

Bellyache bush (*Jatropha gossypifolia*) management manual

Control options and management case studies from
across Australia



Northern Territory Government



Department of Agriculture and Food



Australian Government

This manual has been produced by the Department of Employment,
Economic Development and Innovation with funding from the
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Queensland Government

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Copies of this publication are available from:

Tropical Weeds Research Centre
PO Box 187
Charters Towers, Qld, 4820
Ph +61 7 4761 5700

Photographs supplied by Fiona Barron, Faiz Bebawi, Sid Clayton, Charles Curry, Grace Evans, John Fisher, Murray Fuller, Barbara Madigan, Jancie Meeson, Trevor Meldrum, Adam Northey, Kelli Pukallus, Anita Randall, Ricardo Segura, Belinda Shaw, Joe Vitelli, Marie Vitelli, Wayne Vogler, Argyle Diamond Mine, Northern Territory Parks and Wildlife Service, Northern Territory Weed Management Branch.

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Principal author

Anita Randall, Weed Scientist, Biosecurity Queensland, Department of Employment, Economic Development and Innovation, Tropical Weeds Research Centre, Charters Towers, Queensland.

Participating authors

Dr Shane Campbell, Professional Leader, Biosecurity Queensland, Department of Employment, Economic Development and Innovation, Tropical Weeds Research Centre, Charters Towers, Queensland.

Dr Wayne Vogler, Senior Weed Scientist, Biosecurity Queensland, Department of Employment, Economic Development and Innovation, Tropical Weeds Research Centre, Charters Towers, Queensland.

Dr Faiz Bebawi, Senior Weed Scientist, Biosecurity Queensland, Department of Employment, Economic Development and Innovation, Tropical Weeds Research Centre, Charters Towers, Queensland.

Barbara Madigan, District Experimentalist, Biosecurity Queensland, Department of Employment, Economic Development and Innovation, Tropical Weeds Research Centre, Charters Towers, Queensland.

Case study contributors

Robert 'Bud' Abbott, Shilo.

Dr Faiz Bebawi, Senior Weed Scientist, Biosecurity Queensland, Department of Employment, Economic Development and Innovation.

Dave Bowman, Manager, Willeroo.

Sid Clayton, Supervising Land Protection Officer, Tablelands Regional Council.

Charles Curry, Project Officer, Southern Gulf Catchments.

Dr Kunjithapatham Dhileepan, Principal Entomologist, Biosecurity Queensland, Department of Employment, Economic Development and Innovation.

Dan and Louise Firth, formerly of King Creek Station.

John Fisher, Manager, Bromvil.

Murray Fuller, Territory Weed Management.

Emily Gillespie, Environmental Advisor, Argyle Diamonds Limited.

James Gorman, Eley National Park, Northern Territory Parks and Wildlife.

Dr Tim Heard, Senior Research Scientist, CSIRO Entomology.

Meat & Livestock Australia.

Adam Northey, Facilitator, Victoria River District Conservation Association.

Danielle McGinness, Eley National Park, Northern Territory Parks and Wildlife.

Sam McKenzie, Eley National Park, Northern Territory Parks and Wildlife.

Belinda Shaw, Project Manager (Pest Management), Greening Australia, Rockhampton.

Russell Smith, Strathmuir.

Tracey Vinnicombe, Biosecurity Officer, Department of Agriculture and Food, Western Australia.

Ralph and Lyn Woodard, Branmore.

Foreword



Large areas across northern Australia's rangelands are becoming infested with the exotic weed bellyache bush.

Bellyache bush detrimentally affects the agricultural and environmental value of these rangelands and unique environmental areas and threatens to expand its impact. Isolated, scattered plants quickly develop into dense stands and established infestations increase in size. Productive pastures are eventually reduced to bellyache bush monocultures and biodiversity declines.

This manual provides a summary of our present understanding of bellyache bush ecology and management in Australia. It brings together a comprehensive range of control and management tools for combating this weed. These represent the combined experience of many landholders, researchers, community groups, government officers and others who are tackling the bellyache bush problem.

I gratefully acknowledge the funding provided by the Commonwealth government to produce this manual and recommend it to all land managers faced with the challenge of controlling bellyache bush and to those in areas at risk of invasion.

A handwritten signature in black ink that reads "Tim Mulherin". The signature is written in a cursive, slightly slanted style.

The Hon. Tim Mulherin, MP,
Minister for Primary Industries, Fisheries and Rural and Regional Queensland

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Introduction

Bellyache bush (*Jatropha gossypifolia*) is an invasive shrub that can have significant economic, environmental and social impacts. Introduced into Australia for ornamental purposes, bellyache bush is now found across the tropics of Queensland, the Northern Territory and Western Australia. It is ideally suited to the seasonally wet/dry climate and has the potential to invade vast areas of our tropical savannas.

Bellyache bush forms dense thickets, excluding pasture and other vegetation. It takes over productive grazing land, reduces biodiversity and restricts access for activities such as mustering. It is also highly toxic to both animals and humans, with significant stock losses attributed to the weed.

It invades beds and banks of ephemeral watercourses, floodplains, open woodland and grassland. Productive river frontages are often most at risk of invasion. Bellyache bush is an opportunistic weed that thrives on both natural and human-made disturbance. It grows and spreads rapidly via seed and vegetative parts and is capable of producing large amounts of seed from a young age. Some seed may remain viable in the soil for long periods, resulting in continuing seedling establishment.

Using this manual

This manual outlines the ecology and impacts of bellyache bush, discusses a range of control methods and provides planning tools to assist in weed control. The information presented is based on a review of published information and discussions with researchers, technical experts and weed managers.

It also contains a number of case studies that give practical examples of how bellyache bush is being managed in different parts of northern Australia. These case studies show how various methods and strategies have been applied in diverse situations.

We hope that this manual will act as a practical reference tool for land managers, helping them to equip themselves with the skills and knowledge needed to manage bellyache bush on their land.



Section 1 Ecology



Ecology

1.1 Description

Bellyache bush (*Jatropha gossypifolia*) is an erect perennial shrub with a shallow root system. Field studies have shown that plants can live longer than 10 years, with anecdotal evidence suggesting life spans greater than 20 years.

The shrub generally grows to around 2 m in height, although it can reach up to 4 m under favourable conditions. The canopy can measure more than 2 m across. Bellyache bush has a sympodial growth habit, meaning it has multiple branches that can each continue to grow even if the main stem has been damaged.

Seedlings have thick, single stems with a few leaves sprouting from the top.



Newly emerged bellyache bush seedlings.



Bellyache bush is an erect, branched shrub.



Bellyache bush seedlings.

1.1.1 Plant variability

In Australia, bellyache bush plants display significant variation which appears to be associated with multiple introductions from a number of countries. This variation has led to suggestions of the presence of several biotypes (based largely on morphological differences), although it is possible that further studies could reveal some of these biotypes to be different varieties.

The most apparent difference between biotypes is leaf colour. For example, the biggest infestation in the Northern Territory (upper Daly River catchment) comprises plants with bright green leaves. In Queensland, bronze to purple is the predominant leaf colour in most infestations.



This plant growing near Lake Argyle, WA, shows the green leaf colouration.



In some biotypes, immature leaves are red, purple or bronze, while mature leaves are green.



At this location green and bronze plants grow side by side.

1.1.2 Stems

Bellyache bush has thick, fairly soft stems with coarse glandular hairs. The thin bark is green or red when young, turning grey as the plant ages. The stems exude a sticky watery sap when damaged. Very large plants can have a stem measuring more than 15 cm across at the base.



Stems of bellyache bush ooze sap when damaged.



Stems turn grey as plants age.

1.1.3 Leaves

Bellyache bush leaves have 3–5 lobes and measure 4.5–9 cm by 5–13 cm. The leaf margin is very finely toothed and edged with sticky, gland-tipped hairs. Leaves are held on stalks 2–7 cm long, which are also covered with sticky hairs.

The leaf colour depends on biotype and the age of the leaf, but ranges from green to bronze, red or purple.

The plant loses most of its leaves during the dry season, although plants in moist areas (such as along watercourses and dams) may keep their leaves year-round. The loss of leaves is usually very rapid, with plants either being in full leaf or almost leafless. Any remaining leaves are usually small and are found near the top of the stem. New season growth often commences in September/October in response to increasing temperatures. Small leaves may be produced even in the absence of rainfall; however, rainfall appears necessary for full leaf development.



Leaves have 3–5 lobes and can be green, bronze, red or purple. (Photo: NT Weed Management Branch)



Bellyache bush often loses most of its leaves during the dry season.

1.1.4 Flowers

The small flowers of bellyache bush range from light red through to dark purple on the outer sections of petals and have a yellow centre. They measure 6–9 mm across and are held in clusters at the ends of stems. The flowers produce large quantities of nectar to attract insects, which assists in pollination. There are usually separate male and female flowers, although bisexual flowers are produced occasionally.



Flower colour ranges from light red to dark purple with a yellow centre.

1.1.5 Fruit

Bellyache bush fruits are round to oblong, three-lobed capsules, about 12 mm long and 10 mm wide, usually containing three seeds. The hard capsules are bright green when immature, pale green or tan and woody at maturity. The fruit is dehiscent, 'exploding' when ripe and catapulting seeds up to 13 m from the plant.



Fruit are bright green, turning brown as they mature.

1.1.6 Seeds

Bellyache bush seeds are brown, 7–8 mm long and 3–4 mm wide. The fresh seeds have a fleshy, lighter coloured structure called a caruncle on one end. These growths are rich in fats and proteins and attract ants, which aid in local seed dispersal.



Seeds are brown with a caruncle on one end.

1.2 Reproduction

Bellyache bush plants are prolific seed producers. One adult plant can produce between 2000 and 12 000 seeds per year, depending on environmental conditions, plant biotype and the density of the infestation.

Plants typically begin producing seed in their second year. However, under ideal growing conditions, they can begin producing seed capsules in as little as 10 weeks from germination.

Bellyache bush also has the potential to flower and fruit year-round, although seed production peaks in the late wet season in most locations. The first flush of new leaves and flowers may begin before the first rains of the wet season, although rainfall events accelerate growth and seed production. Under high moisture conditions, such as infestations around dams, seed can be produced all year.

Seed bank studies indicate that most seed in the soil will expire within four years, although some may last six years or more under dry conditions. Mass seed germination usually occurs with the start of the wet season, but seedlings can emerge at any time of year if conditions are favourable. For example, in North Queensland any rainfall event greater than 25 mm can trigger germination. The density of seedlings can be very high, up to 300–400 per square metre. Not all seedlings will survive, however.

Bellyache bush will also regenerate vegetatively from stem cuttings or from whole removed plants. Dumped garden material, plants dislodged by flooding or discarded plant parts from control activities can all regrow. Pulled or cut plants left lying on the soil surface are capable of reshooting or regrowing roots several months later. Discarded plant off-cuts have also been recorded producing viable seed up to 12 months after cutting, even without reattaching to the soil.



Seedling density can reach 300–400 per square metre.



Cut plants can regrow roots.

How long does bellyache bush seed live?

The Tropical Weeds Research Centre in Charters Towers ran trials to see how long bellyache bush seed could survive in the soil.

The first trial involved burying fresh seeds at various depths. Seeds were buried under either natural or rain-sheltered conditions (to simulate dry periods), then dug up at regular intervals and tested for viability. The results showed that seed lasted longer under dry conditions, with a small

percentage still viable after 72 months (six years). Under natural rainfall, most seed germinated within the first 12 months and the seed bank expired within four years.

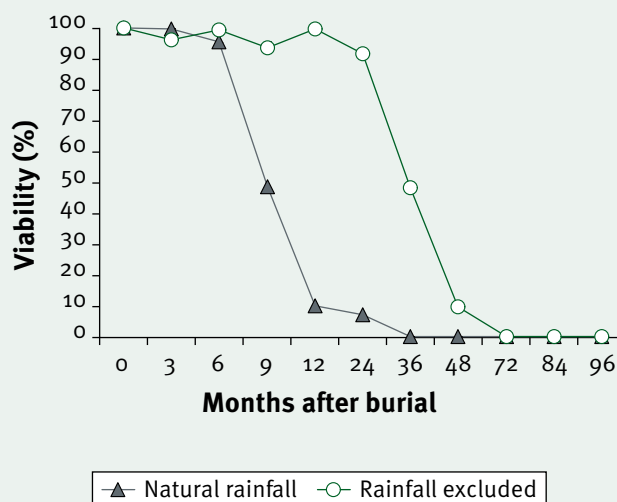


Figure 1: Bellyache bush seed viability.

Researchers also buried ant-discarded seeds collected from the middens of ant nests and found that a very small percentage was still viable after eight years. Why these seeds lasted longer than intact seeds is not clear.

A second trial examined natural depletion of the seed bank after complete removal of established bellyache bush infestations. Researchers removed all of the bellyache bush from two sites—one with rocky soil and one with heavy clay soil. Researchers then returned every month to remove any new seedlings. After four years, no more seedlings emerged from the heavy clay site, while it took five years for germination to cease at the rocky site.



Trials found a small proportion of seed can survive in the soil for longer than six years under dry conditions.

1.3 Dispersal

The dehiscent fruit capsules of bellyache bush mean that most seed is initially dispersed in a radial pattern around the parent plant. As many infestations are found in riparian areas, the most significant long-distance dispersal mechanism is water. Seeds and plants can be transported a considerable distance in floods. Once deposited along watercourses and floodplains they have an ideal growing environment.

Some ants—particularly meat ants (*Iridomyrmex spadius*)—appear to be local seed dispersal agents, collecting seeds and carrying them up to 40 m to their nests. Ants feed on the caruncles (nutrient-rich growths on the seed) and then discard the seeds. The ant nest—moist, friable and rich in nutrients—provides an ideal germination site for bellyache bush seeds. Seedlings can often be observed germinating in clumps from ant middens.

Other animals may disperse seeds over longer distances. For example, the male great bower bird (*Chlamydera nuchalis*) may decorate its bower with fruits of bellyache bush and, in doing so, disperses the seeds. Seeds may also be spread in mud, adhering to feral pigs, livestock or native animals.

Humans are deliberately or inadvertently responsible for long-distance dispersal. In the past, bellyache bush was deliberately transported as a garden plant. Dumped cuttings and garden material were probably the main source of early infestations. Seeds may also be accidentally transported as a contaminant of soil and sand or on vehicles and machinery.



Male bower birds may decorate their bowers with bellyache bush fruits, thus aiding seed dispersal.

Top and above: Native meat ants disperse seeds—their nests provide ideal conditions for germination.



Seedlings often germinate in clumps from ant nests.



Seedlings germinating in fresh alluvial deposits in a creek bed.



*Plants can even grow from flood debris caught in trees.
(Photo: J Meeson)*

1.4 Habitat

Bellyache bush is very hardy and well adapted to the seasonally wet/dry climate of our northern rangelands. Open woodland and grassland are readily invaded by bellyache bush, though it is especially suited to creek and river banks and floodplains. Periodic floods may help its spread by removing other plants and providing fresh alluvial deposits where bellyache bush can germinate without competition. Fires often fail to penetrate riparian areas, which may further benefit bellyache bush.

Although infestations often begin in riparian habitats, bellyache bush will expand onto non-alluvial soils and grow in upland areas. Bellyache bush is an opportunistic weed that thrives in disturbed areas. It will readily colonise areas of bare soil or where natural vegetation has been disturbed. It is often found in places such as mine sites, abandoned homesteads, refuse tips, roadsides and overgrazed pastures. The combined effect of drought and overgrazing can give bellyache bush an opportunity to invade.

Bellyache bush appears to tolerate a broad range of soil types. It thrives on sandy loam soils associated with watercourses and also seems to tolerate saline soils, growing down to the high tide mark in some locations near Darwin (Northern Territory) and Wyndham (Western Australia). Plants have been observed growing out of rock crevices in road cuttings near the Burdekin Falls Dam (Queensland).



Bellyache bush infestations often begin in riparian areas.



Bellyache bush can also invade disturbed areas in urban locations such as Castle Hill in Townsville.



Bellyache bush spreading out from a riparian habitat into pasture.



This tolerant weed grows down to the high tide mark on Channel Island, near Darwin. (Photo: NT Weed Management Branch)

1.5 Distinguishing bellyache bush from other plants

Bellyache bush belongs to the plant family Euphorbiaceae. There are no native *Jatropha* species in Australia, although there are several other introduced species such as physic nut (*J. curcas*).

Physic nut

Physic nut is an erect shrub, usually growing 2–4 metres in height. It has green leaves 15 cm across with 3–5 rounded lobes, heart-shaped or similar to ivy. Unlike bellyache bush, the leaf margins and stalks of physic nut lack gland-tipped hairs. Physic nut has small yellow-green flowers. The fruit is yellow when young, turning black when mature, and up to 4 cm in length. The fruit is much larger than bellyache bush fruit. Physic nut seeds are also black and measure 1.5–2 cm in length.

Like bellyache bush, physic nut was introduced into Australia over 100 years ago, probably also as an ornamental garden plant. It is currently found in Queensland, where it has become a minor weed, mainly in Cape York. It has formed small thickets in several areas but its impact is localised compared to bellyache bush.

In recent years, there has been interest in using the seed of physic nut for the commercial production of biodiesel in Australia. Physic nut is declared in Western Australia and the Northern Territory and, although it is not declared in Queensland, its control is recommended. New importations into Australia are prohibited by the Australian Quarantine and Inspection Service (AQIS).



Top and above: Physic nut (Jatropha curcas) leaves and fruit. (Photo: G Evans)

Castor oil plant

Bellyache bush is sometimes confused with castor oil plant (*Ricinus communis*), with both often found in similar areas. Although they are in the same family of plants, the two species are easily distinguished by the shape of their leaves. Castor oil plant has larger leaves with 7–9 pointed lobes (compared with 3–5 lobes for bellyache bush). The fruit of castor oil plant are also much larger (2.5 cm across) and covered with soft spines.



Top and above: Castor oil plant can be distinguished from bellyache bush by the leaves and fruit.



Castor oil plant leaves have 7–9 pointed lobes (top) compared with 3–5 lobes for bellyache bush (centre and bottom).



Section 2 Impacts



Impacts

2.1 History of spread

Bellyache bush is native to Central America. Its exact origin is uncertain, but possibly centres on the drier islands of the Caribbean and the Venezuelan coast. It has been introduced as an ornamental and medicinal plant to many other tropical countries where it has since become naturalised. The species' current range includes Australia, Africa, Asia and North and South America. Genetic studies suggest that there have been multiple introductions of bellyache bush into Australia from several different countries.

The plant was first introduced into northern Australia in the late 1800s. It was cultivated as a hardy garden ornamental, capable of growing well in poor soil and with little water.

By the 1920s, it had escaped, probably due to dumping of plants and cuttings, and became naturalised. The majority of infestations are found near old townships or homesteads, dumps, roadsides, overgrazed paddocks and the banks of watercourses.



Bellyache bush was introduced into Australia as a garden ornamental.

2.2 Current distribution

Bellyache bush is now widespread across northern Australia, especially along watercourses and associated floodplains.

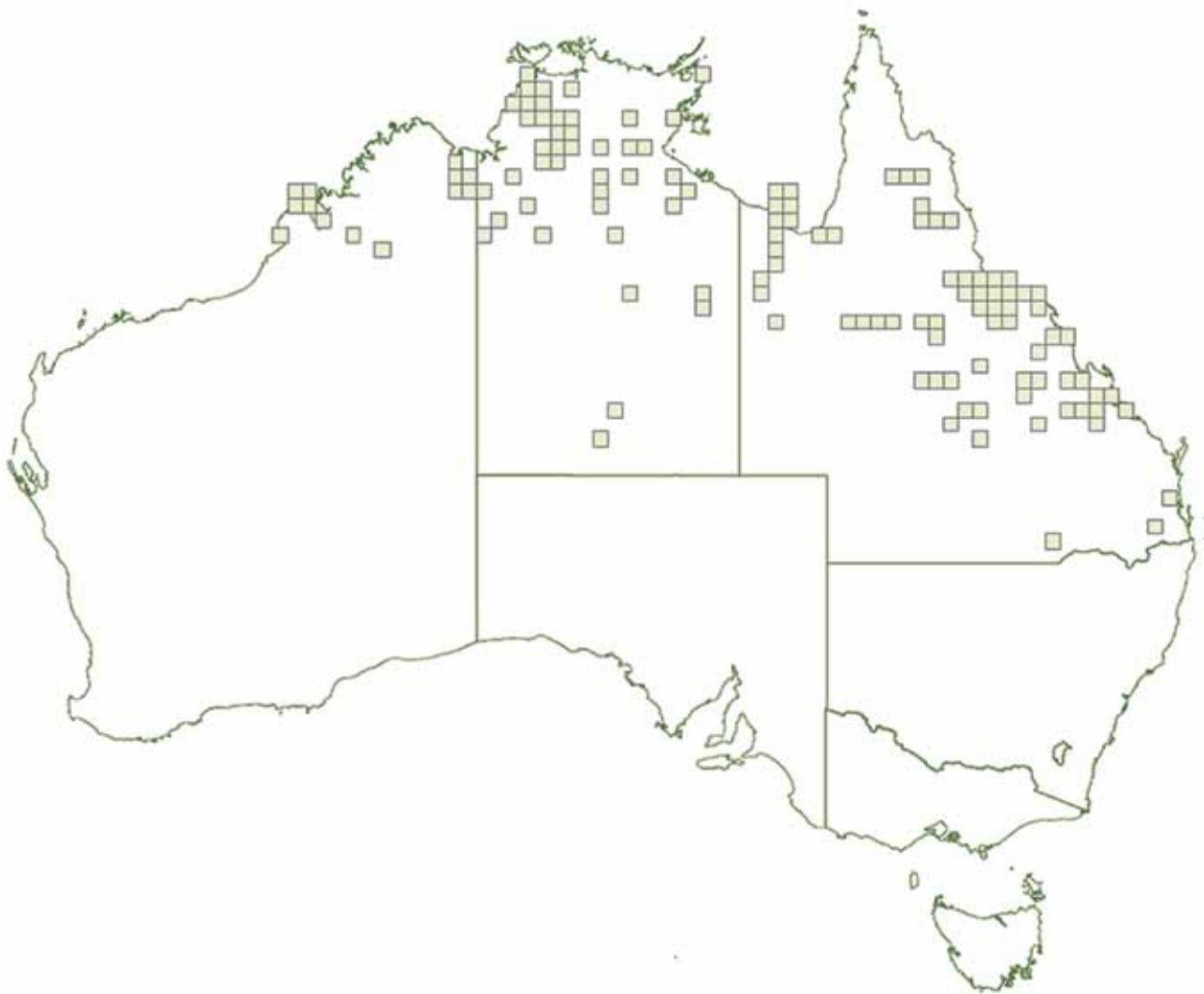
In Queensland, it is found in the Burdekin, Fitzroy, Walsh, Palmer, Flinders and Gregory River catchments, as well as the headwaters of Lake Eyre Basin. It is estimated that more than 40 000 ha are infested in the Burdekin catchment alone. Scattered infestations are also found in Central Queensland.

In the Northern Territory, bellyache bush is most prevalent in the Daly, McArthur, Roper and Victoria River catchments, the Gulf region and the Barkly Tableland. Infestations are also found in several coastal monsoonal areas, including the Darwin region.

Widespread populations exist in Western Australia's east Kimberley, with large infestations in the Lake Argyle catchment and the Halls Creek area. Smaller infestations occur in the west Kimberley around the towns of Derby and Broome and on the Fitzroy River. Bellyache bush also occurs in the Pilbara towns of Karratha and Port Hedland.



Riparian infestation on the Palmer River in Far North Queensland.



Current distribution of bellyache bush in Australia.

Digital data supplied by the states and territories with national collation through the National Land & Water Resources Audit (NLWRA). Projection and datum: Geographics, GDA94. Map produced by the Pest Information Group, Biosecurity Queensland, Department of Employment, Economic Development and Innovation. The information in this map is derived from the National Weeds Assessment 2006 dataset, developed as part of the joint NLWRA and the Australian Weeds Committee (AWC) – National Weed Assessment project, and has been produced solely for the internal use of the department. Whilst all care is taken in the preparation of this map, neither the department nor its officers or staff accept any responsibility for any loss or damage that may result from inaccuracy or omission in the map or from the use of the information contained therein. All rights reserved. No part of this map covered by copyright may be reproduced or copied in any form or by any means whatsoever without the written permission of the department.

2.3 Potential distribution

Bellyache bush is ideally suited to the seasonally wet/dry climate of Australia's tropical north. Most populations of the weed occur where the average annual rainfall is 400–1200 mm. The heaviest infestations occur in areas with 600–1000 mm of rain per year.

Its semi-deciduous nature and fleshy root system allow bellyache bush to tolerate very dry conditions; during drought this may give it a competitive advantage over many pasture species. Bellyache bush is not tolerant of frost, which may limit the southern extent of its distribution. It is possible that its range will extend further south if global warming shifts ecological latitudes southwards.

Bellyache bush is still in the relatively early stages of invasion, but it has the potential to infest much of our tropical savannas. The weed may invade new areas, and existing infestations have the potential to increase in size and density. Where some infestations currently exist only along watercourses, they may expand away from the watercourse onto drier, non-alluvial soils.

Infestations are capable of expanding rapidly. In one study conducted by Biosecurity Queensland researchers in North Queensland, an infestation expanded by 76% in three years, despite having only half the average rainfall over that period. In wetter areas the expansion can be even more dramatic. In the Northern Territory, one infestation grew in size by 146% in just one year.



Infestations can spread rapidly—the photo above was taken three years after the photo below left.

2.4 Economic impacts

The spread of bellyache bush can cause significant loss of productive grazing land, as the plant forms dense thickets where little grass can grow. As it is unpalatable to stock, it can proliferate at the expense of valuable pasture species. Productive river frontages and flats are often most at risk of invasion.

Areas of dense bellyache bush infestations along the Burdekin River frontage country in North Queensland now have a carrying capacity of zero. Before invasion, these pastures would have carried around 1AE (adult equivalent – 450 kg steer)/4 ha.

Bellyache bush is also highly toxic to animals and can have a direct economic impact on the pastoral industry through poisoning of livestock. Ingesting any part of the bellyache bush plant can cause gastrointestinal irritation and is potentially fatal. Cattle, horse and goat deaths have been reported in Queensland and the Northern Territory. Livestock tend to eat bellyache bush only during times of drought, when pasture is scarce and of low quality. They may also accidentally ingest seeds and dry leaves off the ground when trying to eat sparse dry grass or leaf litter.

The branched nature and sticky leaves mean that both animals and people find dense infestations difficult to penetrate. Mustering costs can be increased and fence lines obscured. Access to land for recreational activities, tourism and other uses may also be restricted.



Stands of bellyache bush allow little or no pasture to grow.



Bellyache bush can cause stock deaths during dry times.

2.5 Environmental impacts

Bellyache bush forms monocultures—large pure stands with little other vegetation. The shallow root system and dense canopy allow very few understorey plants to grow. It is difficult for new tree seedlings to establish and grow through the bellyache bush. Consequently, once mature trees in an infested area die, they will not be replaced. This causes a loss of biodiversity and reduces habitat available for native wildlife.

Bellyache bush can also harbour feral animals such as pigs. Native animals appear largely unable to use the plant except as shelter and may also be susceptible to poisoning. Unconfirmed cases of wallabies dying after eating the plant during drought have been reported. Some native insects also appear to be susceptible to the plant's toxins and may become immobilised by sticking to the glandular hairs.

Dense infestations can significantly alter fire regimes. Bellyache bush monocultures suppress the development of a grass fuel load and consequently do not readily burn. Bellyache bush can also increase soil erosion or destabilise creek and river banks due to its shallow root system and suppression of ground cover species.



Bellyache bush forms monocultures, which reduce biodiversity.



The sap appears to be toxic to some native insects.

2.6 Health impacts

Bellyache bush is toxic to humans. All parts of the plant are poisonous if ingested, particularly the seeds. Mild cases of poisoning can occur, for example, by failing to wash your hands after handling the plant.

Symptoms of poisoning include acute intestinal pain and a burning sensation in the throat about half an hour after eating, followed by nausea, vomiting and diarrhoea. In severe cases, poisoning can be fatal.

Cases of severe poisoning in humans have occurred, although no deaths have been recorded in Australia. Children are more susceptible, with as little as three seeds (contained in a single fruit) capable of killing a child. As the weed becomes more widespread it may pose more of a threat to children, who may find the fruit and seeds attractive.

The watery sap of bellyache bush can also cause acute dermatitis or skin irritation on contact, and it leaves permanent brown stains on garments.



Bellyache bush is toxic. To minimise health risks, always wear gloves when handling bellyache bush.



The fruits may appear attractive but contain poisonous seeds.



Bellyache bush sap can cause dermatitis.

2.7 Legal status

Bellyache bush is a declared weed in Queensland, the Northern Territory and Western Australia.

Queensland

In Queensland, it is a Class 2 declared plant under the Land Protection (*Pest and Stock Route Management*) Act 2002. This means it is recognised as widespread, but due to its serious impacts it should be controlled to limit further spread. Landholders are required by law to try to keep their land free of bellyache bush. It is also an offence to keep or sell the plant.

Northern Territory

Bellyache bush is declared a Class B weed (growth and spread to be controlled) and Class C weed (not to be introduced to the Northern Territory) in the Northern Territory under the *Weeds Management Act 2001*. This means that landholders must make reasonable attempts to control the growth and spread of bellyache bush and prevent further introduction to the Northern Territory.

At the time of writing, the declaration status of bellyache bush in the Northern Territory is under review. A proposal is being made to change isolated infestations to Class A (targeted for eradication), with more established sites retaining their current Class B status.

Western Australia

In Western Australia, bellyache bush is declared at two levels under the *Agriculture and Related Resources Protection Act 1976*. It is classified as a P1 weed across the whole state, which prohibits the movement of plants and seeds within the state, including contaminated machinery and produce.

The weed then has an additional declaration depending on location. In the southern part of the state (south of the 26th parallel), bellyache bush is also a P2 declared weed, meaning any infestations must be eradicated. The infestation must be treated to destroy existing plants and prevent propagation each year until no plants remain. Again, the spread of seed or plant parts must also be prevented.

North of the 26th parallel, where widespread infestations already occur, bellyache bush is declared a P4 pest. This aims to prevent the infestation spreading beyond its existing boundaries. The spread of seeds and plant parts must be prevented both within and from the property.



Section 3 Managing bellyache bush



Managing bellyache bush

3.1 Weed management

Effective weed management involves minimising the risk of new infestations and reducing the impact of current weed problems.

3.1.1 Prevention

The most cost-effective way of dealing with any weed is to prevent its introduction. Stopping the spread of bellyache bush into clean areas should be a management priority. By identifying the most likely means of spread to and within a property, the risk of new infestations can be minimised.

A single transported seed has the potential to begin a bellyache bush infestation. Ensure that all roads and tracks on your land are free of bellyache bush. Clean any vehicles, weed control equipment and machinery that have been in bellyache bush infested areas. Avoid moving contaminated material (particularly soil or sand) into areas free of bellyache bush.



Bellyache bush along roads and tracks can be a source of seed spread.

3.1.2 Early detection

Early detection of new infestations is vital. A small, new infestation is easier and cheaper to control than a large, old population where a massive soil seed bank may already be in place.

Water is one of the main dispersal mechanisms for bellyache bush. Flowing water can carry bellyache bush seed and plant parts downstream. Flood events through a bellyache bush infestation can also carry seed and plant parts to the extremities of the flooded area. These seeds and plant parts, when deposited, are in an ideal environment for

germination and reshooting. Such areas should be checked periodically for bellyache bush and any plants found controlled before they set seed.

The ballistic seed dispersal of bellyache bush means that seeds are generally deposited in a radial pattern around the parent plant. Small, isolated patches can therefore increase in size rapidly and should be treated as early as possible.

There is also a risk that some native, domestic and/or feral animals could potentially spread bellyache bush away from main infestations. This is most likely to occur through mud (containing bellyache bush seeds) sticking to parts of the animal's body. Land managers should always be on the lookout for outlying plants and treat them immediately.

Treating small patches is not that difficult as hand removal is an effective option. However, ensure that the plant material is disposed of in a manner that prevents re-establishment (e.g. burn or hang plants in trees). It is also important to note the location so that you can return to kill any seedlings that may emerge in the future.

When conducting any routine management activities, such as mustering, fencing and checking waters, develop a habit of looking for weeds such as bellyache bush. Also ensure that all employees and contractors working on the property are able to identify bellyache bush as this will increase the likelihood of plants being found (if present) on your land.



Flowing water is a major dispersal mechanism for bellyache bush—it can spread rapidly through river systems.

3.1.3 Managing bellyache bush

When dealing with an established infestation, decide whether the objective is to eradicate, control, contain or monitor the infestation. This will depend on the size or density of the infestation, ease of control and resources available.

Eradicating bellyache bush from an area requires commitment, as the plant can reach reproductive maturity quickly under favourable conditions and a small portion of the seed bank can persist for several years (refer to section 1.2 'Reproduction'). Nevertheless, researchers and land managers have proven that large, established infestations of bellyache bush can be controlled. Most effort is needed in the first couple of years to treat the initial infestation and subsequent seedling regrowth. Generally, the majority of seedlings will emerge during the first few wet seasons following control activities, with numbers declining rapidly thereafter.

To cover all potential scenarios, a long-term management strategy is needed to treat seedlings that may emerge while a viable seed bank remains. With several years of follow-up, the problem can be resolved.

3.2 Developing a weed control plan

Any weed control program needs to be carefully planned to achieve the best possible results with minimum cost and effort. Your control program should span at least five years and be updated annually. It needs to be flexible enough to allow for changes, such as drought or fluctuating costs, or to take advantage of opportunities that may occur. For your plan to be effective you need to commit to it and see it through to the end.

The suggested steps for developing a control plan are outlined in the following sections. The focus here is on developing a control program for bellyache bush, but the principles are the same for other weeds. All weeds for a property should be included in the same plan and should be integrated into an overall property management plan.

You may want to consider relevant local government, catchment or regional priorities and plans and how your plan fits with these. There may also be potential to co-ordinate control programs with your neighbours.

Planning can seem a daunting experience if the bellyache bush problem is large or if you lack

experience in weed management. If it is difficult to begin the planning process, start on a smaller (patch or paddock) scale or seek help.

Your local government or relevant state/territory department can help you with the planning process and provide advice on which control methods to choose. (Contact information is listed in section 7.1 'Weed contacts'.)

For help developing a weed control plan for your property, you can also access the OnePlan pest management planning module via the DEEDI website. Visit www.deedi.qld.gov.au and search on 'OnePlan'.

In most states and territories, tree-clearing permits will need to be considered if there is a risk that native vegetation may be affected by control techniques (refer to section 7.2 'Vegetation management'). Make sure you allow sufficient time to acquire any necessary permits as they can take several months to go through the approval process.

You may also need permits to conduct control burns or use off-label herbicides (refer to section 7.3 'Off-label permits and variations').

3.2.1 Identify problem areas

The first step is to identify the extent of the bellyache bush problem on your property. A good way to do this is using a property map—this could be an aerial photograph, satellite image or hand-drawn map. The map should be as accurate and current as practically possible, as this allows more precise estimates of control costs and makes it easier to track the long-term effectiveness of your control program.

On the map, mark natural features and improvements such as:

- property boundaries
- fences, sheds, yards and stock routes
- roads and tracks
- dams, drainage lines and stock watering points
- terrain, soil type and areas of natural vegetation
- land use, pasture type and quality
- features outside your property, such as seed sources on neighbouring land.

Then mark areas of bellyache bush and other weeds, noting the size and density of each infestation. It may be useful to make separate transparent overlays for the different features marked. There are many computer-based mapping packages available that can be used to develop property maps and insert multiple overlays, including weed distribution.

3.2.2 Prioritise areas for control

Once all the weed areas are marked, prioritise the areas for control, including:

- *isolated or outlying infestations*. Treating these areas can help slow the weed's spread. The infestation could be considered outlying at a number of scales, from paddock to catchment.
- *infestations that are small or easy to treat*. Start with the smallest areas and gradually work towards denser infestations. Work on upstream infestations first.
- *significant seed sources or areas with a high probability of spread*. Infestations in riparian habitats are likely to produce large quantities of seed which are easily spread by water. Work 'top-to-bottom' in catchments or sloping areas.
- *infestations in high value or vulnerable areas*. These could be areas of high pastoral production or valuable wildlife habitat, such as river frontage.

Also consider your legal and ethical responsibilities, such as threats to neighbouring properties.

It is important not to take on too much at once. Don't try to treat more in the first year than you have the resources to follow-up in coming years or you risk making the problem worse. Divide the infestation into smaller, more workable areas.



In a carefully planned weed management program, isolated patches will be treated first.

3.2.3 Determine control options

Consider the most appropriate control method for each situation (refer to section 4 'Control methods'). Determine the methods required for both initial and follow-up control. Usually a combination of methods is required. If other weeds are present this may influence your choice of control methods so that all weeds can all be treated effectively.

Implementing the correct strategies from the beginning will likely reduce future control costs. If necessary, seek advice from local government or departmental weed officers about which control methods to use. Alternatively, conduct small scale trials of your chosen control methods.

Also take into account the effect of your chosen control methods on the soil and other plants once bellyache bush has been killed. Consider ways of minimising environmental damage and making the area more resilient to reinvasion.



Identify the resources available before deciding which control method to use.

3.2.4 Develop a financial plan

Cost is often a major factor in deciding which control methods to use. Estimate the costs of different control options for each priority. Also consider future costs—the amount of ongoing control required is often underestimated. Note that if follow-up control is not implemented the initial costs and labour input will be wasted.

Identify the resources that are already available or affordable (such as spray equipment, machinery and labour), as this may indicate which methods will be the most economical. Consider working

bees or ‘barter days’ with neighbours where possible. In some areas Landcare, regional natural resource management (NRM) groups or local governments have spray equipment for hire or loan.

Check to see if there are any financial incentives available to assist with control programs, then integrate control costs into short-term and long-term property budgets.



If using machinery, be sure to include hourly running costs in your weed control budget. (Photo: M Vitelli)

3.2.5 Schedule activities

Weed control must be a regular part of property management and needs to be included in the yearly schedule.

Scheduling control activities at the optimum time can ensure the best kill rate and therefore most economical use of resources. Consider the effectiveness of control methods at different times of year and balance this with time and labour available for weed control. For example, spraying of herbicides is most effective against bellyache bush during the active growing season (i.e. the wetter summer months).

Schedule all weed control activities for the coming year, specifying what is going to be done, where and when. All weed management activities need to be included—initial control, follow-up and monitoring. If possible, incorporate other property management activities, such as routine burning. Make sure you build some degree of flexibility into your plan to accommodate unforeseen circumstances, such as floods and prolonged droughts.



Schedule follow-up control before plants set seed. (Photo: J Fisher)

3.2.6 Monitor progress

Monitoring is often the most neglected area of weed management, yet it is a vital part of any control program. Monitoring previously treated areas can:

- identify areas of regrowth or seedling emergence where follow-up is required
- show changes in pasture condition, carrying capacity or regeneration of native vegetation
- help assess the effectiveness of different methods to improve future control work.

For effective monitoring, you need starting data (gathered before control work begins), as well as progressive data (gathered during the program).

Using photo points is a simple and effective way of monitoring and is more reliable than memory. Take photographs from the same point over time to record changes. Be sure to take some photographs at the same time each year to make suitable comparisons.

You could also measure changes in bellyache bush density, pasture composition and yield or movement of infestation boundaries.

It is also important to document the control costs and resources used. It may be helpful to keep a diary of control works as they happen.

‘At-risk’ areas also need to be regularly inspected for new outbreaks. Monitor newly disturbed areas (e.g. those affected by fire, flood, heavy grazing or earthworks), as well as areas near seed sources (e.g. downstream from current infestations). Your property map can be used as a baseline to mark treated areas and any new infestations as they are detected.



Top to bottom: Photo points will help monitor the progress of your control program. (Photos: J Meeson)

3.2.7 Follow-up

Follow-up control is a crucial part of managing bellyache bush. Although most control methods give high kill rates initially, large scale seedling recruitment generally occurs after the next rain, especially where the soil is disturbed. As such, a single treatment without any follow-up is likely to worsen your weed problem.

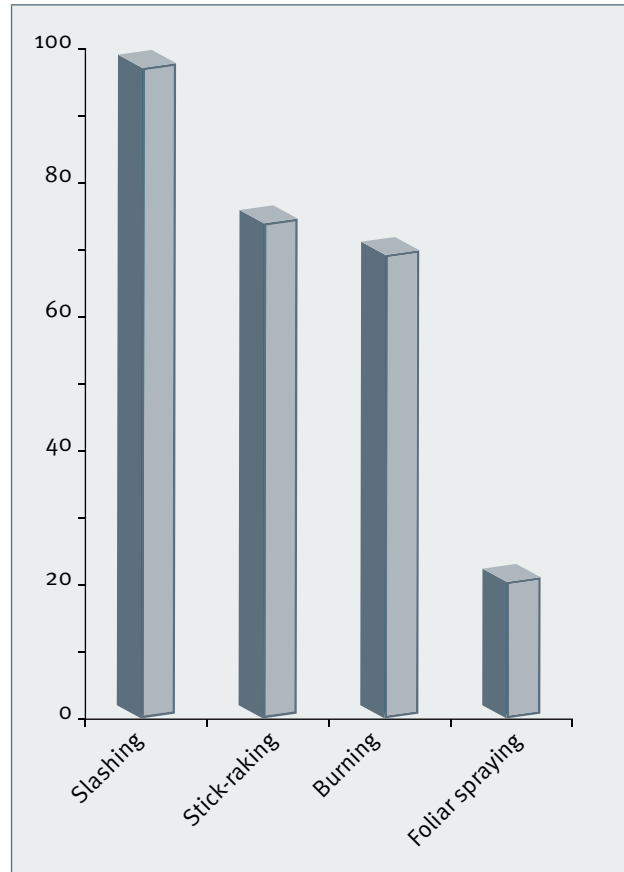


Figure 2: Number of seedlings recruited for each plant killed.

A research trial found that for every adult plant killed, between 20 and 97 seedlings took its place, depending on the control method used.

Plants that survive the initial treatment, along with any new seedlings, must be controlled before they set seed. If you do not do this, the time and resources spent on your initial effort are wasted.

How regularly you will need to monitor and re-treat areas will vary depending on habitat, prevailing environmental conditions and the amount of competition being imposed by other plants, particularly grasses. Plants growing under ideal climatic conditions in bare areas can set seed

within 10 weeks, necessitating follow-up control every 2–3 months.

Follow-up timeframes may be lengthened to greater than 12 months where bellyache bush is growing in competitive pastures (refer to section 4.2 ‘Pasture management and competition’ for further details) and/or during relatively dry periods.

A study was undertaken in northern Queensland by Biosecurity Queensland researchers to find how quickly bellyache bush could become reproductive when growing in three different habitats. On average, new bellyache bush plants produced fruits within 92, 311 and 468 days when growing in bare areas, a rocky area and improved pasture, respectively.

When follow-up control is implemented, there will generally be a large reduction in the soil seed bank after the first year, associated with mass germination during the wet season. Thereafter, there will be a gradual reduction in seedling recruitment as the soil seed bank is depleted. However, studies have shown that seedlings can continue to emerge for up to five years after removal of all seeding plants and that some seed can remain viable for six years or more under prolonged dry conditions.

It is vitally important to plan, budget for and implement follow-up control for several years, otherwise your bellyache bush problem—despite initial control efforts—may worsen.



*Follow-up control is vital to treat seedling growth.
(Photo: M Fuller)*



A single treatment without follow-up may worsen your weed problem, due to high seedling recruitment.

3.2.8 Evaluate progress and review plan

Review your weed control plan annually to improve the efficiency of future control work.

Assess whether control works were implemented as planned and whether they achieved their targets. Use the information collected from monitoring to see which methods worked and where additional resources might be required. Also examine whether costs came in under or over budget. Incorporate any necessary changes into your plan for coming years.



Section 4 Control methods



Control methods

Bellyache bush can be controlled. There are a number of control options to choose from, including the use of herbicides, machinery, fire and pasture management. No single method will be suitable for all situations. Many situations require a combination of methods (integrated management) to achieve complete control.

Land managers generally learn through experience when it comes to weed control by trialling various methods and assessing the results in their particular situations. As such, the objective of the following sections is to provide information on the various control methods that will allow informed decisions to be made on which control activities may be most suitable for particular situations.



The size and density of the infestation will influence the control method you select.

4.1 Herbicide control

Herbicides are a useful tool in the management of bellyache bush. The choice of appropriate application method, herbicide, rate and timing of application are all essential in determining the success of chemical control. As with any method, follow-up control is vital. If a heavy infestation is sprayed, then ignored, it can actually worsen the problem.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) regulate the use of herbicides. Herbicides must be sold with approved labels listing the situations, application methods and rates registered for that herbicide for each state or territory. Users can check current product registrations using either the APVMA website or the Infopest database produced by the Department of Employment, Economic Development and Innovation (refer to section 7.3 'Off-label permits and variations'). In some circumstances, specific permits, known as off-label or minor-use permits, may be issued for the use of herbicides in situations other than those specified on the label.

Measures must be taken to ensure the safety of users and the broader environment, as there are risks associated with any use and handling of herbicides. The approved labels also provide safety information for the use, storage and disposal of the herbicide and container. Material Safety Data Sheets (MSDS) containing further information are also available for each herbicide and should be on hand whenever you use the herbicide.

Prior to using herbicides, carefully read and follow all label instructions and ensure personal protective equipment is worn. Always use herbicides in accordance with state/territory and/or local government native vegetation legislation.



Bellyache bush after spraying.

4.1.1 Foliar spraying

Foliar spraying is the application of herbicide to the foliage and stems of plants using various types of spray equipment. The herbicide is usually diluted in water and an adjuvant (wetting agent) may be required. Studies have shown that foliar applied herbicides can achieve 95–100% mortality of bellyache bush plants—including mature plants. The herbicide must be applied to the point of run-off, so that leaves are thoroughly wet. Best results are achieved if the herbicide is applied while plants are actively growing and in full leaf, preferably before flowering and fruiting.

Selective foliar spraying is one of the most effective treatments for bellyache bush control, as it allows the maintenance of grass cover for competition. There is potential for off-target damage, particularly for plants susceptible to the herbicides used (such as legumes, forbs, tree seedlings and small shrubs).

Spray equipment can vary from a simple garden or backpack sprayer to boom sprays. In many situations, a quad bike or vehicle-mounted spray unit with extension hoses will be appropriate. Hand-held equipment may be feasible for scattered plants growing in situations where the operator can move through the infestation.

There are two herbicides currently registered for control of bellyache bush using on-ground spray equipment—metsulfuron-methyl and fluroxypyr. Both are produced by several companies and sold under various trade names. Fluroxypyr is also available at different concentrations, each having its own specific application rate. Registration information is shown in Table 1.

Fluroxypyr and metsulfuron-methyl are selective herbicides, meaning they generally do not affect surrounding grass. Note that it may take 4–6 weeks or longer before symptoms from using metsulfuron-methyl are seen; symptoms from using fluroxypyr will show within a few days.

It is essential to use an adjuvant (wetting agent) with metsulfuron-methyl for controlling bellyache bush. The recommended wetting agent, as specified on the product label, must be used to achieve the best results. All herbicides must also be used at the recommended rate to minimise off-target damage.

At the recommended rate, metsulfuron-methyl has some residual effect, suppressing the growth of bellyache bush seedlings for 1–2 months. It will also suppress the growth of other susceptible plants (such as legumes, shrubs and tree seedlings). Fluroxypyr has no residual effect.

Foliar spraying

- Can kill 95–100% of bellyache bush plants.
- Selective herbicides allow grass to remain and compete with bellyache bush seedlings.
- Four consecutive years of foliar spraying have controlled established bellyache bush infestations.
- Registered herbicides are metsulfuron-methyl and fluroxypyr.



Spot spraying isolated plants.



Foliar sprays should be applied when plants are actively growing.

Table 1a: Registration details for metsulfuron-methyl for bellyache bush control in Australia (adapted from Infopest, November 2009, Department of Employment, Economic Development and Innovation, Brisbane). Always read and follow all herbicide label instructions. Registration details may change over time.

Formulation	Registered trade names	Application rate	Situation	Registered states/territories	Cost of herbicide only*
Metsulfuron-methyl (600 g/kg)	Accurate® 600 WG	10 g/100 L + penetrant	Land—commercial/industrial/public	Qld	\$0.90–1.45 for 100 L of spray mix
	ARM Metsulfuron		Pastures—native		
	AW Militia 600 WG		Rights of way		
	ChemAg Metsulfuron WG				
	Conquest Metsulfuron 600 WG				
	DuPont™ Brush-Off® Brush Controller				
	Genfarm Metsulfuron 600 WG				
	Innova® Metsulfuron 600				
	Ken-Met 600 Water Dispersible Granule				
	Macspred® Metmac™ 600 WG				
	Metsun 600				
	Nufarm Associate®				
	Two-Way 600 WG				
	United Farmers Metsulfuron WG				
	WSD Metsulfuron				
Metsulfuron-methyl (600 g/kg)	Chemforce Metsulfuron 600 WG	10 g/100 L + penetrant	Land—commercial/industrial/public	All	
	eChem Metsulfuron-methyl WG		Pastures—native		
	Ospray Metsulfuron 600 WG		Rights of way		
	Rygel Metsulfuron 600 WG				
Metsulfuron-methyl (600 g/kg)	Farmoz Lynx® WG	10 g/100 L + penetrant	Land – commercial/industrial/public	Qld, WA	
	Titan Metsulfuron 600 WG		Pastures Rights of way		
Metsulfuron-methyl (600 g/kg)	Generex Metsulfuron	10 g/100 L + penetrant	Land – commercial/industrial/public	Qld	
	Ozchem Woody Weed Spray		Pastures		
	Parti-San 600		Rights of way		
	RainbowGreen Metsulfuron Brush Control				
	United Farmers Metsulfuron Methyl 600				

*Costs are approximate only and based on largest commercial size available September 2009. Prices may vary considerably between trade names and region where purchased.

Table 1b: Registration details for fluroxypyr for bellyache bush control in Australia (adapted from Infopest, November 2009, Department of Employment, Economic Development and Innovation, Brisbane). Always read and follow all herbicide label instructions. Registration details may change over time.

Formulation	Registered trade names	Application rate	Situation*	Registered states/territories	Cost of herbicide only**
Fluroxypyr (200 g/L)	Acclaim® Conquest Neon 200 eChem Staroxy 200 Farmoz Flagship® 200 Genfarm Fluroxypyr 200 Innova® Fluroxypyr 200 Kenso Agcare Fluroken 200 Nufarm Comet® 200 Ospray Fluroxypyr 200 EC ProStar Restrained* 200 Titan Fluroxypyr 200 EC Uni-Rane® 200	500 mL/100 L	Agricultural land—non-crop Forests—timber production Land—commercial/industrial/public Pastures Rights of way	Qld, NSW, WA	\$7.85-10.60 for 100 L of spray mix
Fluroxypyr (333 g/L)	Starane™ Advanced	300 mL/100 L	Agricultural land—non-crop Forests—timber production Land—commercial/industrial/public Pastures Rights of way	All	\$8.00 for 100 L of spray mix
		0.6-1.8 L/ha (pre/post plant) or 0.3 L/100 L	Forests—softwood production		
Fluroxypyr (400 g/L)	Decoy 400 Nufarm Comet® 400	250 mL/100 L	Agricultural land—non-crop Forests—timber production Land—commercial/industrial/public Pastures Rights of way	Qld, NSW, WA	\$10.30-11.00 for 100 L of spray mix

*Withholding period for grazing/cutting for stock = 7 days; no withholding period for forests/timber or softwood production.

**Costs are approximate only and based on largest commercial size available September 2009. Prices may vary considerably between trade names and region where purchased.

4.1.2 Aerial spraying

Aerial spraying may be an option for large, dense infestations or in areas of limited access and rugged terrain where on-ground methods may be difficult to apply. There is a possibility of off-target damage to native vegetation and a permit may be required (refer to section 7.2 'Vegetation management').

Aerial spraying will be impractical in some locations with high tree cover, especially along watercourses. Studies into aerial application have shown that high kill rates can be achieved in open areas, but mortality of bellyache bush decreases substantially with increasing tree cover.

It is easy to cover large areas when aerial spraying but unless there is a commitment to follow-up all treated areas, the initial investment will be wasted. Massive recruitment of bellyache bush may occur after aerial application and needs to be taken into account.

There are currently no herbicides fully registered for aerial control of bellyache bush. If it is considered, an off-label permit may be required and discussion with the APVMA or a local weed officer will be necessary. In the Northern Territory, aerial spraying may be permitted if it complies with conditions outlined in the *Agricultural and Veterinary Chemical (Control of Use) Act 2004* (refer to section 7.3 'Off-label permits and variations' for specific details).

Aerial spraying

- Effective provided there is minimal tree cover.
- Can cover large areas, but will worsen the problem without follow-up.
- May require a vegetation management permit (refer to section 7.2 'Vegetation management').
- An off-label permit will generally be required, as no herbicides are fully registered for this application method.



Aerial spraying may be an option in inaccessible areas. (Photo: T Meldrum)

4.1.3 Cut stump and basal bark treatments

Basal bark treatment refers to spraying the full circumference of the stem from ground level up to a height of 20 cm (higher on larger plants). The stem needs to be fairly dry and free of dust and mud for the herbicide to be effective.

The cut stump method involves cutting the bellyache bush stem horizontally as close to the ground as possible using secateurs, loppers, saws or brush-cutters. The herbicide is then applied to the entire cut surface immediately. If not applied within 10 seconds, the plant's cells can close up and prevent the herbicide from entering, and the plant may regenerate. The cut stump method also requires disposal of the plant, as cut sections can regrow or produce seed up to 12 months after being cut. Drying and then burning plants may be the best option.

Both cut stump and basal bark techniques can produce good kills of bellyache bush. These methods are highly selective. There is less chance of damage to native plants, making these treatments useful near watercourses or in sensitive areas where spray drift is an issue. They are also effective at any time of year. However, they are quite labour-intensive and are probably only feasible for relatively small areas where operators can easily move through the infestation or where plants are too large to be pulled out by hand.

There are no fully registered herbicides for cut stump or basal bark application for bellyache bush in Australia. Individuals/organisations wishing to use these techniques in particular areas would

need to obtain minor use permits. Some users in Queensland and Western Australia only may be covered by off-label permits for control of environmental weeds (refer to section 7.3 'Off-label permits and variations'). Users will need to consult the permit conditions and seek advice from their local weed officer. In the Northern Territory, cut stump or basal barking may be permitted if it complies with conditions outlined in the *Agricultural and Veterinary Chemical (Control of Use) Act 2004* (refer to section 7.3 'Off-label permits and variations' for specific details).

Cut stump and basal bark treatments

- Labour-intensive but highly selective.
- Cut sections can produce seed or regrow for up to 12 months after being cut.
- No fully registered herbicides, but current off-label permits may apply in some situations.

4.2 Mechanical control

Mechanical control methods may be suitable for large, dense infestations. These methods can reduce the biomass of infestations and improve access for follow-up control. They can be quick and relatively cost effective, but intensive follow-up treatment is required since seedling regrowth may be massive due to physical disturbance of the soil.

Promoting seedling emergence can be advantageous by helping deplete the seed bank more quickly, provided regrowth is controlled before it matures and replenishes soil seed reserves. Conversely, equipment that promotes seed burial will lengthen seed longevity.

It is important to only treat areas small enough to be immediately and regularly monitored and followed up with appropriate control measures or the problem will likely worsen.

Use of heavy machinery is not suitable for heavily timbered areas. In most states and territories, permits will be required if native vegetation is likely to be damaged during control operations. Contact your relevant authority (refer to section 7.2 'Vegetation management').

Make sure seeds and plant parts are not spread on machinery. Thoroughly wash down *all* machinery and vehicles used in control activities before moving to other areas.



Mechanical control methods that disturb the soil, such as stick-raking, can cause massive seedling emergence.



Seeds and plant parts can be easily spread by machinery used in control activities.

4.2.1 Stick-raking

Stick-raking can directly kill plants and clean up infested areas, establish firebreaks or provide access so other control methods can be implemented. It can also provide a good seedbed for sowing pastures to compete with weed seedlings.

Stick-raking has been found to cause greater than 90% mortality of bellyache bush, with mostly smaller plants surviving. However, as it bares the soil surface, it will generally result in massive recruitment of seedlings. One study showed that for every bellyache bush plant killed by stick-raking, 74 plants were recruited from the seed bank. As in all control methods, timely follow-up control is essential to kill surviving plants and seedlings before they set seed.



Top and above: Stick-raking can clear dense infestations but disturbs soil and removes competitive grasses.

Stick-raking

- Can clear large, dense infestations and open up areas for follow-up control.
- Expect large scale seedling recruitment.

4.2.2 Slashing and mulching

Slashing is restricted to flat, open woodland areas away from watercourses where equipment can be manoeuvred between trees. The ground also needs to be clear of any debris, so it may be more appropriate as a secondary treatment after logs or other obstacles have been removed by other control methods (such as stick-raking). Heavy-duty mulchers are more robust than slashers and can handle some woody debris on the ground.

The use of heavy-duty slashers or mulchers will kill most mature bellyache bush plants, though seedlings and small plants may survive. Plants must be cut as close to ground level as possible when they are actively growing, during or soon after the wet season. Cutting during the growing season minimises reshooting. In the dry season, many plants may survive cutting, especially when cut higher above the ground. The cut tops are also more likely to reshoot.

Studies suggest that slashing has one of the highest rates of seedling recruitment of any control method (refer to section 3.2.7 'Follow-up'), so intensive follow-up treatment is needed. Repeated slashing can be a useful method to achieve temporary suppression of seed production. It can make follow-up with other methods easier and may increase the efficacy of fire once the slashed material has dried.

As with any equipment, weed seed spread from infested areas to other paddocks or properties is a concern. The addition of a blower on a slasher could reduce weed seed spread by up to 99%. Remember to check and clean all equipment when moving machinery out of a weed-infested area.



Slashing during the growing season is an effective way of killing mature plants.



Heavy-duty mulchers can clear dense areas.

Slashing and mulching

- Can kill up to 100% of mature plants.
- Should be performed in active growing season for best results.
- Very high seedling recruitment requires intensive follow-up.
- Most suitable in flat areas of open vegetation.
- Mulchers may reduce reshooting from cut plants.



Mulched bellyache bush plants. (Photo: A Northey)



Blowers mounted on slashers can help reduce weed seed spread.

4.2.3 Cultivation

Cultivation or ploughing may be appropriate in arable lands where fodder cropping is an option or for preparation of land prior to sowing of pasture.

Dozer-drawn, heavy offset, disc ploughs fitted with drum seeders can be used between trees in uncleared land to knock down bellyache bush and sow pasture seeds that, once established, will provide competition for emerging seedlings. However, the use of cultivation or ploughing as a control option is likely to be limited to specific situations and would need to be repeated several times or used in conjunction with other techniques (such as herbicides) to control seedling regrowth.

Cultivation

- May be appropriate in arable lands.
- Seeding with sown pasture at the same time will provide competition for bellyache bush.
- Follow-up control will be necessary.

4.3 Hand removal

4.3.1 Hand-pulling or digging

Bellyache bush has a shallow root system, so it can be easily removed by hand, especially if the soil is moist. Larger plants can be dug out or hoed if necessary.

Hand-pulling is very effective, since the whole plant is removed with minimal soil disturbance. However, if left lying on the ground, pulled plants can reattach to the soil and regrow or even produce seed up to a year after pulling. One way around this is to pile the removed plants and burn them once dried.

Hand-pulling is suitable for small patches and isolated plants or for removing seedling regrowth during follow-up treatment. It may also be useful in extremely sensitive areas (such as vine thickets). However, hand-pulling is not feasible for large or widespread infestations and may be difficult with very large plants.

Hand-pulling

- Bellyache bush is easily hand-pulled due to shallow roots.
- Good technique for follow-up in small areas.
- Pulled plants can stay alive and regrow many months later.



The shallow root system of bellyache bush means you can easily remove small plants by hand.



Hand-pulling may be suitable for small patches or isolated plants.

4.3.2 Cutting

Cutting plants close to ground level during the growing season can kill adult bellyache bush plants. Some plants may reshoot from the base, especially if cut during the dry season or when cut higher above the ground. The cut tops are also able to reshoot, regrow roots or produce viable seed, so they should be gathered and burnt or hung where they are not in contact with the ground (e.g. in trees or on fences).

Cutting using a brush-cutter or hand tools may be useful for relatively small infestations, environmentally sensitive areas or places where access with machinery and vehicles is difficult.

Cutting

- Cut bellyache bush low to the ground during the growing season for best results.
- Useful for small patches or where vehicle and machinery access is difficult.



Cut plants may reshoot from the base.

4.4 Fire

4.4.1 Controlled burns

Bellyache bush is sensitive to fire, and fire can be an effective tool provided there is enough fuel. Young plants tend to be more susceptible than mature plants. Bellyache bush stems will blister but they do not usually ignite, so there needs to be enough grass or other vegetation to carry a fire. In dense thickets of bellyache bush where the fuel load is suppressed, fire may fail to reach sufficient intensity to kill plants.

There may also be significant variation in the effectiveness of fire across a site due largely to variability in fuel loads. Even with good fuel loads and ideal conditions for burning, successive burns may be required before most of the original plants are killed.

Controlled burning may be especially effective for isolated or scattered plants within established pastures. It can be used as a means of slowing spread, by killing scattered plants at the edge of a dense infestation and preventing them encroaching further into pastures. Controlled burning can also be useful as a follow-up treatment once the infestation has thinned out and grasses have returned.

Up-front costs of using fire as a management tool may be minimal. However, burning may mean losing valuable pasture. There are also costs involved with excluding stock before a burn and establishing fire breaks. In dry areas, a sufficient grass fuel load may only be possible after several years of above average rainfall.

Bellyache bush seeds are susceptible to fire, but burning will not kill all seed in the soil. In field trials, fire killed all seed on the ground surface below a fuel layer, but more than 80% survived on bare ground or at 2 cm or more below the surface. Studies also show that most seeds are found 1–5 cm below ground, so many seeds are buried beyond the reach of lethal temperatures. Most of the seed bank will usually survive, resulting in large scale seedling recruitment in the following wet season. Fire could exacerbate the problem if not followed up.

Fire may not be appropriate in sensitive areas—like riparian zones—but is suitable for adjoining frontage country, which is most at risk from

bellyache bush invasion. Fire can also pose risks to people, property and wildlife, so precautionary measures must be taken and adequate resources made available to control the fire. Appropriate approvals should be obtained from relevant local authorities before conducting controlled burns.

Fire

- Bellyache bush generally won't burn, so a grass fuel load is needed.
- High mortality of bellyache bush plants will occur if burnt.
- Juvenile plants are most susceptible.
- Fire will kill some seeds, but many survive.
- High seedling recruitment usually occurs afterwards.



Fire can be an effective control method, but there must be sufficient fuel.



High fire temperatures blister bellyache bush stems.



Burning can promote massive seedling recruitment.



Scattered plants amongst pasture may be successfully controlled with fire.

4.4.2 Hand-held burners

Hand-held burners or flamers have proven effective for bellyache bush control.

Flaming for 10 seconds around the base of each plant has been shown to kill 92% of treated bellyache bush plants. This method can be used to kill individual plants in small or scattered infestations without sacrificing pasture and can be useful where chemical or mechanical control is inappropriate.

Flaming is effective at any time of the year, though precautions must be taken during dry times if there is flammable material surrounding plants.

Hand-held burners

- 10 seconds exposure is sufficient to kill most plants.
- Useful where chemical or mechanical control is not appropriate.
- Be careful if applying during dry times.



Ten seconds of intense heat to the base of the plant can kill bellyache bush.



Hand-held burners may be useful for treating isolated plants.

4.5 Biological control

Biological control is the use of a living species, usually an insect or pathogen, to control the growth or spread of a weed. Biological control won't eradicate a weed, but can help lessen weed impact, contain infestations and reduce spread in the long term. Biological control can also enhance the effectiveness of other methods.

Surveys are conducted in the weed's home range to look for potentially damaging insects or pathogens. Potential agents then undergo lengthy and expensive testing under quarantine conditions. This is to ensure that agents will attack the weed in question but will not adversely affect native flora, plants with commercial or horticultural value or plants with other desirable qualities.

Bellyache bush has been a target for biological control in Australia since 1996. The only agent so far released is the seed-feeding jewel bug *Agonosoma trilineatum*. Thousands of these insects were released across Queensland and the Northern Territory between 2003 and 2007. To date, the jewel bug is not known to be established in the field.

Several other agents are undergoing host-testing to assess their suitability for release, and further surveys in Central and South America are underway to search for new agents.

More information on the biological control program for bellyache bush can be found in section 6 'Technical updates'.



Male, female and immature jewel bugs.

4.6 Pasture management and competition

One of the most important aspects of long-term weed control is managing land to make it less susceptible to invasion.

A healthy pasture situation is a significant deterrent to weed invasion. Bellyache bush, in particular, thrives in disturbed areas and is often a symptom of poor land condition. Good pasture management (both native and improved) is therefore vital to limit the spread of bellyache bush into clean areas and also to minimise the risk of reinvasion of controlled areas.

Pasture management involves:

- achieving and maintaining pasture competition
- monitoring land condition
- understanding grazing pressure and managing stocking rates
- spelling paddocks
- managing water points
- fencing different land types
- using herbicides strategically.

Research has highlighted the importance of maintaining a healthy pasture to compete with bellyache bush. Field trials showed that when there is good grass cover:

- seedling recruitment is reduced
- plants grow more slowly
- plants take longer to reach reproductive maturity
- plants have a much higher natural mortality rate (compared to areas void of grass).

A study in northern Queensland followed survival and growth of bellyache bush seedlings exposed to different levels of grass competition in a buffel grass (*Cenchrus ciliaris*) dominant pasture.

After seven years, minimal mortality (4%) had occurred in bare areas (no pasture) while mortality exceeded 60% where pasture was present. Surviving plants growing within the pasture also took much longer to reach reproductive maturity than those in bare areas. For example, 66% of plants in bare areas were reproductive after 12 months, compared with less than 1% in grassed areas. After four years, 94% and 8% of plants were reproductive in bare and grassed areas, respectively.

Control practices that kill bellyache bush but not pasture will be best for achieving long-term control in pasture situations. Research showed that selective foliar spraying had the lowest rate of bellyache bush seedling recruitment compared with other methods (slashing, burning and stick-raking), as it allows the maintenance of grass cover to provide competition.

Re-establishment of ground cover should be a priority after control in areas without existing,

healthy pasture. Where possible, conserve perennial grasses and reintroduce pastures to mechanically treated areas by managing stocking rates and/or sowing pasture. Mechanical control can provide a seedbed for sowing pasture species. As well as providing competition with weed seedlings, re-establishing pastures can help control soil erosion in flood-prone areas and increase carrying capacity for livestock production, thus reducing the time required to recoup the costs of weed control.



Healthy grass cover can minimise invasion.

Pasture management and competition

- Bellyache bush thrives on bare ground.
- Maintaining a competitive pasture will:
 - reduce the number of bellyache bush seedlings that emerge
 - contribute to higher seedling mortality
 - delay the onset of bellyache bush seed production.

4.7 Integrating control methods

This section has highlighted the individual control options available for managing bellyache bush infestations. However, it is important to consider

how they can best be integrated to address not only the initial infestation but also the subsequent regrowth that will occur while there is a viable bellyache bush seed bank. Any single treatment, applied without follow-up, will result in the problem becoming worse. A long-term commitment (often 4–6 years) is needed to effectively control bellyache bush.

Given that a number of control options are available for bellyache bush, there is flexibility to select several combinations that will all eventually achieve a similar outcome (i.e. control of bellyache bush). This is important as there are many factors to consider in a weed control program. No single strategy will be effective in all situations.





Factors to consider include:

- the size and density of the infestation
- life stage of plants (seedlings or mature plants)
- accessibility
- landscape features (such as slopes or waterways)
- presence of other weed species
- presence of non-target species (such as pasture or native trees)
- time of year
- resources available
- cost
- off-target effects of control methods on native vegetation
- any permit requirements (refer to sections 7.2 ‘Vegetation management’ and 7.3 ‘Off-label permits and variations’).

To assist with the selection of management strategies for particular situations, Table 2 rates the suitability of various control options for treating scattered and dense initial infestations and for follow-up control.

Details on several possible integrated control methods are also provided on page 47, based largely on the findings from a large scale integrated trial on bellyache bush and the experiences of land managers who have been dealing with infestations on their land (refer to section 5 ‘Case studies’ for further examples).

Table 2: Potential control options for bellyache bush.

Control option	Initial infestation		Follow-up	
	Isolated plants or scattered clumps	Dense infestations	Isolated plants or scattered clumps	Dense regrowth
				
Stick-raking		✓ ✓ ✓		
Slashing ¹	✓	✓ ✓ ✓	✓	✓ ✓ ✓
Mulching ¹	✓	✓ ✓ ✓	✓	✓ ✓
Ploughing ² (cultivation)		✓ ✓		✓ ✓
Aerial spraying ³		✓ ✓ ✓		✓ ✓ ✓
Foliar spraying ⁴	✓ ✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓
Cut stump ⁵	✓ ✓ ✓		✓ ✓ ✓	
Basal bark ⁵	✓ ✓		✓ ✓	
Brush-cutter/hand cutting ⁶	✓ ✓		✓ ✓	
Hand removal ⁷	✓ ✓ ✓		✓ ✓ ✓	
Fire ⁸	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Hand-held burners ⁹	✓ ✓		✓ ✓	

Suitability of control options: ✓ = low ✓ ✓ = moderate ✓ ✓ ✓ = very good

¹Where the terrain is suitable and there is not too much debris on the ground.

²May be appropriate in arable lands, particularly if the area is seeded with competitive pasture/fodder plants.

³An off-label permit is required. In the Northern Territory exemptions may apply (refer to section 7.3 'Off-label permits and variations').

⁴The most appropriate application method will vary depending on density and area to be treated.

⁵As there is no full registration for these techniques check to see if they can be applied under existing minor use permits (refer to section 7.3 'Off-label permits and variations'). In the Northern Territory exemptions may apply (refer to section 7.3 'Off-label permits and variations').

⁶Best when undertaken during the growing season and as close to the ground as possible.

⁷Applicable only for small areas.

⁸Will not carry into dense infestations where there is generally no grass.

⁹Option for scattered/small areas where herbicides are not preferred (e.g. organic farms or sensitive areas).

Repeated foliar applications and maintenance of a competitive pasture

The repeated use of selective foliar herbicides is generally very effective and achieves high mortality of bellyache bush without affecting the grasses that are present. Establishment of a competitive pasture layer as quickly as possible following initial control will significantly reduce seedling recruitment of bellyache bush and adversely impact the growth and development of any new seedlings, particularly the time to reach reproductive maturity. In some pastoral situations lightening of stocking rates may be sufficient to encourage grass growth, while in others re-seeding with improved pastures will be necessary. In the integrated control study where grazing was excluded, single foliar applications of metsulfuron-methyl during the growing season on an annual basis achieved control of bellyache bush within four years.

Initial stick-raking followed by other mechanical or herbicide applications

Stick-raking is a good initial technique for clearing dense infestations and making the area more suitable for follow-up control activities. It will be restricted to areas of suitable terrain and where the density of native vegetation is thin enough to allow passage of the machine between trees. While stick-raking is capable of killing most of the bellyache bush plants present, the disturbance created will provide an ideal opportunity for seedling recruitment. Establishing dense grass cover as soon as possible will be advantageous and can be expedited by undertaking re-seeding at the same time as the stick-raking. Suitable follow-up options could include slashing/mulching, foliar spraying of selective herbicides or possibly burning once a fuel load has established.

Slashing/mulching repeatedly or follow-up with spot spraying

Slashing as close to ground level as possible when plants are actively growing is highly effective for initial control. However, slashing is restricted to relatively flat terrain where there is not a lot of debris on the ground. Heavy-duty mulchers perform a similar role but are more robust and able to handle some woody debris. As with other mechanical techniques, large scale seedling recruitment can be expected afterwards necessitating follow-up control. Repeating slashing annually would be appropriate but foliar

spraying should be considered once bellyache bush regrowth becomes patchy. This will allow more grass to be left to compete with bellyache bush plants.

Incorporation of burning as either an initial or follow-up technique

Burning is worth considering in control programs particularly if bellyache bush is widespread over large areas. It can be applied cost effectively on a broad scale but does require considerable resourcing (labour and fire fighting equipment) to ensure it is undertaken safely. It can slow the spread outwards from infestations by killing isolated plants growing within the pasture. Fires will not carry within dense patches of bellyache bush, so another technique, such as foliar spraying or use of machinery, will be needed initially to treat these plants. Fire could, however, be used later on to kill regrowth, provided grasses have been allowed to establish in these areas through either re-seeding or natural regeneration.

Refer to section 6.1 'Researching integrated control options' for further details on the integrated research trial that was undertaken in North Queensland.



Top and above: This infestation in the Northern Territory was brought under control over a four-year period with repeated selective foliar spraying. (Photos: J Meeson)



Section 5 Case studies



Case studies

Bellyache bush in the Desert Uplands

John Fisher (Bromvil) and Anita Randall



Background

Bromvil covers 13 101 ha in the Desert Uplands region of central western Queensland, approximately 40 km north of Muttaborra. The property receives an average rainfall of 430 mm per year and lies in the headwaters of Lake Eyre Basin. Previously grazed by sheep, it now carries around 400 breeder cattle. John Fisher took over management of Bromvil and neighbouring Dotswood in 2006.



Bromvil manager John Fisher with some bellyache bush regrowth.

The threat

On Bromvil, there was a total of 550 ha where bellyache bush was found, including dense thickets and areas of scattered plants. Most of the plants were found along a system of gullies running through the property, on red clays and sands. John said the infestation was over 150 m wide at its head, with plants reaching well over 2 m in height and no grass cover underneath.

‘When I first came here, you had to push your way through it.’



Dense thickets of bellyache bush excluded other vegetation. (Photo: J Fisher)

According to John, bellyache bush probably arrived onto the property as a garden plant 40–50 years ago.

‘It basically worked its way down from the old house into the gully.’

He says a 30 m patch, mistaken for castor oil bush, sat there for many years until one wet year the population seemed to explode.

‘It would have been slowly spreading downstream and then finally got the right conditions.’

John sees bellyache bush as well-suited to the desert channels country, spreading away from the gullies into drier areas. He says it can be difficult to spot isolated plants that come up away from the core infestation.

‘It’s extremely opportunistic. It’ll use anything it can for cover—it’ll hide under logs or come up through clumps of spinifex.’

One small patch was discovered under a large coolabah tree approximately 1 km upstream from the head of the main infestation.

‘It’s up and off the stream, out into the desert country. The only way it could’ve been taken there is by birds or stock.’

For John ‘it was a matter of trying to jump on the infestation before it got worse’. He also feels a responsibility to limit its spread downstream into the rivers feeding Lake Eyre.

‘If it gets into those rivers out here, and people don’t do anything about it, you’re going to lose all that country. You won’t be able to muster out of it—it’ll wreck the whole ecosystem.’

Control

John has been using twice-yearly foliar spraying to control bellyache bush since his arrival on the property in 2006, as well as hand-pulling and digging out isolated plants. He has set up permanent photo monitoring points so he can track the progress of his control program.



Isolated plants are dug up or hand-pulled as soon as they are found.

Just prior to his arrival, much of the infestation was blade-ploughed, which John advises against due to the huge amount of seedling recruitment.

‘Sticking a dozer with a blade plough into it made it really take off.’

In late 2006, John sprayed a section of the infestation with a fluroxypyr (Starane* 200) and water mix with added wetting agent.

‘It killed what I treated, but we had a lot of rain that night I finished spraying, and it was like a green carpet of seedlings within a week.’

John was then successful in obtaining funding for an ongoing control program through Desert Channels Queensland (DCQ), the natural resource management body in his area. He was advised to try a metsulfuron-methyl based herbicide, and in early 2007 he sprayed the whole infestation with Brush-Off® (plus a wetter) from top to bottom. The results were less than ideal.

John switched back to fluroxypyr (Starane™ Advanced) for his next round of spraying later that year and has continued to use it with good results. He sprays in the wetter summer months when the plants are actively growing, using a ute-mounted spray unit.

‘It’s got a 100 m roll, so basically, you pull up, walk in, then spray your way back out to the outside edge.’

He adds a dye to the mix to help keep track of where he has sprayed. Fluroxypyr herbicides show results in a few days, which also allows him to easily spot missed plants and treat them.



Bellyache bush recently sprayed with Starane™ Advanced.

He sprays the entire infestation, first in November–December, then 3–4 months later to treat the seedlings that have emerged. He aims to keep seed production to a minimum, although by this stage some of the new plants have already begun seeding.

‘It’ll seed twice a year, depending on the conditions. It’s a shocker.’



Spraying scattered plants. (Photo: J Fisher)

John has found that the herbicide doesn't appear to work as well under some conditions. One year, due to a broken pump on the spray unit, there was a three-week break in spraying where temperatures cooled by 2–3 °C. He found that compared with the first round of spraying, the herbicide seemed to only kill the top part of the plant and the bellyache bush was able to reshoot.

'Whether the sap was slowing down ... you could see where it would probably kill anywhere from 6–10 inches of the top.'



Bellyache bush reshooting from base after spraying. (Photo: J Fisher)

Achievements

John's persistence is paying off. The infestation has been contained within its original boundaries and has thinned out substantially.

'It's definitely not spreading as far as I can see ... and if we can keep it down without it throwing seeds, it (the infestation) will definitely get smaller as well.'

John has seen native grasses and buffel grass returning to treated areas.

'When I first started it was bare as a board. There wasn't anything growing there, and now all the grasses are coming back, so it is actually rejuvenating the country by knocking it down.'

Cattle are also now able to move through the infested area and are feeding amongst the treated plants. The improved access has also made it easier for continuing control works.

'You'd have to shoulder your way through it. Now we've got it down ... you can walk through and it's all grass.'

There is still plenty of seed in the soil, but John has seen a gradual reduction in the number of seedlings, and the amount of effort required, with each round of control.



Grasses are now returning to Bromvil's treated areas.

Future plans

John estimates about \$35–50 000 of DCQ and in-kind funding has been spent trying to control bellyache bush. About 80 000 L of herbicide mix has been used. He plans to continue with the current control program.

'We'll probably go back twice a year like we are now.'

John is happy with what he has achieved and thinks they will get on top of the problem.

'It's good to go back there now. You can see all the grasses coming back.'

Landholder cooperation in Central Queensland

Belinda Shaw (Greening Australia), Russell Smith (Strathmuir) and Anita Randall



Neighbouring landholders near Ogmore on the Central Queensland coast have formed a group to cooperatively attack their bellyache bush problem. The infestation, along approximately 20 km of Deep Creek, is one of only four known infestations in the Fitzroy Basin, making it a highly strategic target for control.

Background

The infestation began from a railway siding at Kooltandra, where bellyache bush had been planted in the gardens. When the siding was abandoned in the early 1980s, plants were pushed into Deep Creek and the infestation has since spread downstream to cover 20 km of creek across seven properties.

One of those properties, Strathmuir, has approximately 12 km of infested creek—the biggest section of bellyache bush. Strathmuir covers 9700 ha and runs 2400 head of cattle. It has been in the Smith family since 1959 and is now run by Russell and Anita Smith. Russell is also president of the Marlborough Landcare Group.

Russell says initially he wasn't aware of his problem.

'It was there a few years before we actually knew what it was. It was only a couple of plants. If we'd known then we would have pounced straight onto it.'

Russell says after several years the infestation then suddenly worsened.

'And that's when we realised we had a headache.'

The problem

While the bellyache bush was mostly confined to riparian areas, Russell has found isolated patches further away and has no doubt it would invade these areas if given the chance.

'I've found it about 3 km off the creek. I'd say the birds must have carted it ... If we left it go, it would keep on creeping out onto the higher country.'

In some places, the bellyache bush was more than 50 m wide. Although the area covered was relatively small, Russell could see the impacts if left unchecked.

'We would have lost production, because those creek flats, they're usually our best country when it's drying off. It's still green in there, protected from frost, it's a bit sandier.'

The bellyache bush was also restricting access to the creek and fence lines. Russell further points out the effect it can have on soil erosion.

'When you get that bellyache bush and there's no grass underneath and you do get a flood, there goes your topsoil.'

Coming together

The group formed in 2007 when Russell approached the Fitzroy River and Coastal Catchments Inc. (FRCC), who then contacted Greening Australia. Belinda Shaw, project manager at Greening Australia in Rockhampton, said she was keen to help the landholders involved.

'Most of them had been trying to do something over the years; it's just that they hadn't been putting in large scale, collaborative, concerted efforts. They thought they were the only ones fighting it. We brought them all together at a meeting at Russell and Anita Smith's property and they started talking about the problem and sharing ideas on controls. They then started working on the problem all together.'

The group has had regular meetings and workshops run by Greening Australia, supported with funding from the FRCC. Belinda ran a workshop on property pest management planning and helped each landholder develop individual property pest management plans. Belinda said she also coordinated the delivery of a global positioning system (GPS) workshop, which Greening Australia conducted.

‘Following the GPS workshop they went out and used the GPS to mark the points on their properties where the bellyache bush actually is, to put the skills learnt at the workshop into practice and to assist in formulating a map of the bellyache bush to attach to the property pest management plan, so that was really useful as well.’



Landholders from the group gather for a GPS workshop. (Photo: B Shaw, Greening Australia)



Satellite image showing a section of the bellyache bush infestation on Strathmuir. (Map: Fitzroy Basin Association and Greening Australia)

Belinda said the group was also successful in obtaining funding to assist with on-ground bellyache bush control.

‘Russell predominantly funded it himself up until then, and so did all the other landholders. There was some funding getting around through the FRCC (the subregional group of the regional NRM body ‘Fitzroy Basin Association’), through the Neighbourhood Catchments program. They received \$20 000 initially for all those seven properties.’

The group decided to allocate \$15 000 to Strathmuir for contract spraying by Greening Australia, while \$5000 would be spent on herbicide to be spread among the seven properties.

Control

Belinda said the \$15 000 was used to spray the densest areas on Strathmuir in February and March 2008.

‘When we decided to do it, we knew the money wasn’t going to do the entire bellyache bush infestation, so we decided to get the biggest bang for our buck. Russell did what he could do, with the scattered plants, pushing back to those dense areas. The most efficient, effective way was to use contract labour to treat the plants that he physically couldn’t do himself. Greening Australia had all the gear, such as the Quik Spray units, quad bikes and spray units, to enable the job to be completed really effectively and efficiently.’

Russell said he wasn’t making progress by himself on denser infestations and also suspected he may have been spraying at the wrong time of year.

‘I had been spraying a couple of years leading up to that, but wasn’t getting too far because I was by myself ... I was spraying probably late April, early May. I think you’re better off October through to end of March or early April. I don’t think you can go much past that, it’s not growing as vigorously.’

While all the landholders had been attempting some control previously, they too had limited success. They decided to trial both fluroxypyr (Starane* 200) and metsulfuron-methyl (Brush-Off®) herbicides for the initial contract spraying on Strathmuir. Belinda said they found metsulfuron-methyl was the cheapest and most effective for their situation.



Site before treatment in November 2007 (top) and after one treatment in May 2008 (bottom). (Photos: B Shaw, Greening Australia)

In 2009, Greening Australia was again contracted to do spraying on Strathmuir. This time, only five days were needed to follow-up all the previously treated areas, compared to 15 days the first year. Belinda said they were also able to start on some new areas.

‘We were able to go further up the creek and treat the majority of the creek. But in between contract treatments, Russell does a lot of touch-up work as well, in scattered areas. Russell allocates roughly \$12 000 of his own labour and resources to it annually.’

Russell said constant monitoring and follow-up of treated areas is essential, otherwise the initial effort would be wasted.

‘During that growing season, you’ve got to be out there every couple of weeks.’

Russell treats seedling regrowth either by spraying from a quad bike or hand-pulling.

‘I put them in piles with their roots pointing upwards, or in a log. Usually at that time of year when I’m pulling, there’s not much moisture about. But when I’ve pulled them in the middle of summer, you go back a month later and they’re still alive.’

In some areas, Russell is also hoping to use fire as a control measure. He has fenced off the creek area to exclude cattle, but because the bellyache bush is scattered amongst tall grass and other vegetation, it would be difficult to spray.

‘The amount of looking you’d have to do to find it, we’d be better off just burning it.’

Achievements

Belinda said the results achieved in such a short period have been excellent.

‘There were 2 m high plants in there, and there was nothing growing underneath it. But we’ve got it back now to where there is grass coming back through those areas since we’ve had two years of control there. Prior to that, cattle wouldn’t even go down there. There was nothing there.’

Russell was also elated with the results.

‘We thought we might have to re-seed at one stage, but there must have been grass seed

still floating around in that water during the recent flood.'

Belinda also credits Russell's grazing practices with helping the grasses to recover and provide competition for the bellyache bush regrowth. Russell generally spells the infested paddocks during the summer months.

'It's where there are bare patches or the short grass where bellyache bush really gets a kick on.'



Site before treatment November 2007 (top) and after several follow-up treatments in January 2009 (bottom). (Photos: B Shaw, Greening Australia)

Although follow-up is continuing, the problem is now down to a much more manageable level and Russell is confident they will beat the problem.

'When we first started we used to take two men to walk the creek, probably doing a kilometre a day, and we used to go for a fortnight. One person can do that in a couple of hours now.'

Belinda sees the co-operation of the landholders involved as crucial to the program's success.

'The whole idea of bringing the group together was so that everybody was on the same page. Now with the results of the trial and through the initial meeting, all affected properties are actually trying to do something. They recognise what Russell's trying to achieve and they also all talk amongst themselves now about progress.'

Russell also uses his experience to inform other landholders in the wider area of the impact of bellyache bush and the control methods available.

'I think a lot of people don't realise what a problem this is or can be.'



Russell Smith raises awareness of bellyache bush among landholders from the region. (Photo: B Shaw, Greening Australia)

Bellyache bush management on Branmore

Ralph and Lyn Woodard (Branmore)

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Ralph and Lyn Woodard took over Branmore, north of Charters Towers, in 2002. The 1133 ha property contains a mix of buffel grass, native pastures and legumes and runs approximately 100 Brangus cattle. Since their arrival, the Woodards have been working to contain the spread and reduce existing infestations of bellyache bush.

Ralph said it appeared the weed had been rampant along the farm's creek flats for many years prior to their arrival. Some places were so overgrown that the bellyache bush was impenetrable by horses and cattle.

He estimated bellyache bush had infested about 200 ha (or 17%) of the total property and rendered it useless for grazing.

'It was really bad along the creek flats and on ridges, and in some places it covered patches of up to half a hectare.'

Ralph started removing bellyache bush in the first year of his arrival using a mechanical slasher to cut through big shrubby areas.

'I have been dealing with weeds for a long time and I have always found slashing is a good way to make

a start ... We just pushed through the bellyache bush, which was intertwined with rubber vine, and cut it off at ground level. We also sprayed areas of the bush that we couldn't reach with machinery, using metsulfuron-methyl (Brush-Off®).'

In their second year on the property, the Woodards sprayed the previously slashed bellyache bush and continued with a slash-and-spray regime for other areas. Ralph said they used stick-raking and burning along suitable creek lines. He said control measures were best carried out when the bush was actively growing—during or after the wet season—but spraying was effective at any time of the year.



A slasher was initially used to knock down large plants.

In areas where bellyache bush has been controlled for several years, the Woodards have planted buffel grass to out-compete the weed. This has been very successful and has also led to the re-establishment of other native grasses that were previously unable to compete with the prolific bellyache bush.

Ralph sowed the buffel grass at a rate of about 1 kg seed/ha at the same time as stick-raking. These areas were then resown a second time at the same seeding rate. This would be quite expensive if buying-in seed at about \$6/kg, but the Woodards are able to harvest buffel seed from their own paddocks. Ralph said, ideally, the buffel grass should be locked up for a year to become well established. He kept his stock from grazing it until it set seed.

Ralph said that after six years, most of the creek areas infested with bellyache bush had been reclaimed for grazing.

‘I would say under our current control strategy, we have just about removed bellyache bush from across the whole 200 ha initially affected by the weed ... It has been a fairly expensive process ... but we are gradually increasing our stock numbers and it is economically and environmentally worthwhile.’

The Woodards initially had to reduce their cattle numbers to let the buffel and native grasses establish and allow for pasture recovery, as the property had been overgrazed prior to their arrival. Ralph said he believes that, after effectively controlling bellyache bush on the land, he will be able to double his breeding herd to 200 head and boost production and profits.

Integrating control methods on King Creek Station

Dan and Louise Firth (formerly of King Creek Station) and Anita Randall



King Creek Station, north-west of Collinsville in North Queensland, covers 3237 ha along the Burdekin River. Dan and Louise Firth owned the property from 1980–2006.

The threat

Dan said bellyache bush had been present on the property prior to the Firths’ arrival in 1980, having spread down the Burdekin.

‘It was in the river all the time and in patches up the bank ... but it got worse after I was there.’

The property has 11 km of river frontage, a large amount compared to the property size, which was all thick with bellyache bush. At its worst, Dan said it was ‘anything up to a kilometre off the river. It was that thick a dog couldn’t bark in it.’

Dan said the weed was taking up valuable grazing land and restricting access to the river.

‘It kills everything underneath it; it chokes everything out. When you look at all the country that was covered in it, you’re not using it, it’s just gone. All my river frontage was gone.’



Bellyache bush covered large areas of the property.

Dan also saw stock deaths which he attributed to bellyache bush.

‘We lost 20-odd steers—we were feeding them on the river. After that, I wouldn’t put cattle back in there.’

He also said wallabies were poisoned in severe droughts.

‘I’ve seen wallabies die from it, in the dry. They were stripping the bark off it and eating it. Then they were dead all along the river.’

Dan saw the problem worsening and knew he had to do something about it. The bellyache bush was spreading onto higher country, away from the riparian areas.

‘It started to come off the river. It really got a hold there, once it got going. It came to the stage where you had to make your mind up you were going to do it or lose all your river frontage. I thought, once it gets over and gets into all those creeks ... it’s gone, and that’s a big job. It was a big enough job as it was.’



Bellyache bush completely choked out pasture and desirable plants.

Early control

In the beginning, the Firths were hand-pulling and cutting out individual plants.

‘We started doing it along the river. We used to pull it out by hand, but then all the seed was coming up.’

Dan said the plants were also surviving long after pulling.

‘You could pull the stuff out and hang it on the fence and it wouldn’t die—it’d just keep green for weeks it had that much moisture in it.’

Eventually Dan sought help from (former) Department of Lands staff, who came out and collected some plants.

‘(They) wrote a letter back to me ... they wrote that it was highly toxic and they had the name of it—bellyache bush. We didn’t even know what it was. Everybody used to call it castor oil bush or something in those days—they didn’t know. Everywhere I went, to a field day or something, you’d mention bellyache bush and no one knew what you were talking about.’

Dan was advised to try spraying the infestation.

‘Whatever it was that we used initially, it didn’t do much good.’

He also tried repeated ploughing with little benefit.

‘Ploughing is not successful I reckon—you actually plough the seed into the ground. Every time you ploughed it, you brought it back up again. I think you’ve got it forever then.’

In the early 1990s, an above average wet season allowed bellyache bush to thrive and propelled Dan into action.

‘We never really got into it until ‘90 or ‘91. We had a big wet, and that’s when it went, and it was going. That’s when I really started getting into it.’

Chemical control

In 1991, Dan began foliar spraying with fluroxypyr (Starane* 200) but got poor results.

He then heard about Brush-Off® (metsulfuron-methyl) and found it to be highly effective (at least 90% mortality on seedlings) and relatively cheap. Dan was also able to claim a subsidy from his local government, Bowen Shire Council, of around 50% of the herbicide cost.

‘Once you get the right stuff it’s easy to kill actually. It’s not hard to kill it, but it’s just that it spreads that fast.’

Integrating control methods

Dan knew that spraying alone wasn’t enough, so he started experimenting with a number of other methods, such as slashing.

‘Slashing sort of works to an extent. We slashed it, but we had a lot of problems with timber laying in it, you couldn’t get at it properly.’

Dan still felt he was fighting a losing battle.

‘I’d tried slashing it, and I’d tried a few different things, and it wasn’t working.’

Then, in 2002, Dan was introduced to Dr Faiz Bebawi, a weed scientist at the Tropical Weeds Research Centre in Charters Towers, who had been investigating integrated control options for bellyache bush and was keen to try out some different methods at King Creek.

‘When I really got some movement was when Faiz came up. We got together and really started doing it. It was only the last four years or so. Once I got the dozer and got into it, we got some results then, tried different things.’



Landholder Dan Firth and researcher Dr Faiz Bebawi examine a large stand of bellyache bush.

Dan bought a bulldozer that was small enough to manoeuvre between trees.

‘The idea of the dozer was better. I had a rake on the front of the dozer, the width of the blade. It’s (bellyache bush) only shallow-rooted and it pulls out easily. Once you got a good load in front of you, just the weight would tear the rest out ... You raked up everything, got it together, let it dry and then burnt it. Then it was easy to get around and spray it.’

Dan found it didn’t matter what time of year he stick-raked, but he had to be careful not to clear too much at a time.

‘You could go in and doze a big heap, but if you did that it was too much for me to do. I had to go back over all I’d done before. I used to do probably a hundred acres or something like that. Once that rain came and that came up, you only had a certain window of time to get in and do that. Next year, you’d do that again. You’ve got to go back over all that stuff you’ve done before, you can’t let it seed. If you do a hundred acres, you’ve got to do that hundred acres plus the four or five hundred acres you’ve done before.’



Stick-raked plants were piled and burnt once dry.

Follow-up

Dan said the seedling growth after stick-raking could be massive.

‘When you doze it, you break the ground, and it germinates. It’d frighten you—millions of them. Then I used to just go in with my tankers and blanket spray it. You had to wait until your first shower, then once it shot, you got it when it was little and it was that much easier to spray it. If you got winter rains too, it’d come.’

Dan did most of his spraying using a 4WD.

‘I used to put pegs in ... as I drove along, I’d drop a peg, then you’d move over and spray back to that peg.’

He also used a quad bike during the wetter months.

‘Once it rains, it’s hard country to get around, but I had four-wheel bikes and we’d spray off them.’

Using mechanical means to control large plants made it much easier to spray. Dan found that large plants were harder to kill with herbicide. He also found that trying to spray large plants, which could be more than three metres tall, caused problems with overspray getting onto trees.

‘When it was small it was easy, you’d spray it up and let it mist on it.’

Grasses began returning to treated areas, although Dan also sowed pasture seed in some sections.

‘After you clean it, it’s just dead, bare. But then your grass comes back next year, after the next wet. I didn’t think it’d come back like that but it did. It’s not much good grass—spear grass, wiregrass, stuff like that. I eventually put urochloa and buffel up there. I should’ve been seeding while I was dozing. I went around and seeded over it, but it made two jobs instead of one.’

Dan has also used fire to follow-up in treated areas.

‘Once I saw the grass was coming back, and I could burn it, it was good. I put a firebreak right up the river, the full length of it, and I broke it into patches. I used to lock it up to get grass and then burn it—I might put a few horses in it or something. I thought, keep doing that for a few years and then I could start using it again.’

‘Fire rolls it, you’ve just got to get it at the right time, and you’ve got to get it before it seeds. It doesn’t take much, you’ve only got to blister it and it dies. Anything you missed with spraying, you got it with the fire creeping through, it was good. I used to burn it every year. It was cheaper than poisoning it, and quicker. But you’ve got to get that grass back first.’

Dan said his persistent follow-up efforts eventually got the weed under control.

‘You’ve just got to keep going back at it, get it before it seeds, and eventually it was getting to the stage it was a lot easier. You let that seed come on, you’re back there next year. It’s not hard to kill, but it’s just the time. Work’s the only way you’ll get rid of it, and if you can see you’re winning, well you don’t mind. You can keep at it.’



Fire was used to treat scattered plants once a grass fuel load had built up.

Persistence pays

Dan said he was eventually able to reclaim much of his grazing area.

‘We eventually got it all back, I had about 90% of it I suppose beaten, along the river and back in—dozed, pushed up and burnt and poisoned. But I spent a hell of a lot of time to get it like it is. I used to go for weeks on end, just poisoning. I employed one bloke for a month just poisoning. It was more or less an all-year thing, when you weren’t mustering or doing something else.’

‘It cost a lot of money and fuel and time. I had to get a dozer, I got a slasher, I bought a set of discs when they said to plough, and that didn’t work ... I had to buy all those things—and the poison.’

‘You’ve got to do it yourself. You’ve got to make up your mind that nobody’s going to help you, and you’ve got to do it. It’s your place, your problem, get into it and that’s it. But it’s like anything, it helps when someone comes and tells you you’re doing a good job.’

The Firths sold their property in 2006, and the new owner has seen the benefits of Dan’s work.



Once heavily infested paddocks are now clear of the weed.

Bellyache bush control on Willeroo Station

Adam Northey (Victoria River District Conservation Association), Dave Bowman (Willeroo Station) and Anita Randall



Willeroo is a 1710 km² cattle property located around 120 km southwest of Katherine in the Northern Territory. The station lies in the upper reaches of the Daly River catchment. Dave Bowman has been at Willeroo for eight years and has been managing the station for the last five years. Adam Northey from the Victoria River District Conservation Association (VRDCA) has been assisting with bellyache bush control on Willeroo and other properties in the region.



Aerial view of the infestation (pale green areas) in the channels on Willeroo. The infestation extends for more than 30 km.

Bellyache bush was introduced to Willeroo many years ago as a garden plant around the homestead. Most of the current infestation lies in the channels and waterways downstream. Smaller patches upstream possibly originated from plants at squatters' camps. In the eight years Dave has been at Willeroo, he has seen the problem gradually get worse. The creeks and channels on Willeroo lead to the Flora River and eventually into the Daly River, so getting a hold of bellyache bush here is vital to slow its spread into these clean areas.

In early 2008 the Northern Territory Weed Management Branch and VRDCA conducted intensive aerial surveys of bellyache bush on Willeroo and other properties in the region. The surveys found that approximately 10 100 ha of Willeroo, or nearly 6% of the total property area, are infested.



Map showing more than 100 km² of bellyache bush on Willeroo. (Map: NT Weeds Management Branch and VRDCA)

The areas invaded are some of the most productive grazing land on the property, mostly in the channels and on black soils. Dave estimates that the land taken up by bellyache bush could run at least another 1000–1500 head of cattle. The bellyache bush also causes problems when

mustering, as thickets are almost impossible to penetrate and provide cover for cattle. As Adam says, ‘it’s like having a big fence through the middle of the paddock.’



Bellyache bush forms a dense understorey that reduces grazing area. (Photo: A Northey)



The dense thickets restrict access.

Early control on Willeroo consisted of spraying and hand-pulling, which Dave said were effective, but slow.

‘It was so thick with bellyache bush you couldn’t see the buildings from the road.’

Only small areas could be treated at a time, and they were often limited by access—spray hoses could only reach in so far from the edges of the infestation.

Repeated spraying and hand-pulling proved effective in some areas, however, such as one paddock near the homestead. As well as foliar spraying, workers would walk in a line across the paddock hand-pulling plants when work finished early. After many years of continuous follow-up, the area has been all but cleared of the weed—although Dave suspects seed still remains in the soil, ready to emerge if the soil were disturbed.

Willeroo now employs one person full-time on weed control for six months of the year. The VRDCA has also contributed through various projects on the property and sends out a spraying crew several times a year to assist. The team of three local Indigenous rangers and a coordinator are able to put out 2000–3000 L of herbicide mix a day using two ute-mounted spray units.



VRDCA employs local Indigenous rangers to undertake foliar spraying. (Photo: A Northey)

Metsulfuron-methyl (Brush-Off®) is used as the preferred herbicide for foliar spraying, with added wetting agent. Adam stresses the importance of thoroughly wetting the leaves, and he has found that the herbicide is not effective once the leaves start to wilt and stress. For this reason, they generally stop spraying by 2 pm each day.

They also have a very short spraying season as the bellyache bush loses most of its leaves during

the dry season and doesn't take up the herbicide. Generally there will only be a 2–3 week window at the beginning of the wet season, after the plants have sprouted green leaf but before the rains cut off access to the infested areas. Most areas are then inaccessible until the end of the wet season, when there is again only a short period of time before the plants become stressed. Access is also hindered by the fact that many of the infestations are in deeply channelled areas and islands or on boggy black soils.

Various other methods have also been trialled on Willeroo. Slashing was used, and although it successfully killed most plants, it was found that the cut tops would regrow. The use of a heavy-duty mulcher, which would also destroy the tops of plants, was then trialled as part of a VRDCA project in October 2007. The mulching equipment was hired at a cost of \$380–400 per hour. The mulcher could usually clear 4–5 ha per hour, but in some of the rougher country at Willeroo it was only able to treat one hectare per hour. A total of approximately 80 ha was treated over 10 days, at an average cost of \$275 per hectare.

Adam said that, despite the expense, the mulcher gave good results.

'Dave reckons what the mulcher did in 10 days would've taken him 10 years to do.'

As well as clearing whole areas, the mulcher also cut access tracks into other parts of the infestation. Cut plants generally did not regrow, although massive seedling recruitment required intensive follow-up work, foliar spraying with metsulfuron-methyl. However, the amount of herbicide needed was greatly reduced and access for vehicles and spray equipment was much easier.



A heavy-duty mulcher was trialled for treating dense areas. (Photo: A Northey)



Seedlings emerging amongst mulched plants. (Photo: A Northey)



Many seedlings emerged after mulching, requiring intensive follow-up treatment. (Photo: A Northey)



Regrowth 12 months after mulching. (Photo: A Northey)

Over the years, Willeroo has invested huge amounts of time and money trying to control bellyache bush. At present, it is estimated that the station spends around \$70 000 a year on control. The priority now is to clear bellyache bush from the smaller tributaries and push the infestation towards the main channel. The aim is to completely clear the southern (homestead) side of the highway where the top of the infestation is, before moving to the main channel. These areas have now been reduced to isolated plants and small patches. Dave has made sure that his workers know to pull out any isolated plants they see.

The Northern Territory Weed Management Branch has recently allocated funding for bellyache bush control in the Katherine region, with Willeroo as one of the priority areas due to its location at the head of the Daly catchment. The proposed program will involve aerial spraying of metsulfuron-methyl from fixed-wing aircraft (after obtaining appropriate off-label permits), with the possible use of fire as a follow-up treatment. Dave is hopeful that the program will go ahead, as he sees it as the only cost-effective way to make a real impact on such an extensive area.



This area treated with mulching and follow-up foliar spraying now has only scattered bellyache bush plants.

Control of bellyache bush on Shilo

Robert 'Bud' Abbott (Shilo) and Anita Randall



Shilo is a 240 ha cattle property 15 km north-north-west of Charters Towers. When Bud Abbott first took over the property 16 years ago, it had numerous weed problems.

'Bellyache bush was mostly along the creek and out probably about 20 or 30 yards. Rubbervine was the same, and chinee apple through the rest of the place. Between the three of them I probably lost fifty percent of my grazing area.'

A number of ephemeral creeks run through the property, and these were the source of the bellyache bush infestation. New seed was continually coming from infestations further upstream. Bud said the creek areas were the most heavily infested, while scattered plants would appear further away.

'Because it's so flat, the water spreads out a fair way. So because the seed floats it could get spread right out.'

Bud also suspects some seed was moved by animals or on vehicles as it was found further away and up on ridges.



The property was heavily infested with bellyache bush and other weeds.

Bud concentrated his control efforts on the creek lines where the infestation was coming from. Initially he tried pushing it over.

‘I had a go at it with my tractor, and she wouldn’t even look at it.’

He then got a dozer in at a cost of approximately \$160 an hour. The dozer spent 10 days cleaning up bellyache bush, rubbervine and chinee apple.

‘It got rid of a lot of it initially, because it was 6–8 ft high. Then when they were smaller they were easier to control.’

Bud seeded a few weeks after dozing with buffel grass and other species, but still got a thick carpet of bellyache bush seedlings.

‘We just had to go back and just keep going over and over it. In the thicker parts, sometimes it came up like a carpet, so we’d spray the lot. Where it was a lot thinner, we’d go back and just pull them out. I found that just as easy, because they’re easy to pull out.’

He estimates that it took at least three years of intensive follow-up, spending two to three days a week spraying along the creek lines using a quad bike. Bud would return to the same patches every few months to treat new seedlings and missed plants.



A quad bike was used for follow-up spraying.

After the first few years, Bud has continued to follow-up scattered plants as they emerge by spot-spraying or hand-pulling.

‘It’s only the last two or three years you could say that it’s under control. It always comes back ... water comes down and washes all the seeds down. So we really don’t know whether the seeds are washing downstream or whether they’ve come from what’s here.’



Occasional scattered plants can still be found along the creek.

Bud has used both metsulfuron-methyl (Brush-Off®) and fluroxypyr (Starane* 200) as a foliar spray. He has found both to work well but prefers metsulfuron-methyl (with adjuvant) due to the cost.

He has found the herbicide to be most effective between October and May, but sprays isolated plants year-round (as he finds them) with good results.

Shilo was also the site of field trials by researchers from the Tropical Weeds Research Centre who were examining the use of fire as a control strategy. Researchers applied two successive spring burns and found that although it killed many plants, seedling emergence in burnt plots was very high. Bud said that although he has found burning successfully killed scattered plants, it isn't his preferred method of bellyache bush control.

'We burnt off a few times, but just paddocks, not specifically for bellyache bush control.'



Researchers examine burnt plants following an experimental burn.

Bud's property is now almost completely clean of bellyache bush and other weeds. Occasional plants still appear, but Bud is able to keep on top of the problem by treating plants as he finds them.

'Nowadays when I drive round, they're there if you look for them, but it's pretty well under control.'



Areas once thick with bellyache bush and other weeds are now almost completely clean.

Strategic eradication on the Walsh River

Sid Clayton (Tablelands Regional Council) and Anita Randall



Tablelands Regional Council covers 65 000 km² of diverse landscapes from rainforest to dry savanna on the Atherton Tableland in North Queensland. For the past seven years, the council has been running a staged, strategic eradication program against bellyache bush along the Walsh River and tributaries, about 70 km southwest of Mareeba. If allowed to go unchecked in this catchment, bellyache bush would threaten the productivity of large areas of the northern Gulf and Cape York Peninsula rangelands.



Plants on the Walsh River. (Photo: S Clayton)

Sid Clayton, Supervising Land Protection Officer with the council, said he first spotted a single bellyache bush on Laheys Creek in 2000.

‘We were sure there was only one, because we walked up and down, up and down; we had about 10 fellas with us. We all had a good look at the plant there before I destroyed it, then we walked right up and right down and we found no more, it was just that one.’

Sid figured that the plant was a once-off from a dirty vehicle.

‘And it was late 2002 when I found that big infestation downstream. That was an area that we did look at at the time too, so I’m pretty sure it’s come there since.’

Again, they walked the creek looking for plants. They followed Laheys Creek upstream for around 6 km, before they came across a large patch of bellyache bush at a recently constructed dam. Further searches upstream confirmed that the dam was the source of the infestation. Seed had probably been brought in on earthmoving machinery, which had previously been working in infested areas on the Palmer River.

From the dam site, the bellyache bush has now spread downstream along Laheys Creek and associated wetlands to Emu Creek, along 28 km of Emu Creek to its junction with the Walsh River and has continued its spread along the Walsh River. Council has received reports from landowners and recreational fishers that it is present on the Walsh River past Chillagoe.

The threat

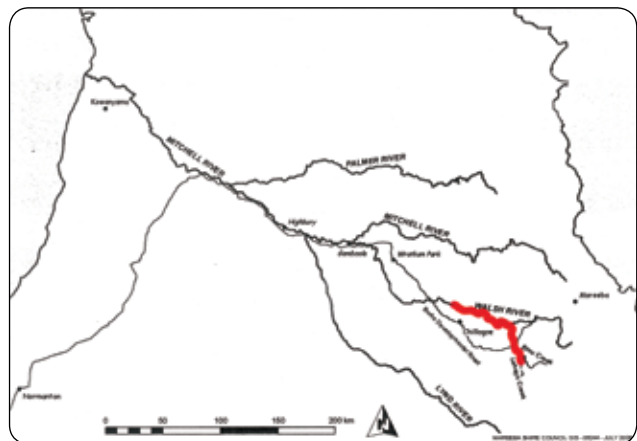
The Walsh River flows into the Mitchell River, which in turn flows through the floodplains of the Gulf of Carpentaria. A large bellyache bush infestation is also being treated on the Palmer River, another major tributary of the Mitchell River. If either of these infestations is allowed to enter the Mitchell River, the entire Gulf plains could be invaded by bellyache bush.

Here the country becomes more fertile black soil and is more subject to flooding. Sid identifies this as an area where bellyache bush could really take hold—as the seeds would disperse on floodwaters into high-quality grazing areas. This could lead to a major reduction in livestock grazing capacity, which would devastate the Gulf cattle industry. Downstream shires and landholders recognise the vital importance of preventing the spread of bellyache bush.

The infestations are already impacting on fauna and flora in the affected areas. In only a few short years, bellyache bush had formed dense thickets in the riparian zone, excluding other vegetation.

‘Emu Creek is a shallow, wide one. In places it’s a kilometre wide and you’ve got bellyache bush from the high ground to the high ground.’

Sid has also witnessed mass deaths of native bees, which he attributes to the poisonous exudates of bellyache bush.



The infestation, shown in red, feeds the Mitchell River running to the Gulf of Carpentaria. (Map: Tablelands Regional Council)

A staged approach

Sid could see that there was a good chance of containing the bellyache bush in the Walsh River and its tributaries, but it needed to be approached in a strategic manner. The council decided that the bellyache bush should be treated in sections, starting at the head of the infestation and working downstream. In this way they could ensure that each section was controllable before moving on to the next, thus preventing re-infestation downstream.

The infested areas run across a large number of properties, including cattle stations and Aboriginal land owned by the Barburrum community. Where landholders don't have the resources to assist with control works, they help by clearing access tracks to the river.

Treatment began on Stage 1 in 2002, soon after the infestation was discovered. Stage 1 involved treating all of Laheys Creek down to its junction with Emu Creek. The council then received external funding from the Northern Gulf Resource Management Group to assist with the program, allowing them to add further stages. Each stage has consisted of around 10 km of creek or river. They have found that attempting any greater area means they are unable to follow-up before the regrowth starts setting seed.

As of 2009, the council have treated around 55 km of infested creek frontage. Sid said as each new stage is added, follow-up continues on the earlier stages behind.

'We make sure that we do two runs a year on the stuff that's been cleared, but every time you do, you find a couple more just trying to get a go on again. If you just walked away and kept working your way downstream you'd have something flare up behind you again for sure.'



Seedlings continue to emerge from treated areas. (Photo: S Clayton)



Map showing infestations targeted in Stage 3 of the program. (Map: Tablelands Regional Council)

Raising awareness

Public awareness exercises are run through local papers and radio to inform both campers who use the infested areas and downstream landholders. Brochures and posters are displayed at cattle sales, community halls and town libraries, and council staff have also used a promotional trailer displaying live plants, posters and fact sheets. Downstream landholders are well aware of the threat, and of the work being done, and destroy any plants they find.

Station owners who rent out sections of the river to campers have been keeping these campsites free of bellyache bush so that campers won't contaminate their gear or vehicles with seeds. Council staff also talk to campers and have installed warning signs in an effort to make them aware of weed seed spread issues when camping in unregulated camp sites.



The council has erected warning signs to help prevent further spread. (Photo: S Clayton)

Sid said the council has also been actively promoting the need for landowners in the affected area to wash vehicles and gear down before leaving their properties.

'We know that the seeds that started our infestation were transported here on earthmoving equipment from another big infestation on the Palmer River. For the sake of a quick wash down we now have miles of river devastated.'

A portable wash-down unit, one of two purchased by Far North Queensland Regional Organisation of Councils, has been borrowed for use on the

bellyache bush project. The unit has a bunded mat, gurneys, vacuum and compressed air for cleaning and pre-emergent herbicide to treat the area after wash down. The trailer can be transported to the treatment sites to wash down vehicles and machinery before they move to other areas.



A portable wash-down unit helps prevent seed spread from control areas. (Photo: S Clayton)



Washing down the mulcher. (Photo: S Clayton)

Control

Tablelands Regional Council employs three full-time weeds staff who spend about four months of the year on bellyache bush control. At various times contractors have also been employed through external funding.

Access into many of the areas is extremely difficult. Often, most of the first season in a new section will be spent trying to gain vehicle access. Station staff have also been helpful in pushing in access tracks for spray crews.

Still, many of the areas can't be accessed at all by 4WD, or even two-wheel or four-wheel bikes, so

teams have to walk in. Sid said all gear—including herbicides, spray packs, tools and camping gear—must be carried in on foot.

‘One place there, where you’ve got about seven or eight kilometres you can’t access at all, there’s a railway line about halfway up the hill. We got the railway gangers to drop off 20 L containers of diesel. So we had little dumps of herbicide and diesel up here, so we could just walk up the hill and get a refill, otherwise we would have been lugging it all in on our backs.’

In areas that are accessible to vehicles, they use foliar spraying with metsulfuron-methyl (Brush-Off®) at 10 g/100 L with a wetting agent. Sid found metsulfuron-methyl to be the most effective herbicide, as well as being cheaper and appearing to have a residual effect in the form of pre-emergent kills. Metsulfuron-methyl gives the best results when the plants are actively growing, but Sid says it also gives some control during the dry season when plants are leafless.

‘I think you do still get some level of control, because the sticks are still green, but not as good as if you’ve got a nice bushy top on it. But when you’ve got big restrictions in the time you can do it anyway, between the wet weather and then the cold weather and waiting for it to come back again, you’ve pretty much got to put it on anyway and hope it gives you some control. Plants usually don’t get new leaf growth until the warmer and more humid weather around September, then access is cut off once the wet season arrives.’



*Plants are foliar sprayed using metsulfuron-methyl.
(Photo: S Clayton)*

Because of the restricted access for vehicles and spray equipment, the council team has had to employ a variety of other methods. They tried hand-pulling plants and leaving them on rocks in the riverbed, hoping that the November heat would kill plants. However, they found that the plants could still be alive months later, and were able to live off their reserves long enough to set seeds. Sid said they also tried basal-bark spraying with Access* (triclopyr/picloram) and diesel.

‘It does kill it in the end, but it takes a long time to kill it.’

Sid said they have also used a steel-bladed brush-cutter in inaccessible areas.

‘It works really well if you can cut them off low enough. Where it’s too stony to use the brush-cutters we use cane knives. We come through behind and spray with Access* and diesel. We spray the stump and the bottom of the cut plant to stop it taking root.’

This is now their preferred method in areas spray units can’t access, and although it gives good results, it is slow and labour-intensive.

Through funding from the Northern Gulf Resource Management Group, a mulcher was hired at a cost of approximately \$100/hour to treat some areas. The mulcher helped greatly in these areas—not only could it mulch large areas of the bellyache bush, but it could push access tracks and build ramps for vehicles to access sandy islands. It also mulched transect lines through the thick bellyache bush patches to allow access for spray equipment.



*A mulcher was used in some dense areas.
(Photo: S Clayton)*



Sid said that other management techniques, such as fire, are not considered appropriate given the location of the bellyache bush in the sensitive riparian zone and the possible effects on native vegetation and habitat.

‘By the time you get to use it, it’s escaped from the river. We don’t want to have to use fire.’

The infestation was also used as a release site for biological control agents. Several releases of the seed-eating bug *Agonosoma trilineatum* were completed but, like elsewhere, the bug failed to establish.



Sid Clayton releasing biological control agents. (Photo: F Barron)

Top and above: Mulching killed mature plants and also improved access. (Photo: S Clayton)

Achievements

The program to date has made impressive progress. Sid was initially worried about how the treated areas would recover.

‘We were thinking we might have to get the catchment management people up there to revegetate some of those places. But it’s self-regenerating. There’s a lot of eucalypts where there was nothing but bellyache bush before, so it looks like its going to look after itself. After 18 months, a couple of wets, it goes back to a natural system.’

Stage 1 (Laheys Creek) has been treated since 2002, and Sid said the bellyache bush has almost been eradicated.

‘It’s pretty much gone up there. Once or twice a year, we go for a walk right through it again, and still find the occasional one.’

However, Sid said it has taken seven years of control to get to this point.

‘And some of those places have been sprayed three times a year for that whole time.’



Area previously treated with mulcher—follow-up is continuing.

So far, approximately 55 km of Laheys Creek, Emu Creek and the Walsh River have been treated. Close to half a million dollars has been spent trying to eradicate the weed, including funding of \$120 000 from the Northern Gulf Resource Management Group.

Despite the success of the program, it is a constant challenge to carry out the work quickly enough to prevent the rapid spread of the plant downstream and, as Sid points out, there are still 400 km until they reach the Gulf. Without further external funding, Sid fears that the program would not have the resources to move further down the catchment and would probably be limited to maintaining the areas already treated.

While difficult, Sid can see the positive impacts their hard work is having.

‘There’s some satisfaction to be had from doing the jobs. They do knock you around and take a long time to do them, but you can go back and see places that you can remember were just wall-to-wall bellyache bush, and now you’ve got 10 ft tall eucalypts in there.’



This area was once thick with bellyache bush.

Note: While there are no registered herbicides for cut stump and basal bark treatment of bellyache bush specifically, Access* can be used in non-crop areas in Queensland under the environmental weeds permit (PER11463).

Controlling bellyache bush in Elsey National Park

Sam McKenzie, Danielle McGinness and James Gorman (Elsey National Park) and Anita Randall



Elsey National Park is located near Mataranka, about 100 km south of Katherine in the Northern Territory. The park covers 13 480 ha and has numerous springs that feed into the upper Roper River. Visitors come to the park to camp, fish, bushwalk, swim in the thermal pools and boat on the Roper River.

Bellyache bush has been present in the park for many years, having spread from a garden planting at a homestead further upstream. Scattered infestations occur along the Roper River with one large, dense infestation located on a patch of land isolated from the riverbanks during the wet season. The park rangers have dubbed this ‘Bellyache Island’.

Sam McKenzie, one of the park rangers, believes Bellyache Island poses a large threat. The infestation is in the centre river corridor, thus any seeds could potentially be transported downstream.

Most of the infestations in the park are found on the northern side of the Roper River, with only scattered plants in visitor areas on the southern side. The bellyache bush is mainly restricted to the riparian zone, up to 300 m off the river, though in some places plants have moved further off the

river into rocky or woodland areas. Sam said park rangers fear it could spread further if given the opportunity.

‘I’ve got no doubt if it kept going it would spread up in the rocks and spinifex.’

The rangers are determined to get on top of the bellyache bush problem here, not only to preserve the natural habitats within the park, but to slow the weed's spread further downstream.



*Bellyache bush in a sandy riparian area.
(Photo: NT Parks & Wildlife)*



The weed has also spread into rocky spinifex areas.

Problems

The rangers face many challenges in controlling bellyache bush in the park. Most of the infestations are completely inaccessible to vehicles during the wet season, as they are located on the northern side of the river, away from visitor areas and sealed roads.

Sam said bellyache bush is initially treated early in the wet season. When plants start growing again, most areas then can't be accessed until after the wet season. In some places it is difficult to get access before the dry weather makes foliar spraying ineffective.

‘By the time you can get to it, it’s already stressed.’

Ranger Danielle McGinness said access issues also make it difficult to prevent seed dispersal downstream. Before the rangers can get back for follow-up treatments, many of the new seedlings have already set seed in as little as four months after germinating.

‘It’s seeding when we can’t get to it. You do all this work, then it floods and it seeds, and you’ve got twice as much to come back to.’

Sam agreed with Danielle.

‘That’s the biggest problem—being able to get back and spray. It’s got to be almost three sprays I reckon. The first one after the first wet season rains, then one in the middle of the wet season and one at the end.’

One solution the rangers have tried is spraying from a boat fitted with a Quik Spray unit, borrowed from the Northern Territory Government’s Weed Management Branch. However, Sam said that this approach is also limited.

‘Once the river gets too high we can’t get the boat in.’

They are also restricted by rocks and rapids in parts of the river.

Control

The rangers are now working to eradicate scattered bellyache bush from the top of the river down, as well as trying to control the largest patch on Bellyache Island.

Scattered patches along the riverbanks are usually sprayed from a vehicle early in the wet season.

If possible, they are then sprayed from the boat 3–4 months later. Rangers then come back and follow-up any missed plants or new seedlings early in the dry season.

In areas with no vehicle access, small plants or regrowth are hand-pulled. Larger plants are cut with a cane knife close to ground level, which kills most plants, although some reshoot from the base. The rangers have found that using the knife to hack at the stump after cutting seems to stop them regrowing. Pulled and cut plants are hung in trees to prevent them regrowing roots where they contact the ground.



In sandy areas, plants are relatively easy to hand-pull.



A cut plant (at left) touching the soil has regrown roots.

Metsulfuron-methyl (Brush-Off®) is used for foliar spraying and has produced good kills. And the rangers have learnt the importance of using the correct wetting agent. Earlier spraying had used a variety of different wetters, sometimes with poor results.

Danielle said they have also found that spraying needs to be completed early in the day, before the heat of the afternoon causes the leaves to stress.

‘We’d make sure we were here early to start spraying, then by lunch time, we’d stop. Once they start to wilt, there’s no point in spraying.’

Previously, spraying would continue all day, which they believe may have also contributed to the poor results they were getting.

On Bellyache Island, Sam said the rangers have been cutting plants using a brush-cutter fitted with chainsaw teeth.

They use the brush-cutter to cut down the large plants, which can be 3–4 m high, to improve access into the infestation. They cut access tracks, approximately every 50 m, which then allows them to walk in with a hose to foliar spray either side of the track.

While most of the adult plants were killed from brush-cutting, some regrew from the base. Initially they tried painting the stumps after cutting, but according to Sam, this didn’t always work either.

‘It didn’t seem to kill the stumps off, and they’ve just grown back; whereas this year, we just came back and sprayed the reshoots with metsulfuron-methyl.’

Danielle said other methods produced similar results.

‘We tried basal barking too, but just the same thing, it died off and then it came back.’



Rangers use a brush-cutter with chainsaw teeth to cut plants close to ground level. (Photo: NT Parks & Wildlife)



Brush-cutters were used to cut access tracks into dense infestations. (Photo: NT Parks & Wildlife)



Cut plants stacked up and ready for burning.

Sam said the rangers have also trialled the use of fire at one site with scattered bellyache bush, further away from the river.

‘It was real late in the dry season, so it was a good hot fire, and only about two hours after we burnt we got some rain. It finished off most of the plants that were there but it just came back ten-fold, so we were lucky we got in and sprayed a lot of it.’

The rangers are also hesitant to use fire regularly for fear of killing off the spinifex grasses.



A hot fire very late in the dry season killed adult plants at this site, but six months later scattered regrowth needed follow-up treatment.

Future plans

The rangers plan to continue with their current methods to follow-up on scattered areas. Although the larger boat with the Quik Spray unit can't be used at the height of the wet season, the rangers also have a smaller boat, which Sam hopes to use to get access to some of the sites across the river.

'It's not so bad with that little tinnie; you can sort of pick your days when you don't get much rain and it slows down, and you can get the boat in and get across. Hopefully this year, we intend on having a quad over this side, so someone can spray all reshoots coming up, so when you do get full access, in March or whatever, there will be less regrowth to treat.'

They also hope to continue control on Bellyache Island, using brush-cutting, foliar spraying and burning. Sam also hopes that they can use the brush-cutting in some other areas.

'There's another site where we brush-cut, and that went underwater, must have been for most of the wet season. You can really see it's killed every plant. Brush-cutting I reckon would be a good option in areas where you know that it's going to flood. If you brush-cut those areas, you know plants are going to get flooded and should die over the wet season. Then you can come back and nothing's been seeding over the wet season.'



This site was flooded for a long period after plants were cut, reducing the number of seedlings that emerged. (Photo: NT Parks & Wildlife)



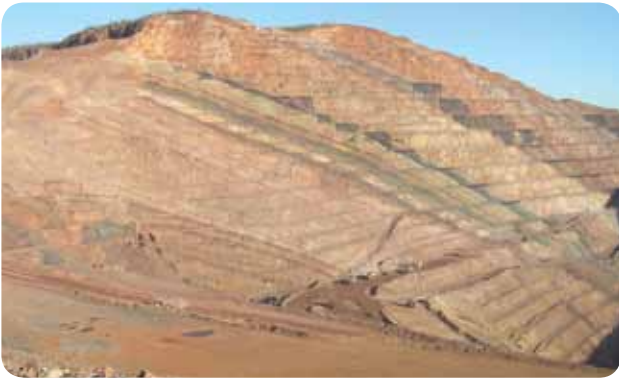
Sprayed plants along the Roper River.

Managing bellyache bush at Argyle Diamond Mine

Emily Gillespie (Argyle Diamonds), Murray Fuller (Territory Weed Management) and Anita Randall



The Argyle Diamond Mine is located in the Kimberley region in the far north-east of Western Australia and is one of the world's largest suppliers of diamonds. It is located to the south-west of Lake Argyle, about 120 km from the nearest town of Kununurra. Argyle currently operates an open pit mine and a processing plant. An underground mine is under construction and a complete residential village is located on site.



The Argyle Diamond Mine, WA. (Photo: Argyle Diamond Mine)

The Argyle Diamond Mine was commissioned in 1985, and it appears bellyache bush may have been brought to the site during construction. The weed was common around the residential village, which suggests it may have been introduced to the village area deliberately as a garden plant or accidentally during construction. The village is located at the top of a hill, and the weed has spread from there into downstream areas. In addition, green waste from the village gardens was being dumped where it could spread seeds into downstream areas.

Emily Gillespie, an environmental advisor on site for three years, explained the situation.

‘We’d been doing a clean up around the camp site, pruning trees and things like that, and the green waste was dumped at the top of the hill.’

Several other weed species are found on the lease, which also appear to originate from the village area, including barleria (*Barleria prionitis*), yellow oleander (*Cascabela thevetia*), white teak (*Gmelina arborea*) and neem (*Azadirachta indica*).



Dumping green waste at the head of a drain helped the spread of bellyache bush. (Photo: M Fuller)

Bellyache bush has invaded several watercourses and adjoining flood-out sandy loam and clay soil areas. It has also spread to other areas, such as in drains below the tailings dam wall, probably carried in on contaminated vehicles or machinery. The infested watercourses on the mine flow eventually to Lake Argyle. While there are extensive bellyache bush infestations in other parts of the Lake Argyle catchment, the bellyache bush at the mine forms the uppermost infestation in this particular creek system.

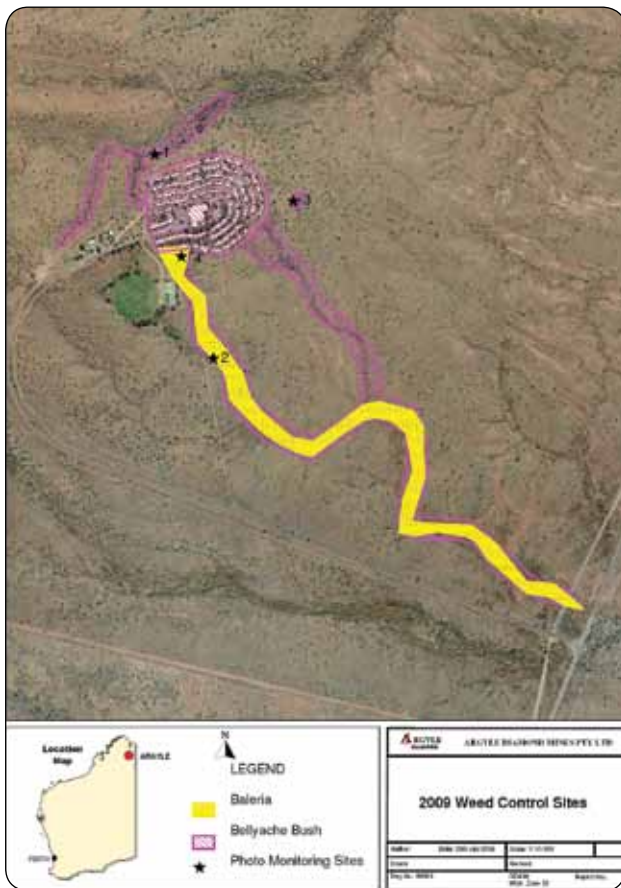
Bellyache bush has the potential for much greater spread on the mine lease and surrounding areas. Along some creeks it has already formed dense monocultures, excluding all other plants.



Patch of bellyache bush located at the bottom of a stormwater drain leading from the village. (Photo: M Fuller)

In the past, weed control at Argyle had been restricted to areas such as roadsides and around infrastructure, with only occasional spraying in other areas. In the past two years though, efforts have been stepped up. In 2008, the mine contracted Territory Weed Management (TWM) to carry out spraying of bellyache bush and other weeds on the lease.

TWM sent a spray crew of four men, two utes each equipped with 600 L Quik Spray units and a quad bike fitted with a 70 L spray tank. The team spent 10 days spraying in April 2008, with a total of 30 000 L of herbicide mix applied. Control was concentrated throughout the village and surrounding creek and gully areas, as well as some smaller patches below the tailings dam wall. Plants were also sprayed close to drains and road areas to reduce the risk of spread.



Bellyache bush and other weeds in the village and surrounding creeks were priorities for control. (Map: Environmental Team, Argyle Diamond Mine)



Foliar spraying with metsulfuron-methyl. (Photo: M Fuller)

Plants were foliar sprayed with metsulfuron-methyl with added wetting agent. Murray Fuller, of TWM, has experience treating bellyache bush in both the Northern Territory and Kimberley regions. He said he has found the most important factor is to ensure that leaves are thoroughly wet (to the point of run-off) with herbicide.

The initial treatment produced good kills of adult plants, but many new seedlings germinated. In 2009, the mine again contracted TWM to complete follow-up spraying and also to begin some work on additional sites. This time, less herbicide and time were required to re-treat all the previously sprayed areas.

Though most plants were killed, some plants appear to have survived this treatment. Leaves initially browned and burnt off, but some of the plants re-sprouted leaves from the stem several months after spraying. This is possibly due to the timing of treatment. In both years, spraying was completed in May. However, in 2009, the wet season finished much earlier, so plants were possibly more dry-stressed and less susceptible to the herbicide.



Some plants have re-sprouted after spraying. (Photo: Environmental Team, Argyle Diamond Mine)



Emily Gillespie (Argyle Diamonds) and Tracey Vinnicombe (Department of Agriculture and Food) inspect one of the treated sites.



Bellyache bush downstream from the accommodation village. Before herbicide treatment, 2008. (Photo: M Fuller)



Eight days after initial spray, May 2008. (Photo: M Fuller)



Six weeks after initial spray, June 2008. (Photo: Environmental Team, Argyle Diamond Mine)



Six weeks after follow-up spray, June 2009. (Photo: Environmental Team, Argyle Diamond Mine)

Most of the plants have now been removed from the village area itself, although some are still emerging from seed in the soil. Follow-up will continue in the creeks surrounding the village.

Emily said the environmental team at Argyle plan to continue the current spraying program and hopefully expand into more areas when their budget allows.

‘Our plan is to always spray these areas that we’ve sprayed now—keep spraying those, and hopefully get more funding.’

Murray also recommended that they use burning in some areas, such as in drains below the tailings dam wall, as there is plenty of fuel and access for spraying is difficult. However, the close proximity to infrastructure makes this a difficult task.

The mine is expected to close in 2020, and Emily said one of the aims of rehabilitating the site is to have all declared weeds eradicated from the lease.

‘It makes sense for us to start getting it under control now.’

Bellyache bush on the Corella River

Charles Curry (Southern Gulf Catchments) and Anita Randall



The Corella River and Lake Corella are located between Mount Isa and Cloncurry in north-west Queensland. The reservoir area is managed by Queensland’s Department of Environment and Resource Management. The river on either side of the lake runs through grazing land.

Bellyache bush was first reported in 2005 when landowners downstream of Lake Corella became concerned about this weed spreading onto their property. Charles Curry, project officer with Southern Gulf Catchments (SGC), then became aware of large infestations around the lake and further upstream. Bellyache bush is not widespread in the southern Gulf region, so it was targeted as a priority area for control.

Charles said the original source of the infestation is unknown, although the infested areas are downstream from the Mary Kathleen Mine, which closed in the early 1980s.

'I'm assuming it probably came out of Mary Kathleen. There doesn't seem to be any more coming down so the upstream infestation must be gone. Certainly there's none around Mary Kathleen now.'

Charles said it is also possible that it was planted as a garden plant on one of the pastoral properties below the mine.

Charles said bellyache bush is now found along Greens Creek, a tributary of the Corella River, and on the Corella River above the lake.

'It's also surrounding Lake Corella, which is under the responsibility of DNR (now part of the Department of Environment and Resource Management). They put in a contractor to kill all the parkinsonia and bellyache bush around the lake's edge. This was helped because they lowered the spillway a couple of metres, so the top shoreline went back around a hundred metres all around the lake's edge. So it left all the parkinsonia and bellyache bush high and dry and made it much easier to kill.'

The initial control was completed in November of 2005, with the contract now let to Cloncurry Shire for ongoing follow-up treatment.



Infestation at the edge of Lake Corella before treatment. (Photo: C Curry)

Areas upstream of the lake, on the Corella River and Greens Creek, had bellyache bush ranging from scattered plants to dense thickets. The infestations were mainly restricted to alluvial soils along the creek and riverbanks. However, bellyache bush also spread further away into rocky areas in some locations and even grew on top of rocky escarpments where it could not have been spread by water.



Bellyache bush formed a dense wall along the creek bank. (Photo: C Curry)



Plants were also discovered high on this rocky escarpment above the Corella River.



This plant was growing in a hollow tree, more than 3 m off the ground. (Photo: C Curry)

These upstream areas were treated by contractors with funding from SGC. An initial treatment—foliar spraying with metsulfuron-methyl—was completed in 2005. More spraying was then completed in these areas in May 2007. Charles said SGC have also been assisting with control.

‘In the meantime we’ve just been wandering up and down the creek, killing it, pulling it all out, treating any regrowth.’

The metsulfuron-methyl spraying generally had good results, although Charles did notice some plants would sprout new leaves from the stem months later and regrow. Seedlings are continuing to emerge from the treated areas but not at the same density as the initial infestation.



Sprayed plants on the bank of the Corella River. (Photo: C Curry)



Sprayed plants sometimes sprouted new leaves. (Photo: C Curry)



Spraying got rid of the original infestation, but scattered plants continue to emerge.

Charles and other staff from SGC have continued to voluntarily treat the regrowth on Greens Creek and Corella River at regular intervals. Staff will walk the creeks, often on weekends, and follow-up with hand-pulling and some cut stump treatment. As well as retreating known sites, they search for isolated plants emerging from water-dispersed seed.

Pulled plants are usually piled on rocks or hung in tree branches where they can't contact the ground. Plants that are too large or difficult to hand-pull are cut as low down as possible using secateurs; both the stump and the cut end are then painted with Vigilant® (picloram gel). Charles has found this method to be successful, although sometimes when stems have to be cut further from the ground (due to the thickness of the stem) they can regrow from the lower parts of the stem after painting.



Smaller plants are hand-pulled.



Pulled plants are placed in tree forks or on rocky outcrops to prevent them regrowing.

Two follow-up treatments were completed by SGC staff in 2007. During March and April 2008, Charles himself pulled or cut and painted more than 3000 plants before they had flowered or set seed. More than 2000 were then treated in May and June of 2009. Mostly new growth from seed is treated; some old growth in rocks well away from the creek has also been discovered.

Charles hopes to continue to follow-up these areas to ensure that the initial treatment was not wasted. He can see that if control is not continued, bellyache bush will soon be back to its original density and begin to spread away from the riparian areas. However, with no upstream infestations to re-infest the area, he can see there is a good chance of beating the problem.



New seedlings continue to emerge. (Photo: C Curry)

Containing bellyache bush in the east Kimberley

Tracey Vinnicombe (Department of Agriculture and Food, Western Australia) and Anita Randall



The east Kimberley region, in the far north-east of Western Australia, is one of the most unique landscapes in Australia. The main land use in the area is cattle grazing. There are also numerous national parks and reserves. Lake Argyle, the largest freshwater storage in mainland Australia, serves the Ord River irrigation area, which has large tracts of irrigated farm land producing a diverse range of crops.

The main towns in the region are Kununurra, built in the 1960s to service the construction of the Ord Irrigation Scheme, and Wyndham, one of the oldest towns in the Kimberley. The Wyndham Port, located on the Cambridge Gulf, plays an important role in mining, pastoral and other industries.

Bellyache bush has been present in some areas of the east Kimberley for at least 60 years. The first plants are suspected to have been planted in Wyndham and at Mabel Downs Station. Cuttings and plants were then transported to many homesteads and town gardens in the region as a garden ornamental. It was favoured due to its hardiness in dry conditions—the same characteristics which have made it such an invasive weed.



Bellyache bush in a riparian area on Mabel Downs station.



Bellyache bush can still be found growing in gardens in Wyndham.

From towns and homesteads, it has spread through creek and river systems to form large populations. There are particularly dense stands around Bow River, the top of Lake Argyle and Halls Creek and surrounding rivers. It is continuing to spread at an alarming rate along permanent water bodies. Bellyache bush is also present in the west Kimberley, particularly around the towns of Derby and Broome; however, its distribution is much more limited.



Most plants in the Kimberley region are of the green-leaf biotype.

The aim of bellyache bush management in the east Kimberley is generally limited to containment, as the large infestations are beyond removal. By the time bellyache bush was considered to be a problem in the Kimberley, it was already so widespread that the focus was directed to other weeds that were more feasible to control.

The declaration status for bellyache bush was only amended in 2006. Previously, it was declared P1 for the whole state (i.e. must not be introduced or spread) and P3 in the west Kimberley (i.e. to be controlled), but there was no requirement for control or containment in the east Kimberley. In 2006, the declaration was changed to P4 in the entire north of the state. This requires that the spread of seeds and plant parts must be prevented both within and from a property.

Tracey Vinnicombe, biosecurity officer with the Department of Agriculture and Food, said that most landholders don't have the resources to eradicate bellyache bush.

'Most of the stations, it's coming in from somewhere else, or it's been there for so long.'

Instead, they target isolated patches in an attempt to contain infestations. For example, Lissadell Station is located at the top of Lake Argyle, where the Ord and Bow Rivers enter the lake, and is therefore continually being re-infested from upstream. The station is containing the infestation along the rivers and lake edge by treating isolated

patches that appear away from these areas, but can't hope to control the main infestation.



An infestation at the top of Lake Argyle.

Tracey said staff from the Department of Agriculture and Food also control some areas.

'Usually it's areas where you can see it's getting away and no-one's doing anything about it. But we really only get a chance when we haven't got something more pressing.'

Much of the work they do is on unallocated crown land around Kununurra, where Tracey is based. As a result, bellyache bush is much less of a problem around Kununurra than Wyndham, where it can be seen growing throughout the town and surrounding areas.

The biosecurity staff generally use fluroxypyr (Starane™ Advanced) as their preferred herbicide. The bellyache bush usually starts losing leaf around May, although this depends on the length of the wet season, and Tracey said they have found that fluroxypyr is not effective once the plant is stressed.

'The most important thing is the time of year. Spray until it drips, use a wetter and watch the temperature on the day.'



Sprayed plants on the King River.

The spraying season in the east Kimberley is therefore quite short and access is restricted during the wet season. Tracey has noticed that plants start to sprout new growth as soon as the humidity rises, allowing her team to get in and start spraying before the wet season really begins. Tracey said they generally spray from the first rains, usually around September.

‘That way, we can get it before the main bulk of the seed is viable.’

Although most plants seed over the wet season, Tracey said it is incorrect to think bellyache bush can’t set viable seed year-round. Even plants with very little leaf can be seen seeding in the driest part of the year.



Seed can still be produced through the dry season.

Biosecurity staff are vigilant in looking for new infestations coming up outside of known areas. Tracey said contaminated vehicles and machinery are now mostly responsible for further spread of the weed. Equipment coming from Wyndham is often contaminated with seed.

‘Most of the areas we’ve found we can put it down to transportation.’

Tracey tries to raise awareness of the need to wash down machinery and prevent further spread. For example, a large road maintenance project has recently started in one of the most heavily infested areas, with a work camp set up on Mabel Downs. Tracey got the crew to set up a quarantine and wash-down area at the work camp.

‘A lot of the creeks that they’ll be working through have bellyache bush, so we need to make sure they aren’t spreading it to new areas.’



Infestations produce lots of seed that can be spread via vehicles and machinery.

Landowners and government staff in the east Kimberley are hopeful that a successful biological control for bellyache bush can be found. Tracey also said that traditional control often leaves bare soil exposed on creek banks, prone to erosion.

‘The length of time that it’s been in some places ... the effect that spraying it all out will have compared with a biological control which will be a lot slower and allow some other stuff to establish underneath.’

Biocontrol is seen as the only way to have a lasting impact on such a widespread weed.



Section 6 Technical updates



6.1 Researching integrated control methods

Anita Randall with Dr Faiz Bebawi (Biosecurity Queensland, Department of Employment, Economic Development and Innovation)

In the late 1990s, landholders and local and state government officers were increasingly recognising bellyache bush as a serious problem. Dr Faiz Bebawi, a senior weed scientist with Biosecurity Queensland (based at the Tropical Weeds Research Centre, Charters Towers), was eager to expand the research into its control.

‘It is a highly invasive species and causes significant social, economic and environmental impacts. It is particularly destructive in riparian zones where monocultures form and ultimately reduce biodiversity to unsustainable levels. Away from the riparian zone, it continues to compete with native species and replace native pasture.’

Past research at the Tropical Weeds Research Centre had led to registration for foliar spraying with metsulfuron-methyl and fluroxypyr, both effective herbicides. As with all weed control programs, though, follow-up monitoring and treatment was required.

‘Land managers may have followed advice as to which herbicides would kill bellyache bush. But if they neglected to include a follow-up program, the next year the problem was much worse because of recruitment from the seed bank.’

Dr Bebawi said that mechanical control and fire had also proved to be effective in killing adult bellyache bush plants in certain situations, but these treatments also required follow-up control measures.

‘Evidently there was a need to move away from traditional or conventional methods into an integrated concept of weed management.’

Dr Bebawi proposed a research project to find the most effective combinations of initial control methods and follow-up treatments and to develop an integrated management strategy for bellyache bush. Ecological studies on bellyache bush were included to better understand bellyache bush and

the implications for timing and effectiveness of control strategies.

‘From the beginning of this project, we had to integrate the concept of ecology with weed control. By understanding our weeds better, their ecology and physiology, we can target the control better.’

Integrated trials

A large scale trial was set up in 2002 on two properties near Charters Towers in North Queensland. Dr Bebawi said the trial aimed to determine the most effective combination of weed control methods over four years.

‘We used four of the conventional techniques available at that time for other weeds—foliar spraying, burning, slashing and stick-raking.’

In total, five treatments were applied in the first year. The ‘nil’ treatment had no control methods implemented. The foliar spraying treatment used metsulfuron-methyl (Brush-Off®) at a rate of 10 g/100 L plus a wetting agent (BS 1000 at 10 ml/100 L). Plants were sprayed overall to the point of run-off, where the herbicide mix began dripping from the foliage. Burning was carried out using the available fuel load in the plots (~2.1 t/ha). The slashing treatment used a tractor-mounted slasher and the stick-raking treatment used a D7 dozer with a 7 m stick-rake. All treatments were applied in the summer months before the wet season began.

Dr Bebawi said each of these initial treatments was then followed up with three consecutive years of slashing, burning, foliar spraying or nil treatment.

‘It was decided that we couldn’t use stick-raking year after year because it is very destructive to the soil and grass layer. So we did stick-raking only in the first year. In total we had 20 treatment combinations, each replicated four times, giving us 80 plots.’

Each plot was around 65 m x 8 m in size, surrounded by a firebreak. Cattle were excluded from all plots. Bellyache bush density in the plots averaged 58 000 plants per hectare.

Dr Bebawi said researchers measured the mortality of juvenile, mature and old bellyache bush plants 12 months after each treatment.

‘We also looked at the impact of these treatments on seedling recruitment and assessed the pasture yield and pasture composition. That was important, not just treating the weed to see if we killed it or not.’

The cost per hectare was also calculated for each treatment.

Results

According to Dr Bebawi, all the primary treatments had high bellyache bush mortality rates—except for fire.

‘If there’s no fuel you can’t kill it anyhow, that was the reason. With the other treatments, stick-raking, slashing and foliar spraying, we had significant mortality. The problem arose the following year.’

Singular applications of spraying and slashing killed up to 100% of plants, irrespective of the size of plants. Stick-raking was most effective on large plants, causing up to 99% mortality, but not as effective on young plants. Burning was variable (88% total mortality), but was most effective on smaller plants (96% mortality). Larger plants were less susceptible to fire (79% mortality).

Twelve months after the primary treatments, it was evident follow-up treatments were essential. For each plant killed with foliar spraying, 20 new plants had established. The other treatments had even higher numbers—97 for slashing, 74 for stick-raking and 69 for fire.

‘The reason why less seedlings were present in foliar sprayed plots is because you do not remove the grass layer. With all the other treatments, all the grass is slashed, removed or burnt—there is no or less competition from the grass. A complimentary competition trial that I undertook clearly demonstrated that fewer bellyache bush seedlings will survive to the adult stage if a competitive pasture (in this case buffel grass) is present. Surviving plants also take much longer to reach reproductive maturity when compared with plants growing in bare areas.’

A maximum pasture yield of 5 t/ha occurred with repeated foliar spraying; however, no matter what the treatments were, ‘there was a consistent

increase in pasture productivity with three follow-ups.’ On average, four years of integrated control increased carrying capacity from 1 beast/20.1 ha to 1 beast/3.6 ha.

Dr Bebawi said application costs varied between treatments and between years for some treatments.

‘The initial cost is always high when dealing with dense infestations. In our studies, herbicide treatment was the most expensive at the beginning, but because of the lower seedling recruitment, the cost drops very significantly the following years. But if you are hiring a slasher or a dozer, or even hiring equipment for a fire, the hiring does not get cheaper, because you are hiring by the hour and largely covering the same area. So the cost of these treatments will remain similar each year. In terms of overall cost, repeated foliar spraying in our study was the cheapest in the end.’

However, treatment costs for individual land managers will vary significantly based on the resources they already have at their disposal and whether or not they need to hire equipment.

Achievements/recommendations

The research showed that four years of integrated control effectively controlled bellyache bush and improved pasture productivity.

Dr Bebawi said using either foliar spraying for four years, or as a follow-up to slashing, stick-raking or burning, was the best practice in terms of bellyache bush mortality, seedling recruitment, pasture sustainability, carrying capacity and cost.

‘In plots where we did four annual foliar sprays, we got zero bellyache bush plants within four years.’

Situations and resources available to land managers can vary. Stick-raking or burning can clear an area while killing most of the adult bellyache bush plants in an infestation. This makes follow-up with herbicides or slashing easier the next year.

‘You can either foliar spray (x 4) or start with any of the treatments and follow-up with chemical control. If you lose some pasture through fire or mechanical control in the primary treatment, a follow-up treatment with herbicide will keep what pasture you have. This (metsulfuron-methyl) is a selective herbicide. That’s the benefit of using a chemical after some of these destructive treatments.’

		Initial treatment				
		Do nothing	Slashing	Burning	Stick-raking	Foliar spraying
Follow-up treatment	Do nothing					
	Slashing					
	Foliar spraying					
	Burning					

Table 3. Results at the end of four years show a once-only treatment on bellyache bush with no follow-up control (first row) will only waste time and money. Initial treatments plus three consecutive years of follow-up treatments (rows 2–4) can control bellyache bush. The best combination of treatments depends on your specific situation and available resources.

Table 3 shows visually the effects of the various combinations of treatments at the end of the four-year trial period.

‘It is easy to see that doing nothing about a bellyache bush problem, or treating an infestation once with no follow-up treatment, will not make your bellyache bush problem go away.’

However, depending on the financial resources and equipment available to a land manager, a variety of options exist for an effective bellyache bush control program. The one essential ingredient to any management plan is commitment. Group activities will also be much more productive particularly on a catchment or sub-catchment basis given the main dispersal mechanism appears to be water.

‘We now have more answers to the bellyache bush problem. We have changed the community perception out there. We are able to say it is beatable; it’s not a problem we can’t deal with. We know how to kill it. We have extended our results to the land managers; some of them have adopted it, and they have reaped good results.’

6.2 Biological control of bellyache bush

Anita Randall with Dr Tim Heard (CSIRO Entomology) and Dr Kunjithapatham Dhileepan (Biosecurity Queensland, Department of Employment, Economic Development and Innovation)

Biological control (or biocontrol) involves introducing natural enemies of exotic weeds or other pests to help control their growth or spread. It is based on the principle that plants are kept in check in their native range by insects or pathogens. Bellyache bush has few natural enemies in Australia, but it is attacked by many species in its native range and, as a consequence, is much less vigorous there.

Biocontrol will never completely eradicate a weed, but can help reduce its impact on agriculture or the environment. It is self-sustaining and inexpensive once established, but it requires considerable initial investment to find agents, host-test, mass-rear, release and monitor agents in the field.

Biocontrol programs take many years from when an agent is first identified in the field in the weed’s

native range to when it is approved for release in Australia. There are also no guarantees that suitable agents will be found, or that they will establish and have an impact on the target weed once released. However, biocontrol may be the only control possible once a weed is widespread, is growing in inaccessible areas or when the cost of traditional weed control is high relative to land value or productivity.

The search begins

Bellyache bush became a target for biological control in Australia in 1996.

In 1997, CSIRO Entomology began to survey insects and pathogens of bellyache bush (*Jatropha gossypifolia*) and its close relative, physic nut (*J. curcas*), in their native range. This research was largely funded by the Northern Territory Government along with some top-up funding from the Queensland Government. More than 220 collections were made in eight countries in tropical America and the Caribbean (Mexico, Honduras, Guatemala, Venezuela, Dominican Republic, Puerto Rico, Trinidad and Curacao). Thousands of insect specimens were collected and sent for identification.

From these, promising candidates that appeared to inflict the most damage in the native range were selected for further study.

Host-specificity testing

Potential agents then underwent extensive testing to ensure that they were specific to bellyache bush and did not attack native or economically important plant species.

Dr Tim Heard, entomologist with CSIRO, supervised the initial testing at CSIRO’s Long Pocket Laboratory in Brisbane. Potential agents were tested on more than 70 closely related plant species.

‘From 1998 we started importing agents into quarantine and doing host specificity testing. We struggled to find agents that were host-specific, that we could rear in quarantine and that, from a practical point of view, we were able to test. That continued for some time. Then we found *Agonosoma trilineatum*. We were able to confirm that it was entirely safe.’

Agonosoma trilineatum, a seed-feeding jewel bug, proved to be highly specific to bellyache

bush. Immature and adult jewel bugs feed only on bellyache bush seeds. They insert their mouthparts into the fruit, inject a chemical that dissolves the seeds and suck up the juices. Feeding destroys the seeds before they mature, which could potentially reduce seed production and slow the rate of spread and recruitment.

Jewel bug

Once an agent is proved to be host-specific, approval is sought for its release in Australia. By the end of 2002, researchers gained approval for release of *Agonosoma trilineatum*—the first introduced biological control agent to be used against bellyache bush anywhere in the world.

Mass-rearing and release of the insects was handed over to the Queensland and Northern Territory Governments. The work was done by biological control staff at the Tropical Weeds Research Centre (Charters Towers) and within the Northern Territory Department of Natural Resources, Environment, The Arts and Sport (Palmerston). The bugs were reared in laboratories and glasshouses on cut foliage with seed capsules. They were then released onto bellyache bush infestations across the Northern Territory and Queensland. Climate modelling was also used in an attempt to find the most suitable release sites for *Agonosoma trilineatum* in Australia. Tens of thousands of jewel bugs were released over four years, with the last release in 2007.

After release, researchers monitored the sites for signs that the insects had established and were surviving in the field. At some sites, jewel bugs were observed several months after release and evidence of feeding damage was noted. However, Dr Heard said none have been observed to persist in the long term.

‘Unfortunately it doesn’t appear to have established. A lot of effort, but it all came to nought in the end.’



A jewel bug (Agonosoma trilineatum) feeds on bellyache bush seeds.

Recommencing the program

In 2007, the bellyache bush biocontrol program was recommenced with funding from Meat and Livestock Australia, CSIRO and the Queensland Government’s Blueprint for the Bush initiative. The collaborative program was established between CSIRO and Biosecurity Queensland (part of the Department of Employment, Economic Development and Innovation).

Dr Heard said the aim was to conduct host-specificity testing for agents identified during earlier surveys and to undertake additional native range surveys in South America.

‘At that point, we were able to say that based on what we already know, we believe these agents are worth testing, and a couple of them were imported. The Queensland Government took over the host-specificity testing. Because CSIRO have a field station in Mexico, we’ve continued to do the native range work.’

Further searching

CSIRO staff based at the Mexican field station again began conducting surveys to catalogue insects in bellyache bush’s native range. Previous searches had focused on Central America, but bellyache bush is also found throughout South America. Climate modelling was conducted to find locations in South America that were most climatically similar to bellyache bush areas in Australia. Dr Heard said the model suggested that regions in northern Paraguay, Bolivia and western Brazil would be the most climatically suitable for sourcing biological control agents.

‘We hadn’t really done South America before; we’d really only done Central America and the Caribbean. The result from South America is that we don’t believe bellyache bush is native to that area. We believe that it’s been introduced through human commerce and trade and horticulture. So the expectation is that the majority of host-specific, co-evolved natural enemies are going to be found in the areas where the plant occurs naturally. The plant’s been there for perhaps millions of years, and it’s had time for the evolution of a suite of host-specific agents to form there. Whereas in the new areas, in South America where its been moved in probably the last 500 years through human activity, then you wouldn’t expect to find those natural

enemies. And that has in fact been the case. We haven't really found anything new in those areas.'

However, further searches in Central America have been successful.

'We've also been continuing to look in the traditional areas where we were looking before, and we have turned up a couple of new agents.'

'The work is continuing. We are still working through the material that we've collected in previous surveys. Because for every day you spend in the field collecting insects, it's probably about 10 days back in the lab, curating those insects, getting them preserved, databasing them, sending them off for identification, getting the identification back, adding all that information to the database and compiling your list of natural enemies. So that's ongoing.'

While most of the field surveys are now complete, one area the researchers do hope to survey in the near future is Cuba, which hasn't yet been searched.

Testing of new agents

The bellyache bush biocontrol program has seen dozens of potential agents go through the host-testing process. Most do not make it through. Currently, only two agents are available for further testing—a rust fungus (*Phakopsora jatrophicola*) and a stem-boring weevil (*Cylindrocopturus imbricatus*).

Rust fungus

Dr Kunjithapatham Dhileepan is a principal entomologist at Alan Fletcher Research Station (Biosecurity Queensland) and has been leading the current bellyache bush biocontrol program. Australian researchers have been working in collaboration with CABI (a not-for-profit, science-based development and information organisation) in the UK, who are conducting testing on the fungus.

'We have completed preliminary host-testing of a *Phakopsora* rust fungus and, on the basis of the preliminary research, we would like to take up more detailed studies. We are now collecting the rust fungi from Mexico, Venezuela, the Dominican Republic and possibly from Cuba also.'

Spores are being collected from both bellyache bush (*Jatropha gossypifolia*) and the closely related *J. curcas*, in order to isolate a strain that is highly specific to bellyache bush. Scientists in Australia also sent over samples of Australian bellyache bush biotypes to evaluate the potential impact of the rust.



Pustules of Phakopsora jatrophicola rust fungus on a bellyache bush leaf in Mexico. (Photo: R Segura)



A leaf of bellyache bush in Mexico infected with Phakopsora jatrophicola rust fungus. (Photo: R Segura)

Stem-boring weevil

The weevil *Cylindrocopturus imbricatus* was imported from Mexico into the Alan Fletcher Research Station quarantine facility for rearing and host-specificity testing. Dr Heard said

it had previously also been imported into CSIRO facilities.

'Both had the same result—we were unable to rear it in our facilities, and we're currently looking at why that is the case. They are able to rear it in the laboratory in Mexico. They are doing some of the preliminary testing over there now.'

'Traditionally, the host-specificity work gets done in Australian quarantine because we've got access to all of the plant species against which we have to test the insects. It's difficult to get Australian plants to work with in Mexico or other parts of the native range. We can also clean up the insect colonies so they're free of their own natural enemies. In their native range, they've got their own suite of natural enemies that come in and attack them. For those two reasons, we don't normally like to do work in the native range too much. But in this case we are in fact persisting in getting as much work done in the native range as we can, so we can continue to make progress and try to find out why we can't rear it in Australian quarantine.'

Dr Dhileepan is hopeful that they will be able to determine how to successfully breed the weevil and re-import it into Alan Fletcher Research Station.

'Once they succeed, they can do some preliminary host-testing there and also standardise the rearing methods. Then once that's done we could bring the insect back to Australia for some host-testing.'

Recent work in the native range investigated the natural host plant use by this insect species. Other plants growing in the area where the stem-boring weevil infests bellyache bush were searched for stem borers. Ricardo Segura of the CSIRO Mexican Field Station collected damaged stems from several unrelated species of plant. He and his team reared out weevils and sent them to an expert for identification and confirmed that they are in fact *C. imbricatus*. Although this spells bad news for the future of this insect, the possibility still exists that there are host specific closely related insects that appear to be the same but are actually different (called cryptic species by scientists). This possibility will be investigated in future work.



Multiple larvae of Cyldrocopturus imbricatus attack the stems of bellyache bush in Mexico. (Photo: R Segura)



Rearing and specificity testing of Cyldrocopturus imbricatus in Mexico. (Photo: R Segura)



*A larva of *Cyllindrocopturus imbricatus* doing extensive damage to a stem of bellyache bush in Mexico. (Photo: R Segura)*



*An adult *Cyllindrocopturus imbricatus* exploring a bellyache bush stem in Mexico. (Photo: R Segura)*

Other research

In order to be able to measure the impact of any future agents, Northern Territory and Queensland Government field scientists have collected baseline ecological parameters for comparison with data after the agents are established.

Researchers are also collaborating with the Queensland University of Technology to conduct studies of plant responses to simulated insect damage. The research has so far shown that all the Australian varieties respond similarly to herbivory. It is also hoped that research can identify the type and frequency of herbivory required to reduce the growth and vigour of bellyache bush seedlings and mature plants. Agents utilising the parts of the plant most susceptible to stress, resulting in a negative impact to the plant, will then be the focus of subsequent searches.

Future of the program

Researchers have struggled to find agents that are specific to bellyache bush and won't attack other plants. Dr Dhileepan said they had been hopeful that bellyache bush was a good target for biocontrol, due to the toxic latex sap.

'I'm surprised, because I thought this sort of plant, because of the latex, we were expecting a highly specific insect. But many of the insects on *Jatropha* appear not very specific.'

'My feeling is we've got only two potential agents left now (the weevil and rust), unless we come across something very interesting in Cuba. You never know, because each country is completely different. But that's the last place we can look now, we've sampled all relevant countries.'

If the weevil or the rust does prove to be host-specific, it could take years before either is approved for release as a biological control agent.



Section 7 Further information



Further information

7.1 Weed contacts

Enquiries about declared weeds should first be referred to your local government pest management/environmental officer.

State and territory weed contacts

Northern Territory	
Department of Natural Resources, Environment, The Arts and Sport	Phone: 08 8999 4567 Email: weedinfo.nretas@nt.gov.au Website: www.nt.gov.au/weeds
Queensland	
Department of Employment, Economic Development and Innovation	Phone: 13 25 23 Email: callweb@dpi.qld.gov.au Website: www.deedi.qld.gov.au
Western Australia	
Department of Agriculture and Food	Phone: 08 9368 3333 Email: enquiries@agric.wa.gov.au Website: www.agric.wa.gov.au
Australian Capital Territory	
Parks, Conservation and Lands; Department of Territory and Municipal Services	Phone: 13 22 81 Website: www.tams.act.gov.au
New South Wales	
Department of Primary Industries	Phone: 1800 680 244 Email: weeds@dpi.nsw.gov.au Website: www.dpi.nsw.gov.au
South Australia	
Department of Water, Land and Biodiversity Conservation	Phone: 08 8463 6800 Website: www.dwlbc.sa.gov.au
Tasmania	
Department of Primary Industries, Parks, Water and Environment	Phone: 1300 368 550 Website: www.dpipwe.tas.gov.au
Victoria	
Department of Primary Industries	Phone: 136 186 Email: customer.service@dpi.vic.gov.au Website: www.dpi.vic.gov.au

General contacts

Weeds Australia	Website: www.weeds.org.au
CSIRO	Phone: 1300 363 400 Email: enquiries@csiro.au Website: www.csiro.au

7.2 Vegetation management

In most states and territories, permits will be required if native vegetation is likely to be damaged during control operations. Contact the authorities listed below for further information.

Queensland	
Department of Environment and Resource Management	<p>For more information about applying to clear native vegetation for weed or pest management, contact DERM by phone or email, speak to a vegetation management officer (VMO) at a DERM service centre or visit the website.</p> <p>Phone: 13 13 04 Email: VMEnquiries@derm.qld.gov.au Website: www.derm.qld.gov.au</p>
<p>There is no fee to submit an application for a permit to clear vegetation in Queensland for the purpose of weed or pest management.</p> <p>All applications to clear for relevant purposes (including weed and pest management) are assessed against assessment codes (e.g. regional vegetation management code, wild rivers code, declared area code) which set out performance requirements that applications need to meet.</p> <p>These assessments ensure that the clearing is necessary to manage weeds or pests and that the clearing will maintain biodiversity, will conserve the regional ecosystems and will not cause land degradation such as soil erosion or exposure of acid sulfate soils. When preparing an application to clear vegetation for weed or pest management, applicants need to address each of the performance requirements in Part W ('Requirements for clearing vegetation for weed and pest management') of the relevant code.</p> <p>The codes are available on the DERM website at www.derm.qld.gov.au or from any DERM service centre.</p>	
Western Australia	
Department of Environment and Conservation	<p>Phone: 08 6467 5000 Email: info@dec.wa.gov.au Website: www.dec.wa.gov.au</p>
Northern Territory	
Department of Natural Resources, Environment, The Arts and Sport	<p>Phone: 08 8999 4478 Email: rangelands.nretas@nt.gov.au Website: www.nt.gov.au</p>
<p>All clearing of native vegetation within the Northern Territory requires prior approval under the <i>Northern Territory Planning Act 2000</i> and/or the <i>Pastoral Land Act 1992</i>.</p>	

7.3 Off-label permits and variations

The permits referred to below are for the generic control of environmental weeds in specified situations, using a limited number of products, and may only apply to certain users. They have not been issued specifically for bellyache bush control. Users will need to consult the permit conditions and seek advice from their local weed officer.

State/territory	Permit number	Expiry date	Details
Queensland	PER11463	June 2014	Control of environmental weeds in non-crop areas
Western Australia	PER9655	March 2012	Control of environmental weeds in various situations
Western Australia	PER4590	December 2010	Control of declared plants in crop and non-crop areas

Land managers can search for current registered products and off-label permits using the Australian Pesticides and Veterinary Medicines Authority (APVMA) website or the Infopest database produced by the Department of Employment, Economic Development and Innovation (Queensland).

Australian Pesticides and Veterinary Medicines Authority (APVMA)	Phone: (02) 6210 4701 Website: www.apvma.gov.au
Department of Employment, Economic Development and Innovation	Phone: 13 25 23 Email: callweb@dpi.qld.gov.au Website: www.deedi.qld.gov.au

Agricultural and Veterinary Chemical (Control of Use) Act 2004 (Northern Territory)

In the Northern Territory a person must not have in their possession OR use a chemical product unless the product is registered in Australia. Exemptions apply.

In the Northern Territory a registered product MUST only be used in situations consistent with those appearing on the label, unless authorised under a permit.

In the Northern Territory a person MAY use a registered product at a concentration, rate or frequency lower than that specified on the label UNLESS this is specifically prohibited on the label. In the Northern Territory a person MAY use a registered product to control a pest not specified on the label UNLESS this is specifically prohibited on the label. In the Northern Territory a person MAY also use a registered product using a method not specified on the label UNLESS this is specifically prohibited on the label.

7.4 References and further information

- Bebawi, F & Campbell, S 2002, 'Effects of fire on germination and viability of bellyache bush (*Jatropha gossypifolia*) seeds', *Australian Journal of Experimental Agriculture*, vol. 42, pp. 1063–69.
- Bebawi, F & Campbell, S 2002, 'Impact of fire on bellyache bush (*Jatropha gossypifolia*) plant mortality and seedling recruitment', *Tropical Grasslands*, vol. 36, pp. 129–37.
- Bebawi, F & Campbell, S 2002, 'The response of bellyache bush (*Jatropha gossypifolia*) plants cut off at different heights and seasonal times', *Tropical Grasslands*, vol. 36, pp. 65–8.
- Bebawi, F & Campbell, S 2002, 'Seed dispersal of a myrmecochorous weed, bellyache bush (*Jatropha gossypifolia* L.), in riparian landscapes of northern Queensland', in A Franks, J Playford and A Shapcott (eds), *Proceedings of the Royal Society of Queensland, Landscape Health of Queensland Symposium*, The Royal Society of Queensland, Indooroopilly, pp. 98–102.
- Bebawi, F & Campbell, S 2004, 'Interactions between meat ants (*Iridomyrmex spadius*) and bellyache bush (*Jatropha gossypifolia*)', *Australian Journal of Experimental Agriculture*, vol. 44, pp. 1157–64.
- Bebawi, F, Campbell, S & Stanley, T 2002, 'Priority lists for weed research in the wet- and dry-tropics of north Queensland', *Plant Protection Quarterly*, vol. 17(2), pp. 67–73.
- Bebawi, F, Mayer, R & Campbell, S 2005, 'Flowering and capsule production of bellyache bush (*Jatropha gossypifolia* L.)', *Plant Protection Quarterly*, vol. 20(4), pp. 129–32.
- Bebawi, F, Mayer, R & Campbell, S 2005, 'Phenology of bellyache bush (*Jatropha gossypifolia* L.) in northern Queensland', *Plant Protection Quarterly*, vol. 20(2), pp. 46–51.
- Bebawi, F, Mayer, R, Vitelli, J & Davis, K 2006, 'Interactions between grazing practices and bellyache bush (*Jatropha gossypifolia*): preliminary results', in C Preston, J Watts and N Crossman (eds), *Proceedings of the 15th Australian Weeds Conference*, Weed Management Society of South Australia, Adelaide, pp. 861–3.
- Bebawi, F, Vitelli, J, Campbell, S & Madigan, M 2004, 'Integrated control methods for bellyache bush (*Jatropha gossypifolia* L.) in northern Queensland: preliminary results', in B Sindel and S Johnson (eds), *Proceedings of the 14th Australian Weeds Conference*, Weed Society of New South Wales, Sydney, pp. 150–2.
- Bebawi, F, Vitelli, J, Campbell, S, Vogler, W, Lockett, C, Grace, B, Lukitsch, B & Heard, T 2007, 'The biology of Australian weeds 47. *Jatropha gossypifolia* L.', *Plant Protection Quarterly*, vol. 22(2), pp. 42–58.
- Bebawi, FF, Vitelli, J, Campbell, SD, Vogler, WD, Lockett, CJ, Grace, BS, Lukitsch, B & Heard, TA 2009, '*Jatropha gossypifolia* L.', in FD Panetta (ed), *The biology of Australian weeds: volume 3*, RG and FJ Richardson, Melbourne, pp. 102–27.
- Csurhes, S 1999, *Bellyache bush (Jatropha gossypifolia) in Queensland. Pest Status Review Series - Land Protection Branch*, Queensland Department of Natural Resources and Mines, Brisbane.
- Heard, T, Chan, R, Wilmot Senaratne, K, Palmer, W, Lockett, C & Lukitsch, B 2009, '*Agonosoma trilineatum* (Heteroptera: Scutelleridae) a biological control agent of the weed bellyache bush, *Jatropha gossypifolia* (Euphorbiaceae)', *Biological Control*, vol. 48, pp. 196–203.
- Vitelli, J & Madigan, B 2002, 'Is aerial control of bellyache bush effective?', in H Spafford Jacob, J Dodd and J Moore (eds), *Proceedings of the 13th Australian Weeds Conference*, Plant Protection Society of Western Australia, Perth, pp. 169–72.
- Vitelli, J & Madigan, B 2004, 'Evaluation of a hand-held burner for the control of woody weeds by flaming', *Australian Journal of Experimental Agriculture*, vol. 44, pp. 75–81.

Vogler, W & Keir, A 2005, 'The rate of spread of bellyache bush (*Jatropha gossypifolia*) in North Queensland', in W Vogler (ed), *Proceedings of the 8th Queensland Weed Symposium*, Weed Society of Queensland, Townsville, p. 102.

