs to move between them; just ensure enough space for adequate airflow.
Frequency	How often you provide new plant material will depend on how quickly the insects reproduce, which may vary throughout the year. As a rough guide, check the spread of the colony weekly. 4–6 weeks should be sufficient time for the colony to increase and allow new material to be added. Remove dead cladodes before they decay.
Keeping the colony healthy	▪ Protect cochineal from extremes of temperature. ▪ Cochineal can be impacted by other insects and disease. Talk to a weed professional about which of these factors are impacting the success of the rearing program. ▪ Do not release colonies suspected of carrying a disease into a site, as this may affect the ability of the cochineal to control cacti.

Monitoring

It is important to monitor the progress of any releases of biological control agents to allow decisions to be made on whether further releases or additional input using chemical or physical techniques are required.

Inspect sites monthly to monitor released cladodes and ensure they have remained in place. After a month, examine if there are any signs of the agents (cactoblastis or cochineal) on the surrounding cladodes.

In the second month after release, developing cochineal should be visible on the release plants. In the case of cactoblastis, look for evidence of entry holes on cladodes/pads. If you cut a cladode near an entry hole you may find larvae.

Three months after release, initiate searches on surrounding plants for signs of agent dispersal.

Establishment of the agent can only truly be confirmed once the insect has persisted at the site for at least a full year from the release date. In some instances it may take 2–3 years before much activity is obvious. Unsuitable weather conditions can delay establishment of agents. Biological control is a slow process requiring patience and persistence (see case study on page 138).

Biocontrol Hub – let's chat!

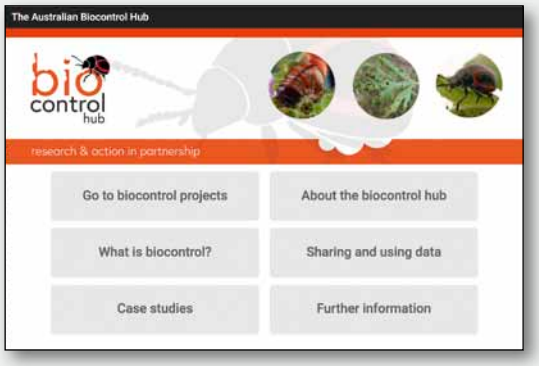
Information sharing is vital to the success of biocontrol for cacti. Recording what cacti species you are controlling and the locations of agent release sites can also assist others obtaining access to the right agents for their infestation.

The Atlas of Living Australia (ALA) is a national on-line biodiversity database that helps information sharing. The Australian Biocontrol Hub is a portal within the ALA that acts as a one-stop shop for data and information sharing on weed biocontrol.

The Biocontrol Hub can:

- Facilitate recording of biological control agent release and establishment data;
- Capture observations of biological control agent spread;
- Ensure biological control agent distribution data is readily accessible; and
- Provide access to biological control extension material.

For further information on how to contribute to or utilise information on the Australian Biocontrol Hub, visit the website: https://biocollect.ala.org.au/biocontrolhub.



Biological control

Advantages	Disadvantages	Caution!	Timing	Integrate with
▪ Can help contain infestations ▪ Can reduce spread in the long-term ▪ Can enhance the feasibility and effectiveness of other control methods and reduce follow-up control costs ▪ Is self-sustaining and provides ongoing suppression on unmanaged/abandoned land ▪ Inexpensive for the land manager to distribute and maintain agent populations	▪ Cannot eradicate cacti ▪ Is not available for all cacti species ▪ Variable results from different agents in different climates ▪ Can be costly to test and approve new agents ▪ Establishment and results may take several years	▪ **Agents are highly host specific**	Release Aug–May **Note:** cochineal is largely dormant over the winter months and should not be released until the days are lengthening and warming	▪ Chemical or physical control of outliers around core infestations

Step-by step biological control checklist

☑ **1. Is your infestation a core infestation?**

- ▶ **Yes – Go to 2**
- ▶ **No – *Choose other control option***

☑ **2. Identify your cacti species – is an agent available?**
(see Table 4.3 on page 104)

- ▶ **Yes – Go to 3**
- ▶ **No – *Choose other control option***

☑ **3. Undertake background checks for the source agent:** For weed control contacts refer to page 147

- Where else has it been used?
- Is the agent permitted in your state/territory or land tenure (e.g. national park)?
- Gain necessary permits (if required) to transport declared plant material.

☑ **4. Collect/rear agents** (see Table 4.4 on page 106)

☑ **5. Release**

- Consider dominant wind direction, release technique, time of year (August–May).
- Will you need to rear insects (cochineal only)?

Sonia Jordan

Placing infected cladodes in the junctions of stems

☑ **6. Augment (help the helper)**

Consider further manual redistribution of infected cladodes throughout the cacti infestation to speed up the process. Augmentation is discussed further in the case study on page 134.

☑ **7. Monitor**

Matt Sheehan

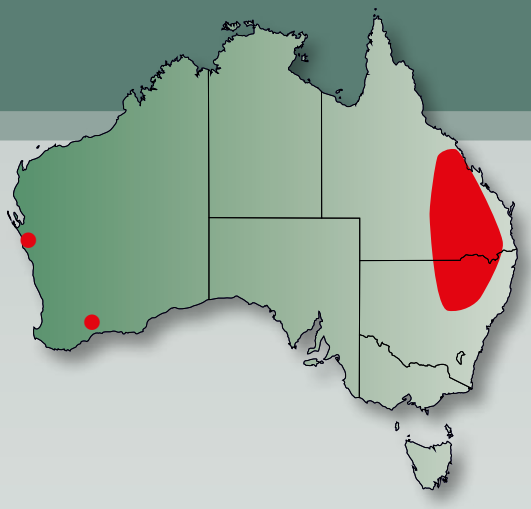
Red-stained meringue-like coverings on pads indicate cochineal is present

Lorraine Edmunds

Opuntia robusta (wheel cactus) heavily infested with cochineal

Sonia Jordan

Cactoblastis damage



Case study

Cactoblastis: Australia's number one biocontrol success story

Rachel McFadyen

History of prickly pear introduction and spread

Opuntia stricta (common prickly pear) originated in Mexico and was brought to Australia in the early days of settlement, probably as a food plant for cochineal insects used to produce carmine (red) dyes. A potted plant was brought to Scone, New South Wales, in 1839 and it spread rapidly north into Queensland. By 1904 it was estimated to have covered 4 million hectares (ha), increasing to 24 million ha by 1926.

In the rich agricultural soils of northern New South Wales and central and southern Queensland, infestations were so thick that land was considered useless for grazing. In 1920, it was estimated that 400,000 ha of productive land were being abandoned each year due to *Opuntia stricta* and photos from the time show narrow roads barely kept open between the walls of cacti on each side (Parsons and Cuthbertson, 1992).

Establishment of the cactus destruction commission

In 1920 the Commonwealth Prickly Pear Board (CPPB) was appointed by the Commonwealth Government and the state governments of Queensland and New South Wales (Walton, 2005). The Board's role was to search for prickly pear insects in the Americas, investigate their host selectivity, transport suitable insects to Australia, and undertake rearing and distribution of the insects.

Development of cactoblastis biocontrol program

Because *Opuntia stricta* originated in North America, initial exploration took place there. However, in summer 1924/25 A.P. Dodd visited northern Argentina and collected the moth *Cactoblastis cactorum* from an *Opuntia* cactus in north-east Argentina, shipping 3000 eggs back to

(i) **(ii)**

State Library of Queensland

Opuntia stricta at Chinchilla farm, Qld (i) in May 1928, before release of cactoblastis and (ii) in October1929 following cactoblastis establishment and destruction of the infestation

Lessons from the cactoblastis story

Successful biocontrol with cactoblastis did not happen overnight. Overseas exploration started in 1903 and many other insects were introduced, tested and released before the success of cactoblastis. Once its potential became clear, a huge effort was made to distribute eggs across the affected regions, with up to 100 men and seven trucks employed at the peak. The program cost $28 million in today's money, and one lesson is that successful biocontrol is not cheap. However, the outcome has been 90 years of cost- and chemical-free control of *Opuntia stricta* over many millions of hectares of productive land, with every prospect that this will continue indefinitely.

The release of cactoblastis was only possible because no cacti species are native to Australia, and off-target impacts were not an issue. Since 1926 cactoblastis has been released in many other countries, with great success in most. However, releases in the Caribbean in the 1960s to control O*puntia* species have resulted in the moth reaching the southern USA and Mexico, where it is threatening the survival of some native cacti. Care must always be taken when releasing an insect which attacks several species, as does cactoblastis.

Queensland. They were successfully reared and host-tested at Sherwood, and immediately seen to have great potential. First releases were made in 1926 and the impact was immediate. By 1928, newspaper headlines were already appearing – 'Prickly pear being cleaned up' and 'Pear on the run'. Mass rearing of the moth, and later collection, and redistribution of the eggs continued until 1933. The CPPB employed numerous men in regional towns to collect egg sticks, put them into waxed paper straws, and post them out to new regions for landholders to pin the straws onto the cactus pads. Over 2 billion eggs were released between 1927 and 1931 (Walton, 2005).

Matt Sheehan

Ignacio Baez, USDA ARS, Bugwood.org

Cactoblastis cactorum: larvae (top), adult female moth laying eggs (bottom)

The result

The impact in the field was spectacular and quicker than expected, as biological control is usually a slow process. The cactoblastis moths spread fast, and dead and dying prickly pear plants became visible almost at once. In some areas, there was significant regrowth of the pear after the initial collapse but the moth built up again and destroyed the regrowth.

By 1932, almost 7 million ha of previously abandoned lands were opened up to new settlers and the previously infested area became productive almost immediately. A 50% increase in population resulted in towns such as Chinchilla, Roma and Dalby in Queensland. It was estimated that by 1939 the value recovered from the infested lands in Queensland was worth a quarter of all primary production from the state (Walton, 2005). The small township of Boonarga, west of Dalby, named their hall 'The Cactoblastis Memorial Hall' and a cactoblastis museum has been developed in Chinchilla. In 2005, the cost benefit ratio of the biocontrol program was calculated at 312:1, with an investment of $21.1 million returning a net present value of $3,110 million (Hosking, 2012).

Continued success of cacti control using cactoblastis

More than 90 years after the initial release, cactoblastis still provides good control of *Opuntia stricta*, and some other opuntioids, in most regions of Australia. In areas that were previously heavily infested, *O. stricta* plants persist in small patches, causing no problems. The opuntioids continue to sustain a cactoblastis population that spreads with any expansion of the cacti. Because of the synchronised generations, larvae can only be found for one or two months in summer, and people can think that the moth is absent when in fact it is present as pupae or egg sticks. Many people also think the moth is coloured orange and black like the larvae, but it is actually very dull greyish-brown, like a large heliothis moth.

However, newly hatched larvae survive poorly in very dry or hard cactus pads, so control can be inadequate in dry or hot regions such as coastal dune areas and islands. Successive drought years, with hot dry summers, can also result in poor larval survival and an increase in the cactus. However, two or more wet summers restores the balance, with the cactus brought under control again without any need for active control measures. In colder regions, development of the moth is slow and there may be only one generation per year, resulting in poor control. In these areas, it may be necessary to use other measures, such as cochineal or chemical control (e.g. in Lightning Ridge, NSW).

Cactoblastis facts

- Cactoblastis moths are strong flyers, so assisting their spread is not necessary.
- Successive drought years can result in poor larval survival, but will reestablish when conditions improve.
- Development of the moth is slower in colder climates. Consider integrating with cochineal or chemical control.

Impact of cactoblastis on cactus species found in Australia (Hosking, 2012)

Cactus	Attacked by cactoblastis?	Destroyed?
Cylindropuntia imbricata	yes	unsure, level of damage unknown
Other *Cylindropuntia*	no	no
Cereus spp., *Harrisia* spp.	no	no
Opuntia aurantiaca	yes	significant damage
Opuntia elata	yes	no
Opuntia elatior	yes	no
Opuntia ficus-indica	yes	no – may kill small plants
Opuntia humifusa	yes	yes, at least locally
Opuntia monacantha	yes	no – plant controlled by cochineal
Opuntia robusta	yes	no
Opuntia streptacantha	yes	no – only young plants
Opuntia stricta	yes	yes, except in very dry hot areas
Opuntia tomentosa	yes	no – only young plants

The future

Cactoblastis continues to be an important management tool today, but it is often overlooked as a tool in new management programs.

Recent release and success with cactoblastis includes:

- Chapman River near Geraldton, WA. Released in 1989. *Opuntia stricta* largely absent by 2004.
- Scadden and Salmon Gums areas, WA. Released in May 2014. Damage evident by 2016.

References

Hosking, J.R. (2012) *Opuntia* spp. *In* (eds M.H. Julien, R.E.C. McFadyen and J.M. Cullen) 'Biological Control of Weeds in Australia', pp. 431-436. CSIRO Publishing, Collingwood, Vic.

Parsons, W.T. and Cuthbertson, E.G. (1992) Noxious Weeds of Australia. Inkata Press, Melbourne, Vic. 692 pp.

Walton, C. (2005) Reclaiming lost provinces: a century of weed biological control in Queensland. Queensland Government, Brisbane. 104 pp.

Follow-up

As with many other weeds, there is no quick fix or one-off treatment when it comes to cacti management – you will need to come back and re-treat. You should be thinking about follow-up before you even start control. Follow-up is paramount for successful weed control and should be included as part of an integrated management plan (e.g. foliar spraying followed by hand removal and site monitoring).

Many years of control may be required for dense infestations to be contained. It takes a minimum of 3 years per site, but more than 5 years at some sites, to control cactus infestations.

Bird dispersal of cacti poses a considerable management challenge. Early detection and control of newly emerged populations is as important as post-control site monitoring. Chapter 2 has more information on planning.

Here are some suggestions based on what weed managers do around Australia currently:

- Visit sites 6 months after initial control and record progress.
- Monitor success of initial treatment. If chemically treated, what percentage have yellowed off, what percentage have died? Can you see any that were missed?
- Continue this every 6–12 months, conducting follow-up control where necessary.

Restoration

Restoration of sites following cacti control may be required in some situations, particularly where natural re-establishment of non-invasive or useful species is unlikely to occur quickly. Where intervention is required, the methods used will depend on the extent of disturbance, environmental risks, land use requirements and restoration objectives. Consider: what do we want the restored site to look like in the future?

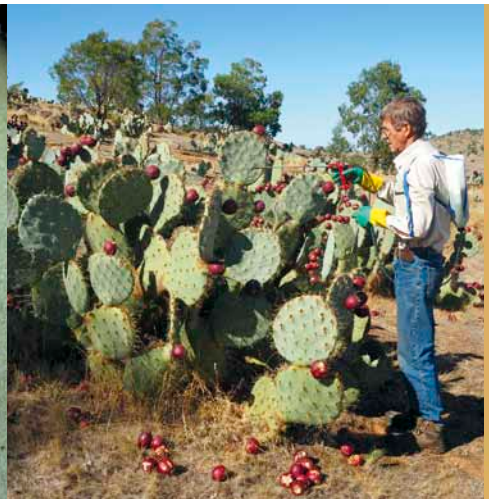
Rehabilitation is a specialist undertaking and is not directly described in this manual. However, during the implementation of a cacti management plan, broad consideration should be given to the next stage:

- What could be the after effects of control (e.g. regrowth of cacti or another weed, bare earth)?
- What will reduce re-infestation (e.g. fencing, hygiene protocols, signage)?
- What, if anything, will increase resilience to reinvasion? Unlike many weeds, cacti do not necessarily require disturbance to establish.
- Is regular and long-term follow-up control enough to enable natural restoration?

Adapted from: Adair, R., James, R. and Blood, K. (2016). Managing weeds: eradication response guide. A guide for planning and undertaking an eradication response to weeds at the early stages of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria.

Chapter 5

Case studies



Case study 1

Cacti eradication: The Northern Territory approach

Chris Brown and Andy Vinter

Management objective: Prevention/ eradication (Territory-wide)

Species: *Cylindropuntia pallida*, *C. fulgida* var. *mamillata*, *C. imbricata*, *C. prolifera* and *Opuntia stricta*

Summary

Cacti are in the early stages of invasion in the Northern Territory (NT) where eradication is a shared management objective across all levels of government and the community. This case study from the Alice Springs region details the Territory's holistic, integrated and cross-tenure approach to tackling cacti at the early stages of invasion. The approach includes a combination of awareness raising, compliance, voluntary reporting, on-ground control, partnerships and community-led action at the urban/bushland interface.

Andy Vinter

Cylindropuntia prolifera (jumping cholla), Mt Gillen, Alice Springs NT

The problem

Garden plantings around mines, pastoral leases and in urban settings are thought to be the source of cacti infestations in the NT. Eradication is a feasible management objective as infestations are believed to be isolated, of limited size and generally of low density.

But eradication is notoriously difficult and a number of challenges must be overcome to ensure success. Challenges facing the NT include:

- **Awareness** There is little recognition or knowledge of the problem. For example, in the dry and arid landscapes of central Australia, many people are attracted to cacti gardens. There is limited awareness that cacti are not native or are potentially invasive, thus cacti are often seen as suitable for use in arid zone gardens.
- **Perception** Cacti may not be considered a problem because there are very few currently in the landscape, therefore impacts are currently low and/or not visible. For example, cacti on Aboriginal and pastoral estates may not be high priorities for management due to the low level of infestations (still in the early stages of invasion) and lack of awareness of cacti impacts. Being recently declared, cacti may also have lower priority than other well-recognised, intensively managed declared weeds.

- **Detection** In order to achieve eradication, every plant and propagule must be detected and destroyed. Small cacti populations in low densities are difficult to detect. In addition, there are vast areas to search and often no clear patterns of dispersal, making delimitation (knowing where they occur) challenging.

The approach

Land managers and the local and Territory Governments are using all available tools to ensure rapid response to cacti eradication through a collaborative approach that includes legislation, education and community action.

Components of the eradication program

Legislative framework support

In 2016, following a Territory-level weed risk assessment, all 27 opuntioid cacti species listed as WoNS, as well as *Opuntia ficus-indica*, were declared under the Northern Territory *Weeds Management Act, 2001*. Under this *Act*, opuntioid cacti that are not present in the Territory are prohibited from entry, while those currently present are targeted for eradication.

The Weed Management Branch of the Department of Environment and Natural Resources (DENR) is working collaboratively with affected landholders in central Australia, as well as rural residents closer to Alice Springs, in managing newly reported infestations of declared cacti. Assistance is provided through:

- On-ground chemical control services;
- Surveillance and mapping of newly identified infestations;
- Assistance with the development of weed management plans to inform ongoing management; and
- Equipment loans (e.g. spray tanks) to affected landholders.

Education and awareness raising

The Weed Management Branch launched a public awareness campaign across the NT to highlight the changes to the declaration status of opuntioid cacti. This campaign is ongoing and uses a number of techniques to spread the message, build awareness and engage landholders and the wider community.

Awareness materials are being used to complement the change in declaration status across the NT. Andy Vinter from Alice Springs Landcare Group designed cacti 'Wanted' posters in the style of old-time western posters. This design was adopted by the Weed Management Branch, and extended to factsheets and letterbox fliers. These materials are designed to raise awareness of declared cacti and their impacts, and encourage urban residents to contact the Weed Management Branch if they suspect they have a declared species in their garden or to confirm cacti identification. Local nurseries are also participating in the public awareness campaign by displaying awareness material at the point of sale.

A major feature of the awareness campaign is the wheelie bin initiative. The Alice Springs Town Council have organised a safe and easy way for the community to dispose of declared cacti growing in residential gardens. Plants can be placed into wheelie bins, which are collected at the kerb and disposed of (via deep burial) with general waste at the waste management facility. To help promote this kerbside initiative to the wider community,

the Weed Management Branch produced 'BIN IT, DON'T SPREAD IT' stickers for placement on residential wheelie bins. A similar initiative will soon be rolled out in the township of Tennant Creek, 500 km north of Alice Springs, where cacti are commonly grown in urban gardens.

Feedback from the education and awareness campaign has been very positive. Urban and rural residents in and around Alice Springs and landholders across the region are contacting the Weed Management Branch to report or clarify the presence of declared cacti on their properties.

Matt Sheehan

Isolated cactus plant on a pastoral property

Community action in cacti control

The Alice Springs Landcare group has been crucial in managing cacti outbreaks along the urban-bushland fringe of Alice Springs. Historic plantings of cacti in gardens have escaped into adjoining bushland areas, only to be spread further by vectors such as kangaroos (predominantly euros) or human activity. The dumping of unwanted garden waste along bushland tracks has also kick-started the spread of cacti into bushland areas. The Landcare group has adopted a systematic approach to survey, map and remove cacti along the urban-bushland fringe of town. Volunteers have developed a safe

Control of coral cactus in the Alice Springs Telegraph Station Reserve

Situated immediately to the north-east of the Alice Springs urban area, the Telegraph Station supports the largest known infestation of coral cactus in the Northern Territory. Control efforts have involved a collaboration between Parks and Wildlife Rangers, Conservation and Land Management students from Batchelor Institute, and Alice Springs Landcare volunteers. Initial mapping of the infestation by students in 2012 revealed a relatively dense core area, and identified the role of euros in spreading material to establish satellite infestations.

Andy Vinter, lecturer and Landcare spokesman, explains that initial efforts focused on foliar spraying. "*We trialled treatments with Garlon™ + water and compared Access™ + diesel, but the results of both were really disappointing.*

Matt Sheehan

Cylindropuntia imbricata resprouting following foliar herbicide application

We found that only 50% of plants were killed after 12 months, meaning re-treatment was required. This has been a key reason why we have now focused our management efforts on mapping and hand removal to contain its spread and get on top of new infestations."

Andy Vinter

Bins used to securely transport hand-pulled cacti from the site to the disposal area

and effective hand removal technique to minimise the risk of accidental spread of material during transport to the deep burial disposal facility. A preference for hand removal has facilitated community involvement in a family-friendly way that demonstrates immediate results. Results are communicated by compiling collection counts (Figure 5.1), volunteer hours (Figure 5.2) and treatment maps. Control efforts have shown that revisiting infestations is vital to ensure eradication, with a minimum of three treatments over three years required to achieve this goal.

The future

It is likely that many of the 27 species of invasive cacti declared in the NT are present in gardens, though they are not all naturalised. Future efforts will focus heavily on raising awareness of the impacts and legal status of cacti as well as inspections and removal of declared cacti from gardens to prevent new naturalisations. Surveillance of high risk areas (such as dumping sites and historic plantings) will be increased, and cross-tenure eradication programs for those species that have naturalised will be continued.

The Alice Springs Landcare volunteers have observed that within two years, *Cylindropuntia prolifera* (jumping cholla) plants can establish from a single cladode, grow to 40 cm high and form new segments. This highlights the need for regular follow-up to reduce spread, with intervals between follow-ups of no more than 12 months.

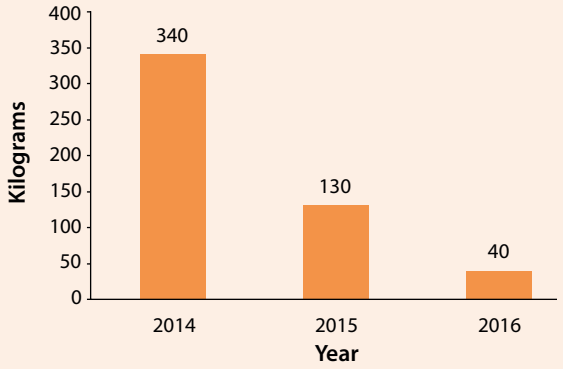


Figure 5.1 Cactus removed from site (kg)

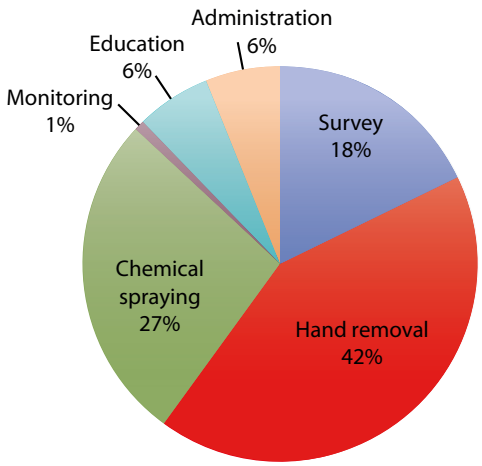


Figure 5.2 Project hours spent on cactus 2012–2016 (total 1655 hours)

Tips

- **Act early.**
- **Respond quickly to new reports of cacti.**
- **Work together.**
- **Be vigilant and flexible.**
- **Consider the best control options for the situation.**

Case study 2

Cactus Warriors: Community-led approach to cacti management

Lee Mead

Management objective: Containment
Species: *Opuntia robusta*

Summary

One of Victoria's worst infestations of *Opuntia robusta* (wheel cactus) occurs in central Victoria, affecting both public and private land. Here, a committed and coordinated community-led campaign has achieved cross-tenure management of wheel cactus by empowering land owners, involving and retaining enthusiastic volunteers and increasing community awareness. After twelve years, the containment of wheel cactus remains a challenge requiring improved integrated management, perseverance and ongoing high spirits.

The problem

While the introduction of wheel cactus to central Victoria is not well documented, it is likely to have been brought to the town of Maldon as an ornamental garden plant during the early 1900s, possibly cultivated in the Baringhup region by immigrant workers during the construction of Cairn Curran Reservoir in the 1940s. Older residents recall isolated populations at Pigeon Hill, Mt Tarrangower and the Nuggetty Hills in the 1950s.

An article published in the *Maldon Times* in 1963 reported that the Vermin and Noxious Weeds Destruction Board had imposed strict enforcement of remedial measures to address the spread of wheel cactus. Little is known about the distribution and spread during the 1960–1970s, but it is believed that enforced control, together with high rabbit populations, may have temporarily kept wheel cactus at bay, only for it to re-emerge as a serious problem again in the 1990s.

By the early 2000s, infestations had grown to approximately 10,000 hectares. Alarmed at the proliferation of wheel cactus in the Tarrangower district, local farmers and Landcare groups decided to take matters into their own hands.

Lee Mead

Extensive, impenetrable infestations of Opuntia robusta (wheel cactus) – the target of strategic and integrated community-led weed management in central Victoria

The approach

In 2005, members of the Maldon, Baringhup and Nuggetty Landcare groups formed a committee called the Tarrangower Cactus Control Committee (TCCC). Their single aim was to eradicate wheel cactus from the local environment.

The TCCC obtained funding from the Victorian Government, which enabled the newly formed group to work in partnership with Parks Victoria to address the control of wheel cactus on both private and public land. In 2008 the committee became an incorporated body and changed its name to the Tarrangower Cactus Control Group Inc. (TCCG). The group is managed by a committee of 10 members, with an executive of President, Vice-President, Secretary and Treasurer.

The TCCG has developed a strategic plan with long and short-term goals, objectives and actions, with the overriding long-term goal of eradication of all major local wheel cactus infestations.The TCCG focus their effort on four key areas of the strategic plan:

1. Coordinate and conduct cacti control

From April to October, when conditions are most favourable, the TCCG conducts monthly cactus control field days, combining a social occasion with a working bee. Control works are undertaken on both public and private lands. The TCCG works closely with Parks Victoria staff, organising work crews and field days to tackle infestations in historic parks and reserves.

The TCCG volunteers employ hand digging and pad injection with glyphosate as the control method.

> *"Not only is injection the most effective method of chemical control for wheel cactus, it also lends itself to a volunteer-based control program such as ours. It means operators can work in close proximity to each other without having to worry about spray drift, and it is therefore more interactive and social."* Ian Grenda, TCCG.

Lee Mead

Showing gratitude for the contributions of volunteers – an important part of any community-led approach to weed management

Attendance at field days is typically between 30 and 40 volunteers plus the land managers. People contribute according to their skills and interests. Most assist with injecting, while some hand dig and others assist in the preparation of food for lunch.

Lee Mead, president of the TCCG, explains the importance of the social element:

> *"The BBQ is a very important component of our day, to ensure that everyone can wind down, socialise, network and feel rewarded for their contribution. We make the effort to include salads and homemade baked goods to ensure the lunch is delicious."*

Planning is key to the strategic approach of the TCCG. Planning commonly includes mapping current infestations, estimating cost of future control and applying for funding to support future works.

2. Increase the number of property owners actively controlling wheel cactus and provide them with support

TCCG actively supports and encourages landholder participation by assisting with wheel cactus control on private property.

> *"When we get a team of volunteers helping on a property, landholders are extremely appreciative and are more likely to continue control work on their own."* Lee Mead.

The TCCG provide incentives such as equipment loans, free disposal of cacti at the local waste disposal, personal support, technical advice and on-site demonstrations of control techniques.

3. Increasing awareness of wheel cactus in the local community

Increasing community participation in wheel cactus management and maintaining volunteer numbers is an objective of the TCCG, achieved through raising awareness and education. Engagement with existing members is maintained through regular email newsletters and the website. Information brochures, Facebook posts and media releases are used to raise awareness of wheel cactus and its control within the wider community.

The TCCG enjoys a high profile in the community by maintaining an active presence, participating in community events and fundraising. Each year, volunteers take part in the Maldon Easter Parade, with cactus-related themes and costumes to raise awareness and celebrate their work.

4. Improving control techniques

The TCCG participate in trials and research to improve integrated management techniques and better understand wheel cactus. TCCG have recently released cochineal and are monitoring the effectiveness of this biocontrol agent in the central Victorian climate. TCCG has also supported studies carried out by Federation University to look at various seed germination requirements and what might break seed dormancy. TCCG's own observations have shown that Australian ravens are a major dispersal agent, with seeds germinating in halos around established paddock trees where they roost. Understanding this has helped predict where new infestations could establish.

Lee Mead

TCCG participating in the Maldon Easter Parade in 2017 – a Mexican theme was used to raise awareness of the origins of wheel cactus

The result

The major strengths of the community model adopted by the TCCG are the committee of management structure and the terms of reference that they adhere to.

> "*We have a diverse skill set within our committee, from book keepers, networkers, strategic thinkers and people who can write funding applications, through to technical experts and on-ground movers and shakers*." Lee Mead.

This breadth of skills, knowledge and support is key to the success of such volunteer organisations, seeking to be strategic and targeted in weed management.

The TCCG has successfully progressed each of its objectives, from awareness-raising to increasing participation by landholders and volunteers in wheel cactus management.

Despite this, wheel cactus continues to spread faster than it can be controlled, which does highlight the limitations of community-led approaches.

> "*The absence of compliance is a serious hindrance when we encounter landholders with core infestations who we cannot engage with. This presents a real disincentive for many volunteers and engaged landholders, and therefore undermines the work that we do. We also have an aging volunteer base and little recruitment from younger generations. This presents a risk factor that future actions will need to address*." Lee Mead.

The future

The TCCG has found a model that works, retaining interest and participation in cacti management.

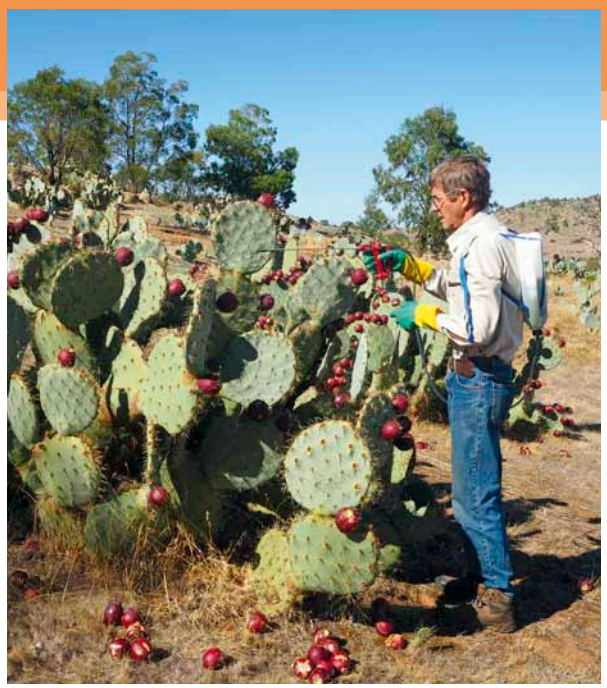
> "*We will soldier on, even though it remains an uphill battle. We are organised, but can only achieve so much as a community group. You have to keep sight of what you can and are successfully achieving, not what is out of your control to achieve.*" Lee Mead.

It is also necessary to think outside the box about how you can get around obstacles and setbacks. Better integration of management methods will help tackle the issues of growing seed banks and continuing spread from core infestations.

> "*The future will see us further embrace biocontrol agents, which is the only tool available to manage core infestations on inaccessible terrain and on land belonging to land managers who are not engaged in the program.*" Lee Mead.

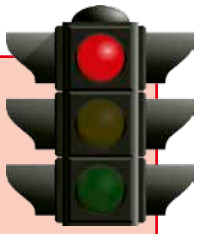
What makes a successful community-led program?

- **Sound planning.**
- **Timeframes.**
- **Good leadership.**
- **Long-term partnerships.**
- **Enthusiastic volunteers with diverse skills.**
- **Induction, training and mentoring for volunteers.**
- **On-going recruitment of volunteers.**
- **Camaraderie, fun and a sausage sizzle!**

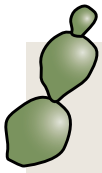


Lee Mead

Stem injection of wheel cactus



When planning control programs that rely on volunteers, be mindful of their likely limitations and factor this into the program. Limitations may include fitness, skills, knowledge or other commitments and conflicting priorities. Providing opportunities to upskill and choosing tasks that match skills and interests are good ways of addressing this.



To learn more about TCCG, or view their strategic plan and governance arrangements, check out their website:

www.cactuswarriors.org

https://www.facebook.com/groups/1978563579043247/

Case study 3

Physical control: Lessons learned from Western Australia

Mick Jones, Kim Eckert and Kay Bailey

Management objective: Containment
Species: Numerous opuntioid species

Summary

Some infestations of cacti can be very dense and hard to control. They may contain multiple cacti species that require different biocontrol agents or herbicide treatments. In the right circumstance, with adequate planning, coordination, integration with other control methods and commitment to follow-up, mechanical control can be a feasible, effective and cost-efficient management method for a range of cacti species. This case study documents three physical control success stories from Western Australia.

1. Mechanical removal and *in situ* burial – Kellerberrin

The problem

Within a few kilometres of the town of Kellerberrin, on a former rubbish disposal site and Aboriginal Reserve, moderately dense stands of *Opuntia robusta* (wheel cactus) and *O. stricta* (common prickly pear) established over a 59 ha area. All previous attempts to control *O. robusta* by the Shire of Kellerberrin using chemical treatment had resulted in regrowth. It had also proven difficult to get spray equipment close to the plants due to the debris staking tyres and catching hoses.

DAFWA

Map of Opuntia robusta (●) recorded sites at Kellerberrin

The approach

As a former dump site, there had been considerable soil disturbance and therefore few canopy trees or other environmental, conservation or native vegetation considerations that would have ruled out mechanical removal as a control option. The site was considered suitable for mechanical removal and on-site burial. Working with the Department of Agriculture

and Food (DAFWA), a project commenced in 2016 following approval by the Aboriginal Development Commission and local elders.

All occurrences of cacti (approximately 200 individual plants) were mapped using hand-held GPSs and a camera mounted on a drone. A number of holes were dug using an excavator near the bulk of the plants, and the cactus and top soil was buried to a depth of 1 m below the surface. Smaller plants and fragments were removed and placed in the holes by hand.

Results

One hundred per cent of the mature cacti have been removed and buried. Six months following control there has been no re-emergence on the site. Some small plants have been located in the surrounding areas. The Shire will manually remove these plants while small.

The future

The need for monitoring of the site has been identified as critical to determine the long-term success of the control. This will include monitoring to determine if any regrowth occurs from the buried cacti, as well as monitoring of new plants from the seed bank. Given that it was a former rubbish tip, restoration of the site has not been factored into future management. Burial of the cacti and some of the rubbish has also significantly improved the aesthetics of the site.

Lessons learned

Mechanical removal can successfully treat cacti infestations and provide a sense of achievement due to the immediate visual outcome. This may be important for ensuring that interest is maintained to undertake the required follow-up.

Diligence is required in any mechanical control program to ensure that all cladodes from the soil surface and on the plant are removed and buried and that none are dropped along the way.

Kim Eckert

Multi-species cacti infestation at Williamstown

2. Large-scale mechanical removal – Williamstown

The problem

An impenetrable, multi-species cacti infestation had established on crown land within a residential leasehold area in Williamstown on the Kalgoorlie Goldfields. Cacti species included *Cylindropuntia fulgida* var. *mamillata, C. imbricata, C. kleiniae*, *Opuntia elata* and *O. ficus-indica*. The infestation was spreading by seed and segments, posing a significant threat to other landholders, particularly the surrounding pastoral leases. The infestation covered approximately 50–70% of the 1 ha site.

The approach

Treatment options were limited due to the density of the infestation. Chemical treatment was not considered due to the volume of chemical that

Kim Eckert

Project partners of the Willamstown cacti removal project

Kim Eckert

Mechanical removal was considered the best control option

would have been required and the proximity of the site to residential properties. Mechanical removal was considered the most feasible option for control.

The project was managed and coordinated by Kim Eckert, CEO of the Kalgoorlie-Boulder Urban Landcare Group (KBULG). Given the complex land tenure issues and the number of stakeholders involved, sensitive and extensive consultation was required to gain support for the project. KBULG conducted extensive community consultation through facilitated public meetings and community liaison. This included letterbox drops around Williamstown prior to the removal, to raise awareness and keep the community informed of progress. "*This was a successful engagement process that resulted in new reports of infestations not previously recorded that were added to the removal operation*", Kim explains.

The site was divided into management grids where removal work was carried out systematically one grid cell at a time.

Kim Eckert

Cacti removal and collection using an excavator

Excavators and graders were used to remove cacti within the grid, and plants and soil were loaded directly onto trucks for disposal. Removal of top soil from the site reduced the seed bank and removed the cladodes or fragments that may have been dislodged during control.

Following removal of cacti from all the grids, the surface of the site was ripped in the hope that this would encourage natural regeneration of native or desirable plants.

Kim Eckert

Removal of top soil reduced the seed bank and dislodged cladodes

Ninety loads of cacti, weighing a total of 700 tonnes, was removed from the site and transported in trucks to an approved deep burial facility at the local waste disposal facility.

The future

Monthly monitoring is carried out at the site and any cacti found are removed by hand. Outliers are foliar sprayed.

Lessons learned

"*Consultation, negotiation, liaison coordination and partnerships ensured a terrific sense of achievement, producing an excellent outcome on what was a significant and intractable issue for the Kalgoorlie-Boulder environment.*" Kim Eckert, KBULG.

3. Hand removal – Pilbara cactus project

The problem

Most naturalised cacti occurrences in Australia originated in gardens. Fortunately, in the Pilbara region of WA, many species of cacti remain in gardens. However, with the transient nature of communities in Pilbara towns, where pot plants are often 'thrown out' rather than moved, there is a high risk of cacti becoming naturalised. In fact, reports of illegal dumping of cacti on pastoral stations adjacent to Pilbara towns were confirmed in 2014. This prompted Rangelands NRM, the Pilbara Mesquite Management Committee and the Department of Agriculture and Food (DAFWA) to develop an innovative project focused on cacti surveillance and removal across the Pilbara region.

The approach

The campaign, titled '*Don't be casual with cactus*', targeted the removal of garden plantings of cacti, including those in pots. Educational packages were distributed to residents on the impacts and threats of cacti to the wider landscape.

The surveillance element involved officers driving up and down every street in all 16 Pilbara urban areas looking for declared cacti, and door knocking any with cactus. An offer to immediately remove the cactus was taken up by the majority of affected residents. The plants were collected (using gloves, tongs, loppers and metal basins), placed in large plastic drums and stored until the volume had substantially reduced. The remains were then deep buried at the Karratha waste management facility.

A second part of the project carried out surveillance on pastoral stations, particularly around homesteads, station ruins and rubbish dumps. Funding was made available to assist land managers to control the cacti found, including the supply of equipment and herbicides.

'Don't be casual with cactus' campaign poster

Results

- Survey completed around 16 Pilbara towns (5853 hectares).
- Removed 125 separate occurrences of residential cacti cultivation (pots and gardens.
- 15 tonnes of cacti removed from residential gardens.
- 13 instances of 'dumped' cacti on the outskirts of surveyed townships were controlled.
- Identified three new naturalised populations (two on pastoral stations and one on a nature reserve).
- Controlled naturalised populations on five pastoral stations and a nature reserve (250 hectares).

Lessons learned

A coordinated, planned approach by government, NRM and Landcare, met with a positive response from Pilbara residents and prevented potential cacti spread in the future.

Case study 4

Looking for cacti: Delimiting surveys for Hudson pear

Bec James and Kate Blood

Management objective: Eradication
Species: *Cylindropuntia pallida* syn. *C. rosea* (white-spined Hudson pear)

Summary

It is one thing to discover that you have a weed on your property, and quite another to determine how extensive that infestation is. Knowing the full extent of a weed infestation helps you choose the most appropriate management approach (see Chapter 2 – Planning). Conducting a **delimiting survey** is one way of determining the full extent of a weed. This case study describes how a delimiting survey was carried out by Department of Environment, Land, Water and Planning (DELWP) staff in the Ouyen State Forest, north-west Victoria for *Cylindropuntia pallida* (white-spined Hudson pear). The survey allowed land managers to conclude with some degree of confidence that *C. pallida* was in the early stages of invasion, informing their decision to manage the infestation for eradication.

The problem

Cylindropuntia pallida has spread in a part of the Ouyen State Forest, approximately 1 km south of the township of Ouyen, north west Victoria. Local DELWP staff have been actively treating it since 2010 using herbicide and hand removal.

Cylindropuntia pallida poses a major threat to important biodiversity in the Victorian Mallee as it is very drought tolerant, it is difficult to see amongst the Mallee vegetation and it forms dense infestations that are injurious to wildlife and exclude native vegetation. Recreational vehicles, wildlife and pest animals moving through the forest have the potential to spread cactus within the forest and to other natural areas.

The aim of the delimiting survey was to determine the full extent of *Cylindropuntia pallida* within the Ouyen State Forest and work towards eradication from this site if it was feasible to do so. There are other infestations in the Mallee and each site needs to be assessed independently.

Bec James

A flagged Cylindropuntia pallida plant found during a vehicle-based delimitation survey in Ouyen State Park Vic

The approach

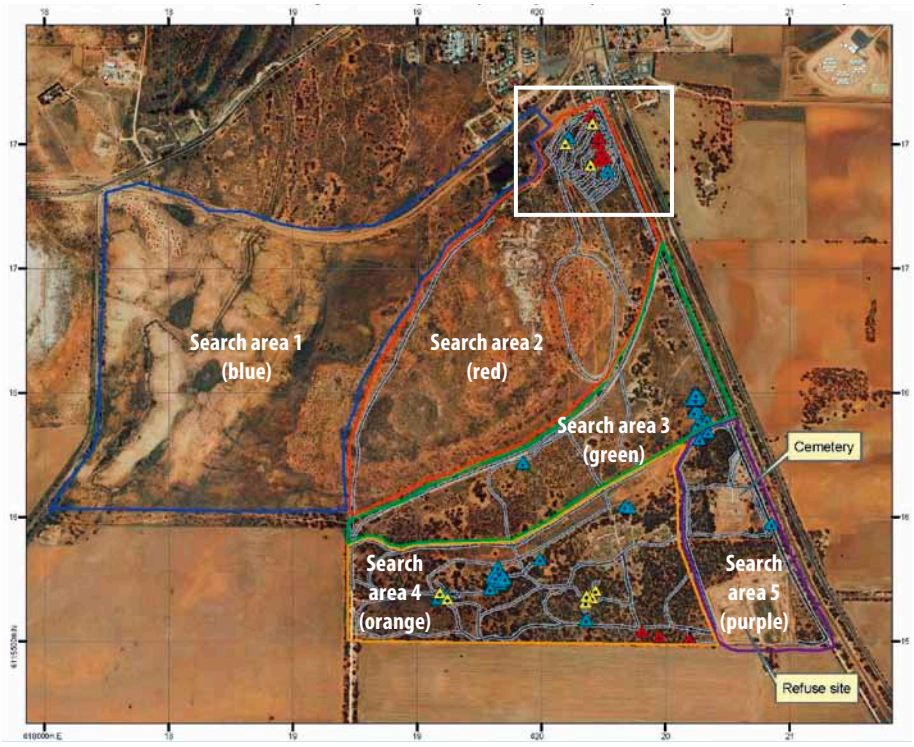
Planning the search before going out in the field to conduct a delimiting survey was a very important first step as Bec James, invasive species project officer with DELWP explains:

> *"Knowing your enemy and how it behaves is the best way to find it. Before going into the field, project staff developed a 'search plan', which was used to develop an understanding of how Cylindropuntia pallida functions as a plant. We researched the plant's biology and ecology, and got an idea of the current situation of C. pallida at Ouyen State Forest. This step included investigating where C. pallida had been recorded previously, the vegetation and habitat present at the site, where the weed might have come from and where it has spread to."*

Tools such as maps, aerial photographs, information on vegetation types, road networks, historical dumping site, spread pathways, and previous recorded infestations were compiled to help inform the search. Hard copies were prepared, with digital versions loaded into a GPS for easy use in the field. The information collected during the search plan was used to **define search areas** and **search methods**, as Bec James explains:

> *"By sitting down and learning about the plant, and the area, using maps and existing data, you can start to paint a picture about what's going on, what you know (and the confidence you have in that knowledge), and what you still don't know. You may see patterns of spread along a roadside, so you know you need to look further along that road."*

The site was divided into five search areas that were defined by the road network (see map below). Two search methods were used in the delimiting survey – vehicle-based surveys and targeted foot-based surveys.



Ouyen State Park showing the five search areas, track logs and sightings of Cylindroputia pallida – yellow dots (2014), red dots (2012) and other cacti (blue dots). The white square indicates the targeted survey area detailed in the map on page 129.

Bec James

Walking in a transect undertaking a targeted survey for Cylindropuntia pallida in Ouyen State Park Vic

Useful equipment for the delimiting surveys included:

- 1 × vehicle;
- 3 × personnel (1 × driver and 2 × searchers);
- 2 × rolls of flagging tape (1 × pink and 1 × orange);
- 1 × clipboard and pen with 'Field Recording Template';
- 1 × A3 map of land status and road network on aerial photography;
- 1 × A3 map of vegetation communities and previously recorded sightings (from corporate database and local records);
- 1 × A3 map of pre-defined search areas with aerial photography;
- 1 × GPS with pre-loaded road network, property boundaries, aerial photography and previous records of *C. pallida* at the site. Ensure the tracking function on the GPS is turned on immediately before the survey was commenced, so that all movement is recorded; and
- 1 × camera or mobile phone camera.

Vehicle-based survey

The road network was considered to be the main pathway of spread into and around the site, so it was decided that all the trafficable roads/tracks would be surveyed for each search area. Each trafficable road/track was driven at 20–30 km/hr with two observers on either side of the vehicle looking at a distance of 15–20 m from the road/track (observable area from the vehicle in Mallee vegetation) for any *C. pallida* infestations.

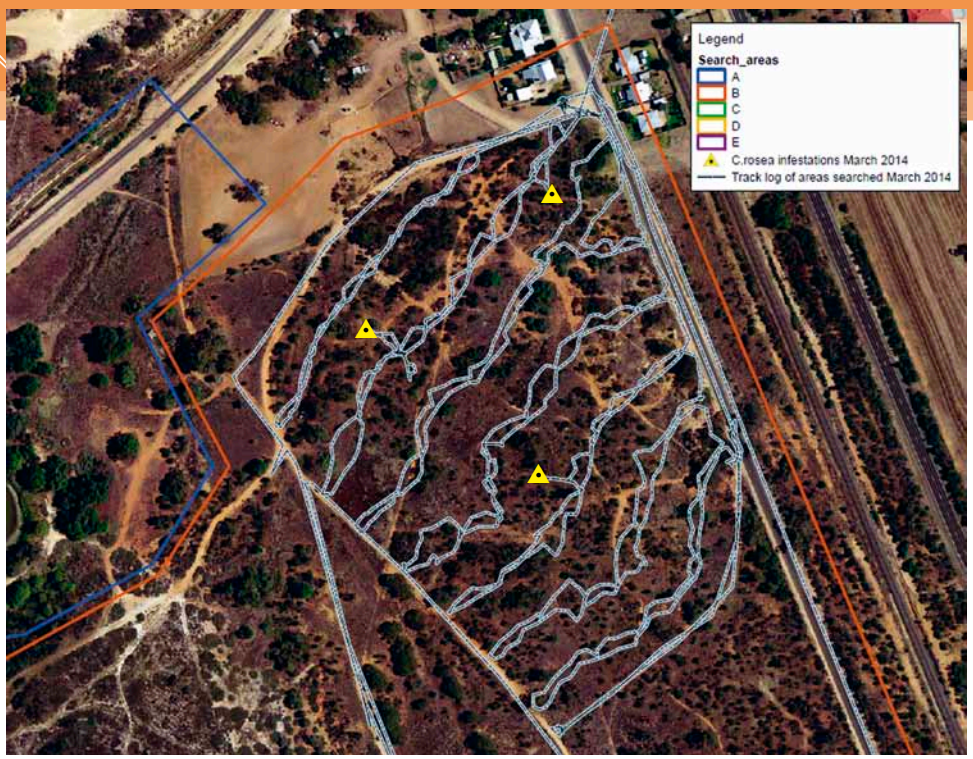
> *"When a Cylindropuntia pallida plant was spotted, we tagged the site using pink flagging tape, took a GPS point, a photo and recorded the required information in a 'Field Recording Template' (page 158). If a plant was located, a general search of the area was undertaken on foot in all directions, including both sides of the road. If no other plants were found in 5–10 minutes of searching, it was decided that the plant was isolated and we continued on with the rest of the vehicle-based survey. If another plant was found, this process was repeated."* Bec James.

Particular attention was given to areas where *C. pallida* had been previously recorded. If there was a chance that not all plants had been detected a search was conducted on foot.

Targeted foot-based survey

One search area occurred outside the road network, where historically there had been a large amount of disturbance and a number of *Cylindropuntia pallida* infestations previously recorded. A foot-based transect survey was considered the best approach.

To undertake the targeted survey in Mallee vegetation, three people walked in a line, approximately 10 m apart, scanning the ground for any *Cylindropuntia pallida* plants. Orange flagging tape or florescent 'paddles' were used to designate completed transects. The targeted survey area (6.7 ha) was searched in its entirety and resulted in three *C. pallida* plants being located. Plants were marked with a different coloured flagging tape or paddle so they could be treated at a later time.



The targeted survey area with the track log of transects walked and March 2014 records of Cylindropuntia pallida plants (yellow triangles)

The result

Back in the office data collation and analysis was carried out by downloading GPS points, track log and photos. A map was created using this data showing all newly recorded infestations in each of the search areas, along with the previous recordings of *Cylindropuntia pallida*. Results were shared with all local land managers and the data was also put into the Victorian Biodiversity Atlas for future reference.

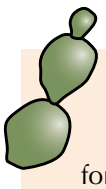
In total 18 *Cylindropuntia pallida* plants were located during the delimiting survey showing the extent of *C. pallida* is restricted to the southern and northern ends of the State Forest, with the core infestation in the northern corner of the forest. Interestingly, when comparing data to the 2012 survey, it was evident that this species is still spreading within the site, perhaps due to vectors such as wildlife, motorbikes and other vehicles that frequent the area.

The survey shows a significant reduction in the number of *Cylindropuntia pallida* plants within the State Forest compared to 2009, suggesting that management efforts by local DELWP land managers have been successful.

The delimitation survey found small isolated infestations, supporting the view that *Cylindropuntia pallida* is at the early stages of invasion within the Ouyen State Forest.

The future

Delimiting surveys have informed the management response (eradication). Surveys will be repeated and expanded into the future to monitor progress toward the management objective and allow for adaptive management.



This case study was adapted from:
James, R. and Blood, K. (2016). Looking for weeds: delimiting survey guide. A guide for planning and undertaking delimiting surveys for weeds at the early stages of invasion on public land in Victoria. Department of Environment, Land, Water and Planning, Victoria.

Case study 5

The one that got away: Spread of *Opuntia monacantha* after floods

Jock Conlon and Henry Rutherford

Management objective: Asset protection (core)/containment

Species: *Opuntia monacantha*

Summary

Opuntia monacantha (drooping tree pear) is well established in the Lower Onkaparinga River catchment in South Australia. Management has proven particularly problematic due to the extent of the infestation, size and density of plants and limited suitable control methods in areas that are steep and difficult to access. The release of the biological control agent, *Dactylopius ceylonicus* in October 2015 at two sites within the gorge has shown promise and is complementing and bolstering ongoing control efforts.

The control program experienced a major setback in September 2016 due to a flood event which spread cladodes, fruit and seed from the core infestation downstream the length of the river, across the flood plain and along the coast. This single event has added a sense of urgency to management efforts, which aim to protect the natural assets and recreational values. A rapid response was needed to remove propagules downstream to prevent new infestations from occuring.

This case study highlights the difficulties and risks of managing cacti in dynamic environments, and the planning required to minimise the impact of unpredictable yet inevitable spread events. It also documents the clean-up efforts that are currently taking place in the lower Onkaparinga River and estuary.

The problem

The Onkaparinga River cuts through the Mount Lofty Ranges forming a spectacular gorge 200 m deep. Downstream of the gorge is a sediment-rich, fertile flood plain and estuary that supports nationally listed ecological communities.

Agriculture was the predominant land use along the lower Onkaparinga River from the 1840s through to the mid 1970s, when grazing was excluded and the Onkaparinga River Reserve was established for conservation and recreation.

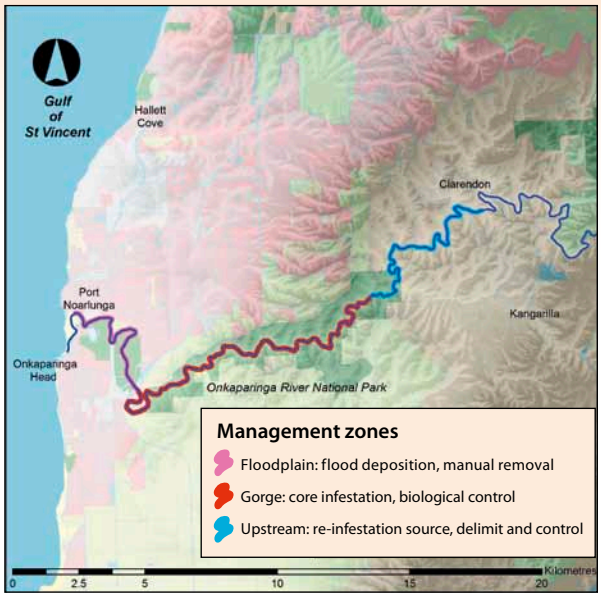
Matt Sheehan

Opuntia monacantha growing on the steep escarpments of the Onkaparinga River gorge – access for control is very difficult

Opuntia monacantha is likely to have been introduced to the region as a garden plant that escaped into the gorge from bird-dispersed seed or from propagules washed in during a flood event. The core infestation consists of mature plants to 10 m tall. A characteristic of *Opuntia monacantha* is that it retains its fruit from year to year, with new fruit developing on existing fruit, creating long chains over time.

Control of *Opuntia monacantha* has been carried out primarily by the Friends of the Onkaparinga Park (FOOP) since 2013, predominantly through drill and fill with diluted glyphosate @ 5:1. While efficacy is generally high, it is extremely labour intensive, slow and access to many parts of the gorge is difficult and dangerous, with some sections requiring rope access. In 2015, the biological control agent *Dactylopius ceylonicus* (a cochineal insect) was introduced to improve management and reduce the vigor and reproduction capacity of the core infestation so that the management efforts of FOOP could focused on chemical control of outliers.

In September 2016, a severe storm event resulted in flooding within the Onkaparinga River, with waters reaching some 10 m above regular flow height, carrying with it large amounts of cladodes, fruit and seed, depositing them at high water mark along the river. Most worryingly, propagules reached the lower reaches of the river and the coast – areas not previously impacted by cacti. The clock is ticking to clean-up the lower reaches before new infestations become established. However, just as importantly, control efforts of the core infestation must also continue to prevent a similar event occurring next time there is a flood.



Locality map of the Onkaparinga River

Henry Rutherford

The Onkaparinga River in flood

The approach

Restabilising biocontrol

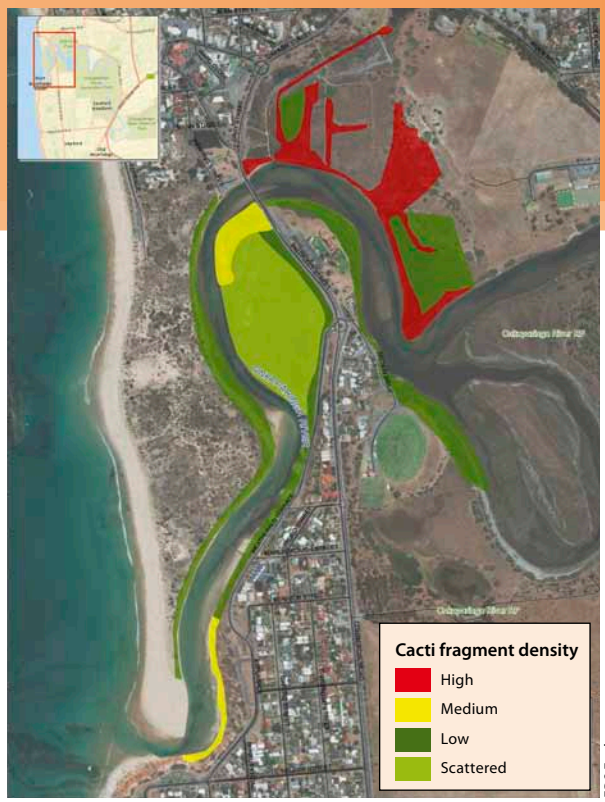
Heavy rain can wash cochineal off cacti. The flood event therefore resulted in a significant decrease in the population of *Dactylopius ceylonicus*. Fortunately, despite both release sites being completely submerged by flood waters, some cochineal persisted. Populations are now naturally re-establishing and this is being assisted and accelerated by harvesting infected cladodes from a number of offsite nursery locations and redistributing them within the core infestation.

Steven Johnson

Biological control augmentation: redistributing agents on infected cladodes following the flood

Clean-up of the flood plain

A clean-up operation was coordinated by the City of Onkaparinga Council, through partnerships with the South Australian Government and volunteer organisations. In October 2016, the river was surveyed on foot from the established infestations to the mouth, concentrating on the elevated area where the flood waters deposited debris. The section was mapped and 17 management grids overlayed in which the density of deposited cacti fragments was estimated. The map (above right) shows density mapping and management grids for the City of Onkaparinga Council-managed section of the estuary. This data was used to estimate cost of cacti search and removal activities.



EBS Ecology

Planning map showing density of Opuntia monacantha fragments deposited by the flood in the lower Onkaparinga River

Methodology

The clean-up and cacti removal operation consisted of teams walking over the management grids in several sweeps. The first sweep was to collect visible cacti fragments at the surface in large plastic garbage bins. The second sweep involved sorting through and turning over the thatch, sediments and soil deposited by the flood. In some areas, the debris was up to 1 m thick. The third sweep involved collecting any additional cacti material that had been exposed. Collected material was stockpiled for collection and disposed of in a secure deep burial facility.

Jock Conlon

Cacti stems and fragments stockpiled during the cleanup operation, ready for collection and deep burial

The future

Clean-up of the estuary will continue for two more summers, and annual monitoring within the 17 management grids will continue into the future. Protection of both the conservation and recreational assets of the estuary is considered a priority by all partners. However, it is just as important to continue, improve and increase management of the core infestation within the National Park, as Henry Rutherford from Natural Resources Adelaide and Mount Lofty Ranges explains:

> "*We need to think outside the square in order to get on top of cacti in such a difficult to access location and, most importantly, reduce the likelihood of another catastrophic spread event on the next flood*".

Goals for the future

- Improve coordination and strengthen partnerships.
- Expand current cochineal biocontrol program and integrate with a release of cactoblastis for biocontrol.
- Develop new cost-effective methods for managing cacti in hard to access places.

Flood is a major cause of spread for all species of cacti. When planning to manage cacti, always ask "*Does my infestation occur in a waterway that is subject to flooding?*"

Matt Sheehan

Opuntia aurantiaca (tiger pear) cladode deposited in a flood event in Wild Horse Creek, 70 km south of Ilfracombe, central west Qld

Lessons learned from the flood

- **Early management is money well spent.**
- **Plan how to manage spread and identify vectors.**
- **Spread events are hard to predict and there is little warning.**

Reference

Department for Environment and Heritage (2004). Onkaparinga River Reserve Management Plan, Adelaide, South Australia.

Cost of cleanup

- Council-managed lands: $13,000
- State Government-managed lands: $32,310

The cost of the clean-up was minimised with many enthusiastic volunteers assisting with the program

- 1000 volunteer hours: $30,000

Projected (and committed) cost for next two summers:

- Council-managed lands: $5500 per year (not including deep burial disposal)
- State Government-managed lands: $1000 per year (monitoring component only)

Henry Rutherford

It is predicted that the cost of the clean-up will reduce significantly over the next two summers as more material is removed. Mapping is a good way to capture the reduction of cacti over time and determine the level of ongoing investment that is required.

Case study 6

Control of coral cactus in Queensland

Elizabeth Clark and Michael Day

Management objective: Asset protection

Species: *Cylindropuntia fulgida* var. *mamillata*

Summary

'Leander' is a grazing property situated in central west Queensland, where, despite a thirty-year chemical control program, the spread and reinvasion of this aggressive weed continues. Recent adoption of an integrated management plan has started to turn things around. Written from the landholder's perspective, this case study documents an integrated approach to weed management, including early results of a biological control trial on Leander.

The problem

Cylindropuntia fulgida var. *mamillata* (coral cactus) was first reported approximately 40 years ago in the Longreach region on crown land at an abandoned main roads camp, established for the construction of the Landsborough Highway. Few people were aware of the weed until the 1980s, when the land was reallocated to 'Permission to Occupy' and large infestations were discovered by lessees. Initial chemical treatment of the infestation at the camp was unsuccessful, and it continued to spread throughout the region.

The primary regional management objective for coral cactus is to reduce its impact on key assets (agricultural and environmental) and reduce further spread. Given its widespread distribution throughout the central west, eradication is not a feasible management option.

Leander is a 12,000 hectare sheep grazing property located near Longreach and is owned and operated by Peter and Elizabeth Clark. They have been tackling coral cactus since they discovered it on the property and adjoining lands in the early 1980s. Leander is situated within the Cooper Creek system, which drains into the Lake Eyre Basin, one of Australia's most iconic wetland and wild river systems covering one sixth of the country. One of Peter and Elizabeth's main motivations for managing coral cactus is to prevent it entering the Basin, which would severely impact grazing and organic production in this iconic and ecologically significant part of Australia. Additionally, coral cactus has had, and continues to have, a significant impact on their livelihood.

> *"Approximately one tenth of our sheep grazing property became unproductive as a result of coral cactus establishment. We were forced to remove stock from approximately 1200 ha to prevent the risk of further spread. It would not be an exaggeration to claim that over the past 20 years of treating this weed, it would have cost $200,000 – a lot of money to pay for a pot plant that was thrown away in a creek".*

When Peter and Elizabeth started managing coral cactus, there was not much known about it or how to control it.

> *"We trialled everything under the sun. But now, through our own learnings and help from others, we have a plan that uses several tools, and it finally feels like we might be getting somewhere."*

The key new tool available to them is biological control and this, combined with other management methods, is proving to be a game changer.

Elizabeth Clark

Exclusion fence – helps prevent the spread by kangaroos and stock

The approach

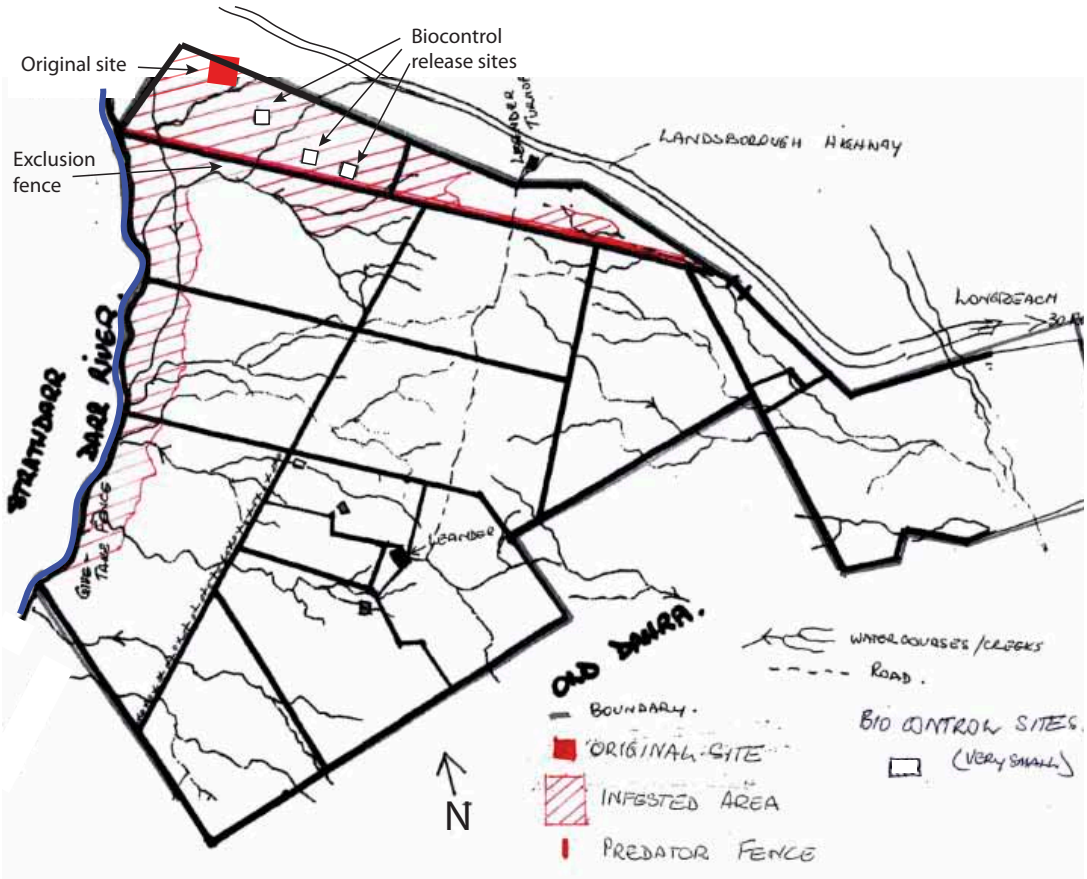
Integrated management

Peter and Elizabeth have adopted a strategic approach to managing their property, involving chemical and biological control and exclusion fencing to contract infestations and prevent spread. Surveillance and follow-up activities are essential and stop the program from going backwards.

The figure below shows a mud map of their property, identifying the current infestation (red hatched area), the original site of establishment (solid red square), management units (exclusion fence – bold red line), adjoining land and geographic features of interest. The core area outside of the exclusion fence (which Peter and Elizabeth lease) is where the biological control agent has been released.

Spread prevention

An important component of integrated cacti management is to prevent reinvasion and further spread. A major spread vector of coral cactus at Leander is kangaroo and stock movement. An exclusion fence has been erected along the northern property boundary to reduce spread by kangaroos and other vectors southward from the core infestation. It also prevents stock from entering the infestation and moving coral cactus into 'clean' areas.



Mud map of Leander, used as a strategic management tool

"We have managed to restrict the cactus to an area that has been fenced off and stock are excluded. There are plants outside this area, but with constant checking and monitoring we can control these outbreaks chemically and push the infestation back into a controlled area."
Elizabeth Clark

Chemical control

Inside the exclusion fence, Peter and Elizabeth use chemical control to treat outliers and push cactus back to the core infestation, with the aim of returning as much land as possible back to production. Peter and Elizabeth currently use two chemical treatments on cactus at Leander.

Peter has found the spray technique is key to high efficacy of chemical control.

"We have had success with two different chemical mixes at label rates: (1) Garlon and water + wetting agent + dye; and (2) Access and diesel + dye. Both mixes require 100% cover to the point of run-off to kill coral cactus. It takes a little more care to achieve this with Garlon and water, but it is effective if applied correctly, and it is cheaper, and friendlier to the operator and equipment. We spray in half-day sessions. Any longer and you tend to get 'cactus blind' and lose enthusiasm as you start to feel like you are trying to empty the Sahara with a teaspoon!"

Surveillance and follow-up

Surveillance and follow-up is critical in an integrated management program, as Elizabeth explains:

"We have treated most of the large plants, but the small ones are hard to see and it is a full-time job doing follow-up and looking for new infestations. Our aim is to keep it confined to the core areas, so when we see any bits outside of the core, we mark the plants with tape and come back and treat them. We also conduct dedicated surveillance regularly, searching and treating in a grid pattern across the property. Walking with a hand sprayer is slow but thorough and effective. Using a four-wheel bike is an efficient use of time but you do miss more."

Peter and Elizabeth's mixing tip for Garlon

In a 20 L container with a screw-top lid, add a smal amount (e.g. 5 L) of the water. To the water add:

1. Garlon (mix well).
2. Activator to the Garlon/water mix (mix well).
3. Dye (mix well).
4. Pour premix into remaining water and mix well.

If you mix in this sequence, it mixes readily, and stays mixed and in suspension. Otherwise it can form globules or strings which will not go through the equipment.

Use the same day that it is mixed. Wash all equipment thoroughly with detergent and water and triple rinse.

Note: This works for Peter and Elizabeth. Please ensure to adhere to the directions on the label.

Biological control release

A new tool for managing coral cactus has arrived – the cochineal insect (*Dactylopius tomentosus*) – and it is showing promising results. The rationale behind the release of cochineal at Leander was two-fold: (1) As a management tool to complement on-going chemical control, and (2) to better understand the establishment and natural spread of cochineal by setting up a monitoring site. In a partnership between Peter and Elizabeth and the Department of Agriculture and Fisheries, cochineal was released at three isolated plots

Matt Sheehan

Feeding female cochineal insects (Dactylopius tomentosus) on a coral cactus plant

Helping the Helper (Augmentation)

Land managers like Peter and Elizabeth can assist the cochineal insect by moving it around their property. There are two good reasons to do this: (1) the more plants infected, the more points there are from which the insect can spread, and (2) a larger area can be inoculated more quickly than waiting for the cochineal to reach those more distant plants through natural dispersal.

If the insect can move 100 m in 12 months on its own, placing cochineal 100 m away from an infected plant will halve the time it takes to infect all plants between the first release point and the second.

Moving infected cladodes is far easier and cheaper than spraying whole plants and, unlike spraying, it does not require the whole plant to be treated.

(approximately 100 × 100 m) on the property. One site was established as a monitoring plot, while the other two sites were established as nurseries for rearing the cochineal for further human-assisted distribution around the property.

The result

Major findings from the trial:

- In 12 months, the cochineal moved 118 m unaided, with spread greatest in the dominant wind direction;
- Over 90% of plants are now infected with the cochineal; and
- Over 6% of plants have died.

These results are particularly encouraging considering that the release scale was small and insects had to build up populations over winter when they are typically less active. The study has shown that dispersal of cochineal can happen easily, even when the distance between plants is over 5 m, suggesting that natural dispersal can be successful even in less dense infestations.

What Peter and Elizabeth have learned from 30 years of cacti management

- Coral cactus has marvellous survival mechanisms.
- It is very difficult to see when small.
- It grows far more quickly than originally thought.
- It spreads readily through disturbance by machinery.
- It spreads rapidly and widely by kangaroos.
- It will grow on any soil type.
- 'Known' methods of control were not necessarily effective.
- Having a planned, coordinated and systematic approach to management is essential.
- Work in half-day sessions:
  - search and treat in grid pattern on foot;
  - tackle it in different ways (chemical, biocontrol and spread prevention);
  - give biocontrol agents a helping hand.

The future

It is expected that the cochineal will have a more dramatic impact on plants in the coming years, as populations continue to build.

And what do the landholders think of the addition of cochineal to their tool kit?

> *"It's bloody marvellous!"* Elizabeth exclaims. *"It has reduced the effort, expense and stress that we have endured in managing coral cactus up to now. But we are also realistic about it – cochineal won't eradicate the cactus, so we can't sit back and forget about it. We still have a big role to play, both in spreading the agent around and continuing to spray and maintain exclusion fences with the aim of increasing the carrying capacity on our land. Biocontrol just gives us a bit of a spring in our step, knowing that we have some little helpers slowly working away as we continue to do the same."*

Case study 7

Wheel cactus control: Pushing past the impossible

Lorraine Edmunds

Management objective: Containment and control (9 properties)

Species: *Opuntia robusta* (wheel cactus)

Summary

Weed infestations can overwhelm land managers at a property, district or regional level. Finding the energy, resources and necessary information to attempt a control program can be daunting, especially for landholders, where landscapes are big and largely inaccessible, communities are small and isolated, and the cost of control is more than the value of the land. This case study examines how a small outback community in South Australia's Flinders Ranges tackled a large *Opuntia robusta* (wheel cactus) infestation head-on, learning a lot along the way that may be helpful to others facing similar challenges.

The problem

Wheel cactus occurrences are recorded for the Blinman area from the 1970s but were probably present decades earlier. Ten years after exceptional rains in 1989, landholders became concerned about the rate of spread and increasing density of wheel cactus across their properties.

> *"We felt overwhelmed, knowing we had to do something but where to begin? When we learned that the seed probably had a 20-year life we knew we were looking at a 25-year control program – a whole generation – if it was to provide a lasting benefit. How do you meet the financial, physical and emotional cost of something that big?"* Bill McIntosh, Gum Creek Station.

Frank Bernhardt

Wheel cactus on cliff-faces and ledges in Parachilna Gorge, with same area after treatment, below

Frank Bernhardt

Knowing where to begin was especially difficult because of several factors:

- **Big complicated landscapes** The area of infestation includes some of South Australia's most rugged mountain country. A highly variable land surface across a relatively small geographic area, it is characterised by deep gorges, peaks to 850 m, cliffs, rocky outcrops, valleys, plains, ephemeral creeks and flood-outs. Many areas can only be accessed on foot, some only using ropes.

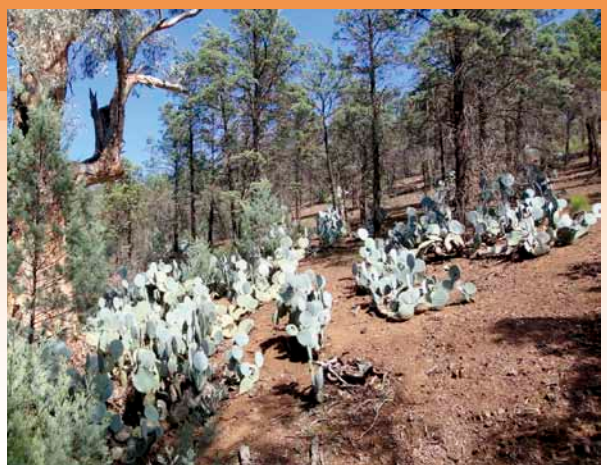
- **Small isolated communities** The principal land use in the area is pastoralism, typically with one resident family (owner/manager) on each property. Properties range in size from several hundred to more than 1600 km^2. Two tiny towns serve the district; Blinman, with a resident population of 17, and Parachilna, with 6 (when the project began). Located 212 km north of Port Augusta, (the closest large commercial centre), the community, by necessity, must be largely self-sufficient.
- **A highly opportunistic weed** Although highest densities occur in white cypress pine woodland (*Callitris glaucophylla*), and above the banks and along the channels of watercourses, wheel cactus is found in most situations. From exposed sites in shallow soils (on the highest peaks and cliff-faces) to dense woodland and the deeper soils of floodout country, wheel cactus occupies almost every ecological niche in the project area.

The approach

In 2003, nine pastoralists from the Blinman and Parachilna districts formed the Blinman Parachilna Pest Plant Control Group (BPPPCG). With funding through the North Flinders Soil Board, the group engaged a part-time project coordinator (a local resident), undertook a landholder survey to capture what was known about the range and density of wheel cactus on their properties, purchased GPS and spray equipment, and hosted a strategic planning workshop which was attended by relevant agencies, weed scientists and pest plant control officers from neighbouring NRM regions.

A project area of 400 km^2 was defined. Two key objectives were set:

1. To plan and implement a control program;
2. To educate the wider community and seek support for on-ground works.



Lorraine Edmunds

Typical stand of mature wheel cactus in white cypress pine woodland, accessible only by foot or experienced quad bike rider

Designing the control program

Applying what it had learned from the strategic planning workshop, the BPPPCG chose containment and control as its primary goals.

The group sought funding through State and Australian Government grant programs to implement and maintain a control program to treat all areas other than a core area of 30 km^2, where biocontrol would be introduced if a suitable agent could be found in the future.

Outliers and scattered populations were systematically targeted, working from the outside of the infestation toward the core. Areas of high conservation value – swamps, springs, watercourses, gorges, floodouts – were also treated.

Herbicide trials, both foliar spray and stem/pad injection, were undertaken during the first 12 months of the program, followed by biocontrol trials (cactoblastis and cochineal) several years later.


Blinman/Parachilna PEST PLANT CONTROL

Chemical Trials - What have we learned?

Frank Bernhardt

Foliar spray and stem/pad injection trials were undertaken to identify the most cost-effective and manageable chemical controls for plants in accessible and inaccessible (foot access only) areas

Contractors did most of the initial knockdown control (foliar spraying and stem/pad injecting). They also set up and monitored trials. Landholders and volunteers assisted with follow-up, maintenance, and cochineal translocation.

Partnering with volunteers

It was evident from the beginning that the BPPPCG would need help from outside the community to undertake follow-up and keep the project going. There was too much ground for landholders to cover. All treated areas had to be inspected and new plants treated within 4 years, before they produced fruit.

Several landholders from the group developed partnerships with volunteers (principally bushwalking groups and 4WD clubs). They provided accommodation and a contribution for fuel (volunteers travelled over 1000 km per trip) in exchange for one week's work annually (8–25 persons). In this way, treated areas could be inspected and new plants controlled (stem/pad injection, hand-pulling and burial, and later, by cochineal translocation).

> *"Partnering with volunteers has been a huge morale lifter for us. Without the help of volunteers we could never get back and monitor all of the treated areas. We only have four years before new plants produce fruit and we have to ensure that no more seed is added to the seedbank in the soil."* Bill McIntosh Gum Creek Station.

The too-hard basket – cliff-face control

Cliff-faces were left in the 'too-hard' basket for several years, until the group secured funding to deliver a staged abseiling-based control program along steep-sided sections of two major creeks. Contractors received specialist training and (over 4 years) treated several thousand plants on cliff-faces, ledges and steeply dipping slopes.

Cochineal is now established in adjacent areas and is expected to control cliff-face recruits.

> *"This work was completely beyond the capacity of our community, but while the wheel cactus remained on the cliff-faces there was a gaping hole in our control program. We knew ravens and other birds ate the ripe fruit and spread the seeds; accessing cliff-faces and ledges was no problem for them. We risked losing the gains we had made treating adjacent areas."* Lorraine Edmunds, project coordinator.

Jenny Barker, SA Arid Lands NRM

Lorraine Edmunds

Biocontrol – trial and release

Several years into the project it became evident that long-term control would only be sustainable if a suitable biocontrol agent could be found. The scale of recruitment over such a large project area was greater than the resources available to the BPPPCG.

Cochineal and cactoblastis were present in the district, persisting from the mid 1990s when Authorised Officers did spot releases through the area. Although they persisted neither agent had spread.

In 2008, BPPPCG commenced a 4-year trial on Gum Creek Station testing two strains of cochineal (*Dactylopius opuntiae)*. Despite being moved in winter (when the insects were dormant) onto just two new host plants, the *'Oratunga'* strain translocated successfully while the NSW strain (three host plants) failed to translocate.

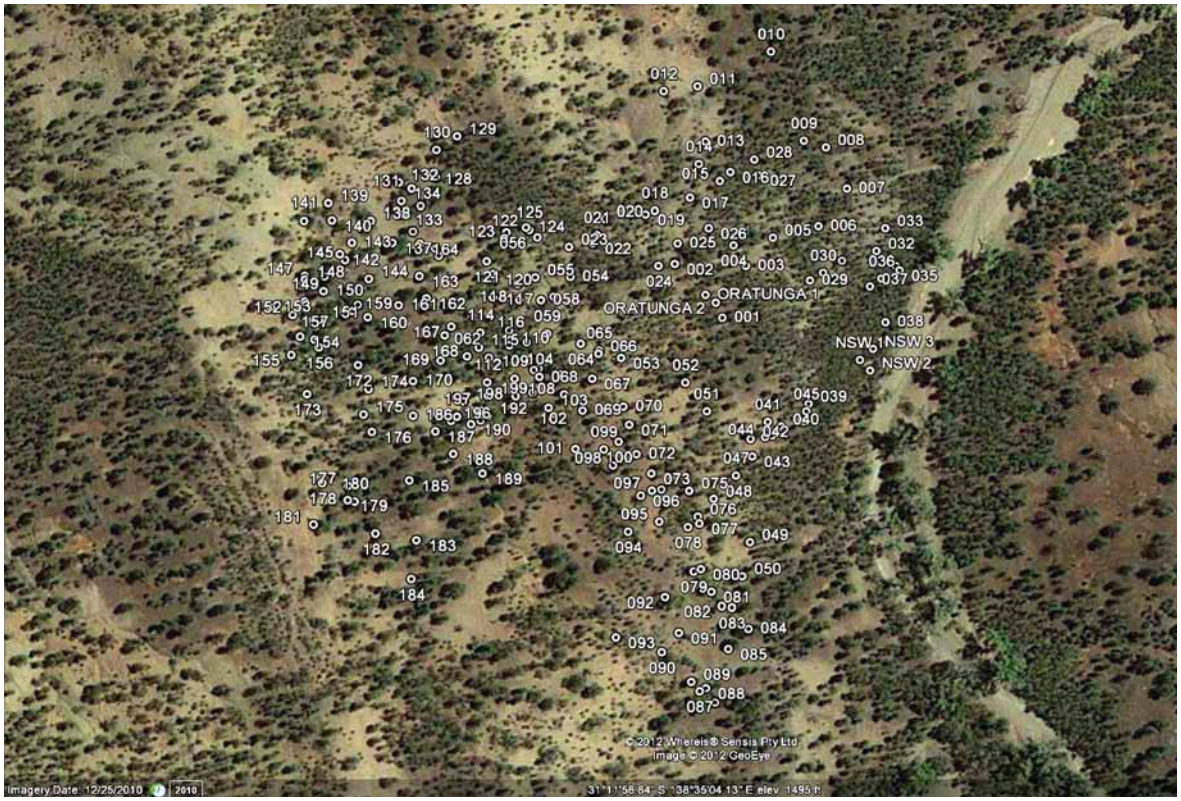
Lorraine Edmunds

In big, complex landscapes, once successfully established cochineal finds the tiny recruits that are missed during searches

Cochineal was slow to establish but after three years it had spread well beyond the original trial site.

In 2011, '*Oratunga*' strain cochineal was released onto 890 plants in the core area. By 2013 it was adopted as a key management control, with further releases in the core area, and at other locations with high recruitment levels. It was also released onto recruits in areas adjacent to cliff-face control sites.

A small cactoblastis (*Cactoblastis cactorum*) trial was undertaken in 2007, but was not successful.



Frank Bernhardt

Gum Creek cochineal trial results after 2½ years. By the end of the first year cochineal had spread from two new host plants (Oratunga 001 and 002) onto 45 plants, increasing to 183 plants by the end of year two. Six monthly inspections were undertaken with all affected plants mapped, until 500 infected plants were recorded within the 500 m² trial site. Plants began to die late in the second year.

Lessons learned

When the Blinman project began, opuntioid cacti were not considered a priority weed group in South Australia. Knowledge of their distribution, invasive potential and how they might be effectively controlled was scant. Although well funded and supported by the South Australian Arid Lands NRM, the group had to learn by trial and error.

Fifteen years on, after an investment of several hundred thousand dollars chemically treating 70% of the original infestation, cochineal has become the primary control. Chemical treatment of isolated plants, outliers and plants in watercourses continues, with some physical removal of small plants that can be removed off site and buried.

Volunteers play a critical role assisting landholders with maintenance and monitoring. When grant money can be accessed it is used to support volunteers and to purchase herbicide and other field equipment.

Through trial and error the group has learned that:

- It is preferable to do something rather than nothing. While the best available information should always be sought sometimes there are no clear answers. Not everything will work but failure is part of the process of achieving long-term success.
- There is strength in numbers. By forming a group, sharing a problem and pooling resources, it is more likely that solutions will be found. Groups are also more likely to secure funding.
- In complex landscapes where access is difficult and the infestation large, biocontrol provides the only real chance of achieving long-term control. It is not possible to find and treat every plant. It may take some time to find and test suitable agents, but it is very important to persist.
- Volunteers are invaluable. They offer a variety of skills and expertise, and greatly increase what can be achieved on the ground. The best outcomes occur when volunteers 'take ownership' of a patch of ground and stay with it over time. It is important to match the experience of volunteers with the environment in which they will be working. Not all volunteers will be suitable.

Lorraine Edmunds

"Sometimes it felt like two steps forward, one step back. Wet years were especially challenging, triggering so much recruitment; very demoralising after years of concerted effort. At times like this it is important to use all the resources available to keep the program going. Maintaining strong morale is critical to long-term success." Lorraine Edmunds, project coordinator.

Questions to ask before starting

- **Do you think you could manage a control program if you had some help or collaboration?**
- **Do others in your district have the same weed problem?**
- **Who might be interested in working with you?**
- **Who do you need to talk to for information and advice about your problem weed and its control?**
- **What resources are available within your community?**
- **Are funding opportunities available?**
- **Will your program be funding-dependent?**
- **Will the project have an end-date or is it likely to be ongoing?**

Chapter 6

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Further information

Herbaria contact information

Australian National Herbarium

GPO Box 1600, Canberra ACT 2601
phone: (02) 6246 5084 Fax: (02) 6246 5249
email: canbr-info@anbg.gov.au
website: www.cpbr.gov.au/cpbr/herbarium

Queensland Herbarium

Brisbane Botanic Gardens, Mt Coot-tha Road, Toowong Qld 4066
phone: (07) 3896 9326 Fax: (07) 3896 9624
email: Queensland.Herbarium@qld.gov.au
website: https://www.qld.gov.au/environment/plants-animals/plants/herbarium/

State Herbarium of South Australia

Old Tram Barn, Hackney Road, GPO Box 1047, Adelaide SA 5001
phone: (08) 8222 9311 Fax: (08) 8222 9399
email: stateherbsa@sa.gov.au
website: http://www.environment.sa.gov.au/Science/Science_research/State_Herbarium

Tasmanian Herbarium

University of Tasmania, College Road, PO Box 5058, UTAS LPO, Sandy Bay Tas 7005
phone: (03) 6226 2635
email: herbarium@tmag.tas.gov.au
website: http://www.tmag.tas.gov.au/collections_and_research/tasmanian_herbarium

The National Herbarium of New South Wales

Botanic Gardens Trust, Mrs Macquaries Road, Sydney NSW 2000
phone: (02) 9231 8111
email: feedbackRrbgsyd@rbgsyd.nsw.gov.au
website: https://www.rbgsyd.nsw.gov.au/Science-Conservation/Herbarium

The National Herbarium of Victoria

Royal Botanic Gardens, Private Bag 2000, South Yarra Vic 3141
phone: (03) 9252 2300
email: rbg@rbg.vic.gov.au
website: https://www.rbg.vic.gov.au/science/herbarium-and-resources/national-herbarium-of-victoria

The Northern Territory Herbarium

Palmerston: Herbarium Building, The Boulevard, PO Box 496, Palmerston NT 0831
phone: (08) 8999 451
Alice Springs: Alice Springs Desert Park, Larapinta Drive, PO Box 1120, Alice Springs NT 0871
phone: (08) 8951 8791
email: herbarium@nt.gov.au
website: https://nt.gov.au/environment/native-plants/native-plants-and-nt-herbarium

Western Australian Herbarium

WA Conservation Science Centre, 17 Dick Perry Avenue, Kensington, Locked Bag 104, Bentley DC WA 6983
phone: (08) 9219 8000
email: herbarium@dpaw.wa.gov.au
website: www.dpaw.wa.gov.au/plants-and-animals/wa-herbarium

Weed control contacts

	Department	Phone	Email	Website
Federal	Department of the Environment and Energy	1800 803 772 (general enquiries)	Submit enquiry at: http://www.environment.gov.au/about-us/contact-us	http://www.environment.gov.au/biodiversity/invasive/weeds/
ACT	Environment, Planning and Sustainable Development Directorate	13 22 81	environment@act.gov.au	http://www.environment.act.gov.au/parks-conservation/plants-and-animals/Biosecurity/weeds
NSW	Biosecurity NSW, Department of Primary Industries	1800 680 244	invasive.species@dpi.nsw.gov.au	www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds
NT	Department of Environment and Natural Resources (Weed Management Branch)	Alice Springs (08) 8951 9210 Darwin (08) 8999 4567 Katherine and the Gulf (08) 8973 8857 Tennant Creek (08) 8962 4314	weedinfo@nt.gov.au	https://nt.gov.au/environment/weeds/weed-management-branch-contacts
QLD	Biosecurity Queensland, Department of Agriculture and Fisheries	13 25 23	callweb@daff.qld.gov.au	https://www.daf.qld.gov.au/plants/weeds-pest-animals-ants/weeds
SA	Biosecurity SA, Department of Primary Industries and Regions SA	(08) 8303 9620	nrmbiosecurity@sa.gov.au	www.pir.sa.gov.au/biosecuritysa/nrm_biosecurity/weeds
TAS	Department of Primary Industries, Parks, Water and Environment	(03) 6165 3777	Weed.Enquiries@dpipwe.tas.gov.au	http://dpipwe.tas.gov.au/invasive-species/weeds
VIC	Agriculture Victoria (Department of Economic Development, Jobs, Transport and Resources)	136 186	Submit enquiry at: http://agriculture.vic.gov.au/about-us/contact-us	http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/weeds
WA	Department of Primary Industries and Regional Development	(08) 9368 3333	padis@dpird.wa.gov.au	https://www.agric.wa.gov.au/pests-weeds-diseases/weeds

Further information

Weeds and the law

Declaration status of opuntioid cacti in Australia

Under the Commonwealth *Biosecurity Act 2015*, the WoNS opuntioid cacti are prohibited entry into Australia. With the exception of *Opuntia ficus-indica*, these species are also declared weeds in many states and territories. Legal obligations vary between species and jurisdictions and range from the prevention of movement and sale to an obligation to control.

It is still legal to trade *Opuntia ficus-indica* in some jurisdictions, and specimens are sold in markets or traded among gardeners. The sale and trade of other opuntioid cacti still occurs illegally via markets, nurseries and internet sites.

Legislation and declaration status of opuntioid cacti in all states and territories is summarised in the table below. Information contained in this table was accurate at November 2017.

Note that the table may not contain all the information relevant to you and that primary legislation, regulations and declaration status of taxa may change. It is therefore important to check with weed authorities in your state or territory to ensure that you are fully aware of your legal obligations in relation to cacti.

Summary of current legislative status for 27 WoNS-listed opuntioid cacti species

Jurisdiction	Relevant legislation	Requirements
ACT	*Pest Plants and Animals Act 2005*	All of ACT: **Must be suppressed** – Applies to all species within the *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* genera. **Notifiable** – Presence must be notified to the Director General. Includes all species within the *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* genera, excepting *Opuntia ficus-indica*. **Prohibited** – Propagation and supply is prohibited for all species within the *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* genera.
NSW	*Biosecurity Act 2015*	All of NSW: **General biosecurity duty** (applies to all opuntioid cacti species) – All plants are regulated to prevent, eliminate or minimise any biosecurity risk they may pose. Any person who deals with any plant, who knows (or ought to know) of any biosecurity risk, has a duty to ensure the risk is prevented, eliminated or minimised, so far as is reasonably practicable. **Mandatory Measure** (applies to all opuntioid cacti species, excepting *Opuntia ficus-indica*) – Must not be imported into the State or sold. **Regional Recommended Measure** – Several regions have additional regulatory requirements for spread prevention and/or eradication of various opuntioid cacti species. Visit the website and search for a particular species or genus for further information. http://weeds.dpi.nsw.gov.au/
NT	*Weeds Management Act 2001*	All of NT and applicable to all opuntioid cacti species: **Class A** – To be eradicated. **Class C** – Not to be introduced to the Territory.

…/Continued from page 148

Jurisdiction	Relevant legislation	Requirements
QLD	*Queensland Biosecurity Act 2014*	All of Queensland: **General biosecurity obligation** – Requires all reasonable and practical steps to minimise the risk of it spreading until they receive advice from an authorised officer. Includes all opuntioid cacti. **Restricted** – Includes a range of requirements, including plants that must not be kept, distributed or moved and must be reported when found. Includes: *Austrocylindropuntia cylindrica*, *A. subulata*, *Cylindropuntia fulgida*, *C. imbricata*, *C. pallida* (syn. *C. rosea*), *C. spinosior*, *C. tunicata*, *C. prolifera*, *O. microdasys*, *O. elata*, *O. stricta*, *O. aurantiaca*, *O. monacantha*, *O. tomentosa* and *O. streptacantha*. **Prohibited** – Includes a range of requirements, including plants that must not be kept, distributed, moved or imported and must be reported when found. All sightings to be reported to Biosecurity Queensland within 24 hours. Includes *Cylindropuntia* species excepting *C. fulgida*, *C. imbricata*, *C. prolifera*, *C. rosea*, *C. spinosior* and *C. tunicata*; all species of *Opuntia* excepting *O. microdasys*, *O. elata*, *O. stricta*, *O. aurantiaca*, *O. monacantha*, *O. tomentosa*, *O. streptacantha* and *O. ficus-indica*.
SA	*Natural Resource Management Act 2004*	Whole of state: **Sale of plants, or produce or goods carrying plants** – All species of opuntioid cacti (excluding *O. ficus-indica*) are banned from sale. **Movement of plants** – prevents transport within or into a control area. Includes all *Cylindropuntia* and *Opuntia* species. **Owner of land to take action to destroy or control plants** – Includes all *Cylindropuntia* and *Opuntia* species. Authorities may recover certain costs from owners of land adjoining road reserves – Includes all *Cylindropuntia* and *Opuntia* species.
VIC	*Catchment and Land Protection Act 1994*	**Restricted** – Prohibits trade, propagation or transport. All species in the *Austrocylindropuntia* and *Cylindropuntia* genera and all *Opuntia* species (except *O. aurantiaca*, *O. monacantha*, *O. stricta* and *O. ficus-indica*) are declared in this category for the whole state. **Regionally Prohibited or Regionally Controlled** – The above prohibitions apply as for restricted weeds. In addition, land owners must take reasonable measures to eradicate (regionally prohibited) or control to prevent growth and spread (regionally controlled). Several species of *Opuntia* (*O. aurantiaca*, *O. monacantha*, *O. robusta*, *O. stricta*) are either regionally controlled or regionally prohibited in various regions throughout Victoria. See the website for further detail: http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds/legislation-policy-and-permits/declared-noxious-weeds-and-pest-animals-in-victoria
WA	*Biosecurity and Agriculture Management Act 2007*	Whole of state: **Declared Pest** – must satisfy import requirements or require an import permit. May also be subject to control and keeping requirements once within WA. Includes all opuntioid cacti. **Prohibited** – excluded from all of WA, unless under permit. Includes *Cylindropuntia leptocaulis*, *C. prolifera*, *C. spinosior*, *O. aurantiaca*, *O. humifusa O. leucotricha*, *O. robusta*, *O. schickendantzii*, *O. streptacantha* and *O. sulphurea*. **Management** – Requires management that will reduce weed impact, numbers or distribution or prevent or contain the spread. Includes *Austrocylindropuntia* species, *Cylindropuntia fulgida*, *C. imbricata*, *C. kleiniae*, *C. pallida*, *C. tunicata*, *Opuntia elata*, *O. elatior*, *O. engelmannii*, *O. ficus-indica*, *O. microdasys*, *O. monacantha*, *O. polyacantha*, *O. puberula*, *O. stricta* and *O. tomentosa*.

Further information

Herbicides and the law

In addition to the regulatory role of the Australian Pesticides and Veterinary Medicines Authority (APVMA), the use of herbicides is also regulated by state and territory legislation. See below for local contact details.

	Department	Phone	Email	Website
National (Australian Government)	Australian Pesticides and Veterinary Medicines Authority	(02) 6210 4701	enquiries@apvma.gov.au	www.apvma.gov.au
ACT	Environment, Planning and Sustainable Development Directorate	13 22 81	environment@act.gov.au	https://ablis.business.gov.au/ACT/pages/87ad5878-2cc8-43c7-ad97-b7f5301e4290.aspx
NSW	NSW Environment Protection Authority (EPA)	131 555	info@environment.nsw.gov.au	http://www.epa.nsw.gov.au/pesticides/pestmmngngNSW.htm
NT	Chemical Services Department of Primary Industry and Resources	(08) 8999 2006 (08) 8999 5511 (switchboard)	chemicals@nt.gov.au	https://nt.gov.au/industry/agriculture/farm-management/using-chemicals-responsibly
QLD	Department of Agriculture and Fisheries	13 25 23	callweb@daff.qld.gov.au	https://www.daf.qld.gov.au/plants/agvet-chemicals-and-residues
SA	Rural Chemicals Group, Biosecurity SA, Department of Primary Industries and Regions SA	(08) 8207 7983	PIRSA.RuralChemicals@sa.gov.au	http://www.pir.sa.gov.au/biosecurity/rural_chemicals
TAS	AgVet Chemicals Coordinator Department of Primary Industries, Parks, Water and Environment	1300 368 550	DPIPWEChemical.Enquiries@dpipwe.tas.gov.au	http://dpipwe.tas.gov.au/agriculture/agvet-chemicals
VIC	Agriculture Victoria (Department of Economic Development, Jobs, Transport and Resources)	136 186	Submit enquiry at: http://agriculture.vic.gov.au/about-us/contact-us	http://agriculture.vic.gov.au/agriculture/farm-management/chemical-use
WA	Department of Primary Industries and Regional Development	(08) 9368 3333	epadisnquiries@dpirdagric.wa.gov.au	https://www.agric.wa.gov.au/pests-weeds-diseases/control-methods/chemicals

Safety and welfare

Further information on safety and welfare policy, standards, guidelines and legislation can be accessed by contacting the following government departments and volunteer organisations.

Chemical Training

A number of providers offer accredited training in the use of chemicals for weed control. To find a provider near you visit the following website and search for the code AHCPMG301 under the 'Nationally recognised training components' search function. Follow the link to find Registered Training Organisations (RTOs) approved to deliver this training package – http://training.gov.au/Search.

Jurisdiction	Website	Contact
NT WorkSafe	http://www.worksafe.nt.gov.au/Pages/default.aspx	1800 019 115
Safe work Australia	https://www.safeworkaustralia.gov.au/	info@swa.gov.au
SafeWork NSW	http://www.safework.nsw.gov.au/	13 10 50
Workplace Health and Safety Queensland	https://www.worksafe.qld.gov.au/	1300 362 128
WorkSafe ACT	http://www.worksafe.act.gov.au/health_safety	13 22 81
SafeWork SA	http://www.safework.sa.gov.au/	1800 777 209
WorkSafe Tasmania	http://www.worksafe.tas.gov.au/	1300 366 322
WorkSafe Victoria	https://www.worksafe.vic.gov.au/	(03) 9641 1555
WorkSafe WA	http://www.commerce.wa.gov.au/WorkSafe/	1300 307 877
Our Community Group	https://www.ourcommunity.com.au/insurance/insurance_article.jsp?articleId=1245	(03) 9320 6800
Volunteering Australia	https://volunteeringaustralia.org/wp-content/files_mf/1377053059VAManagersrunningtherisk.pdf	(02) 6251 4060

Glossary

Adjuvant	A substance added to a herbicide mixture to aid or modify the action of the herbicide.
Affinis (aff.)	With affinity to other, akin to; often used for a provisionally recognised but unnamed taxon considered close to that name, perhaps a hybrid or extreme variant.
Annual	A plant that germinates, flowers and dies in one year or less.
Aril	An additional seed coating present in opuntioid catci but not other cacti. Arils in opuntioid cacti are generally hard and pale in colour.
Areole	Highly condensed and modified short-shoot, growing in the leaf axil as a felted cushion, unique to cacti, usually hairy and/or spiny; from them the flowers and roots and new cladodes arise.
Biotype	Of biological control agents: two or more morphologically indistinguishable forms of a species that can interbreed, but can only be recognised by their survival and development on different hosts and their distinct host preference for feeding or egg laying.
Cladode	A modified, swollen, water storing stem segment that forms the leaves. Cladodes can be cylindrical (e.g. in *Austrocylindropuntia* and *Cylindropuntia* species), or flattened (e.g. in *Opuntia* species, where they are commonly referred to as pads). In opuntioid cacti, cladodes are jointed.
Deciduous	Falling off at maturity, or the dropping off of a part of a plant or animal that is no longer needed or whose purpose has finished.
Elliptic	Of cladodes: planar, shaped like a flattened circle, symmetrical about the long and the short axis, tapering equally both to the tip and the base; oval.
Family	A taxonomic rank used in the biological classification of living and fossil organisms, that groups related genera (see genus). For example, the family of Cactaceae contains about 140 genera.
Genus Genera (pl.)	A taxonomic rank used in the biological classification of living and fossil organisms, that groups closely related species.
Glabrous	Smooth, without hairs.
Globular	Almost spherical (globose).
Glochid	Small, detachable, barbed bristles usually protruding from areloes on cladodes and fruit.
Monstrose	An abnormal, irregular stem growth.
Naturalised	Originating elsewhere, but established and reproducing itself in a new area without assistance.
Nymph	The immature form of some invertebrates that undergoes metamorphosis before reaching adult stage.
Obovate	Of a leaf or cladode: a 2-dimentional shape of which the the length is about 1.5 times the width, and widest above the centre.
Papilla Papillae (pl.)	A small rounded protuberance or nipple-like projection.

Penetrant	An adjuvant mixed with a herbicide spray mix to help the herbicide enter the plant (e.g. through waxy leaves or woody plant material)
Perennial	A plant whose life span extends over more than one growing season
Pericarpal	Flowering and fruiting body – that part of the floral axis surrounding the ovary.
Propagule	Any part of a plant that can become detached to produce a new plant; e.g. bud, cladode, seed.
Prostrate	Lying flat on the ground
Provenance	The geographical and genetic source of a particular plant or seed.
Pubescent	Downy, covered in short, soft, erect hairs.
Pupa	An insect in its inactive immature form between larva and adult.
Riparian	The zone or interface between land and river, creek or stream.
Scarify	To scratch or abrade the protective coating of a seed and may be a prerequisite for germination in some species.
Sessile	Fixed in one place; immobile.
Sheath	Papery outer covering of the spine. Only present in *Cylindropuntia* species.
Species	A group of living organisms consisting of similar individuals capable of exchanging genes or interbreeding. A species ranks below genus.
Stoma Stomata (pl.)	Pores found in the epidermis of leaves, stems and other organs, that facilitate gas exchange between tissues and the atmosphere.
Succulent	Juicy, fleshy, water-retaining; succulent plants store water in specific organs, for example, stem-succulents, leaf-succulents.
Surfactant	An additive (adjuvant) to a herbicide spray mix that increases spray coverage on the leaf and helps the herbicide stick to the plant, increasing herbicide uptake.
Synonym (syn.)	An outdated or alternative name for the same taxon (e.g. *Cylindropuntia rosea* is the synonym of *C. pallida*).
Tepal	The term given to the outer part of a flowers when it cannot be easily divided into sepals and petals.
Tubercle	A small raised area or nodule on a plant surface.
Tuberculate	Having tubercles.
Variety (var.)	In botanical nomenclature, variety is a taxonomic rank below that of species and subspecies. Varieties display a divergence in growth from or other characteristics typical of that species. var. is placed after the specific epithet and is not underlined or italicised.
Vector	A thing or process that helps transport seeds.
Vegetative growth	New individuals arise without process of sexual reproduction when viable propagules become detached from parent plants and establish new independent plants.
Viable	Able to survive and develop.
Wetting agent	A surfactant.

Further information

Acronyms and abbreviations

ALA	Atlas of Living Australia
APVMA	Australian Pesticides and Veterinary Medicines Authority
CAM	Crassulacean Acid Metabolism
CPPB	Commonwealth Prickly Pear Board
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food, Western Australia
DPAW	Department of Parks and Wildlife (Western Australia)
DPIRD	Department of Primary Industries and Regional Development (Western Australia), formally DAFWA
DELWP	Department of Environment, Land, Water and Planning
DENR	Department of Environment and Natural Resources (NT)
FOOP	Friends of the Onkaparinga Park
GPS	Global positioning system
KBULG	Kalgoorlie-Boulder Urban Landcare Group
MSDS	Material safety data sheet
MSMA	Monosodium methyl arsonate
NRM	Natural Resource Management
OEH	Office of Environment and Heritage (NSW)
PIRSA	Primary Industries and Regions South Australia
PPE	Personal protective equipment
PVA	Polyvinyl acetate
SITREPS	Situation report
TCCG	Tarrangower Cactus Control Group
WoNS	Weed of National Significance

Social media

Search for @weedyk8 on Twitter, Facebook, Instagram, Yammer to connect with Kate Blood about weeds.

Search on Facebook for:

- The Weed Society of Victoria Inc.
- Tarrangower Cactus Control Group Inc.
- Weeds of Western Australia
- Canberra & SE NSW Weeds
- Tasmanian Weeds

Conference proceedings:

Australasian Weeds Conference: http://caws.org.au/awc_index.php

Weed Society of Victoria: http://www.wsvic.org.au/

Useful search terms:

The internet is a dynamic place. Government departments and other organisations that house cacti information may change names or move information. Here is a list of useful search engine search terms that may help you locate information should any of the links referred to in the document become inactive: **WoNS, WoNS ALA, invasive cacti, cacti, cactus, managing opuntioid cacti, opuntioid cacti management manual.**

Other resources

Books/documents

Potter, S. and Rutherford, H. (2013). Field identification guide: *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* species. Biosecurity SA, Government of South Australia.

Chinnock, R.J. (2015). Feral opuntioid cacti in Australia. Part 1. Cylindrical-stemmed genera: *Austrocylindropuntia*, *Cylindropuntia* and *Corynopuntia*. State Herbarium of South Australia. ISBN 978-1-922027-43-6.

Potter, S. (2011). Weed management guide, Weed of National Significance: Opuntioid cacti, including *Austrocylindropuntia*, *Cylindropuntia* and *Opuntia* species. Biosecurity SA, Government of South Australia.

Web

Resource	Web address
Weeds of National Significance (WoNS) on Atlas of Living Australia (ALA)	http://weeds.ala.org.au/WoNS/opuntioidcacti/
Weed management guide (brochure, will be revised late 2017)	http://weeds.ala.org.au/WoNS/opuntioidcacti/docs/47053_ERGO_Weed_Mgmt_guide_CACTI.pdf
Cacti identification resources	http://weeds.ala.org.au/WoNS/opuntioidcacti/resources.htm
Cacti identification guide	http://weeds.ala.org.au/WoNS/opuntioidcacti/docs/Cacti_identification_guide.pdf
Australian Invasive Cacti Network	http://www.aicn.org.au/
Weeds at the Early Stage of Invasion	www.delwp.vic.gov.au/early-invaders
Atlas of Living Australia (search for species names to see distribution maps, photos etc.)	https://www.ala.org.au/
Biocontrol portal	http://root.ala.org.au/bdrs-core/wbiocont/home.htm
Tarrangower Cactus Control Group	http://www.cactuswarriors.org/
VicFlora	https://vicflora.rbg.vic.gov.au/
Global compendium of weeds	https://www.researchgate.net/publication/313645439_A_Global_Compendium_of_Weeds_Third_Edition
North West Weeds (NSW) – local information on local noxious weeds	http://www.northwestweeds.com.au/

Herbicide Treatment Record Sheet				
Contractor		Date/Time		
Operator Names		Property/GPS Location		
Area Description (landmarks, etc.)				
Growth Stage (✓)				
Target Species	Seedling	Juvenile	Flowering	Fruiting
1				
2				
3				
Plant Growth/Comments (✓)				
Target Species	Active Growth	No Active Growth	Under Stress (comments)	
1				
2				
3				
Environmental Conditions				
Soil Conditions **(circle)**		Dry	Damp	Wet
Rainfall – Previous 12hrs **(Y/N)** None expected in next 12hrs **(Y/N)**				
Wind Direction				
Wind Speed				
Temperature				
Application Technique (**circle**)				
Foliar Spray	Basal Bark	Stem/pad Injection	Cut Stump	Other
Operator signature		Project Officer signature		

WoNS Core Attributes for mapping taken from 'A Field Manual for Surveying and Mapping Nationally Significant Weeds'

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 where 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 and longitude).
7. Latitude	Latitude in degrees, minutes and seconds. Prefer decimal degrees or AMG 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/longitude was 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 percent. For rapid survey density data may be collected as classed data, e.g. 55–100% cover = dense. **Class number** **Class description** 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.

Field Recording Template for weeds

Use this sheet for recording multiple species or multiple sites during structured field search (e.g. vehicle or foot-based delimitation surveys).

Recorder details	Name: Name of people assisting:	Inspection date:
Site details (Site = the property/parcel boundary within which the weed propagules are located)	Location:	GPS accuracy (m):
	Site address/name:	Datum: ☐ GDA 94 ☐ WGS84
	Location description:	MGA Zone: ☐ Zone 54 ☐ Zone 55
	Land tenure (e.g. State Forest, National Park):	Survey method: ☐ Searching ☐ Delimiting survey ☐ Ad hoc

GPS ref #	**Species**	**Pattern of infestation** Individual, scattered, continuous	**Density** <1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%	**Area**	**Count**	**Age class** (Seedling, sapling, mature)	**Easting**	**Northing**	**Comments** (e.g. roadside, gully)
e.g. 1	*Cylindropuntia pallida*	Scattered	1–5%	5 × 5 m	5	Small cladodes/ segments	548011	6207117	2 m from edge of road on north side

Managing Opuntioid Cacti in Australia