Pond apple

Annona glabra—Annonaceae

management

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Australian Government

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Foreword

Pond apple is an invasive weed with the potential to have major environmental impacts in Australia. Introduced as grafting stock for custard apple, this tree can form dense stands to the exclusion of native species.

Its ability to grow in flooded areas and to tolerate salt water has enabled it to spread through much of the Wet Tropics area of North Queensland. Without intervention, pond apple could spread throughout northern Australia and south to New South Wales.

Pond apple is considered an environmental weed but is also starting to affect commercial enterprises. It is now threatening the cane and cattle industries by growing in and along creeks, fence lines and farm drains.

The National Pond Apple Management Group recognises that only through the combined efforts, diligence and commitment of all affected landholders, communities and all levels of government will we be able to control this weed.

I recommend this manual to all landholders affected by pond apple, and suggest that those at risk of pond apple invasion make good use of the combined knowledge and experience contained herein.

Further, I commend all those who have been responsible, both directly and indirectly, for its production.

Ann Doak
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Section 1

Pond apple: ecology and threat

Introduction

Pond apple (*Annona glabra)* is a major environmental weed of the Wet Tropics bioregion of North Queensland and a Weed of National Significance (WONS). This small to medium-sized tree forms dense stands particularly in swamp areas. Pond apple invades fresh, brackish and saltwater areas and its thickets are capable of replacing whole ecosystems. It prefers the silty alluvial soils of coastal floodplains and is primarily dispersed by water, especially during floods. Disturbed, flood-prone ecosystems, —particularly mangroves, melaleuca woodlands, riparian areas, drainage lines, coastal dunes and islands—are the most at risk from pond apple invasion.

Pond apple currently covers around 2000 hectares of the Wet Tropics bioregion in Queensland, as well as the eastern coast of Cape York, and its potential for spreading throughout coastal regions of tropical and subtropical Australia is considerable. Dispersal of fruit and seeds by water and animals allows pond apple to be easily spread within and between catchments. Unlike many weeds, pond apple has an alarming ability to invade relatively undisturbed areas. Pond apple is also a pioneering plant and will opportunistically invade areas after disturbances such as cyclones and floods.

In Queensland, pond apple is declared as a Class 2 pest under the *Land Protection (Pest and Stock Route Management) Act 2002*, which means it potentially has serious economic, environmental or social impacts. It is illegal to sell pond apple or to keep it without a permit in Queensland.

Ian Holloway

▲ Pond apple can form dense infestations

Ian Holloway

▲ Seedlings can germinate in moist, inundated conditions

Landowners must take reasonable steps to keep their land free of the weed by controlling and, if possible, eradicating any outbreaks on their property. Currently, pond apple is also banned from sale and entry into most other states and territories in Australia.

This manual outlines the ecology and threat of pond apple and a range of control methods and planning tools.

Description

Pond apple belongs to the family Annonaceae and the genus *Annona* (137 species) and has no close native relatives in Australia.

Pond apple is a semi-deciduous tree that can reach 12–15 metres in height; however, it typically grows to 3–6 metres. Young pond apple plants often have stems with swollen bases. Mature plants may develop gnarled, slightly buttressed roots. Pond apple individuals are usually single-stemmed; however, when seeds germinate in groups, the resulting plants have a multi-stemmed appearance. Over time, the stems may fuse together, giving the appearance of a single plant. In these cases, each stem maintains its own sap system, which complicates herbicide control as each individual stem must be treated.

The stems of pond apple are softwood with thin, grey bark, bearing prominent lenticels. Lenticels are small, raised, cork-like structures that are involved in gas exchange, enabling the plants to survive periods of inundation. Native mangroves also have lenticels, so care should be taken during identification.

The leaves of pond apple are alternate, 7–12 cm long, oval-shaped and have a prominent midrib. The upper surface of the leaves varies from light to dark green depending on the age of the plant. Leaves are paler on the underside and there is a distinctive small fold where the leaf blade joins the leaf stalk. It is this fold in the leaves that helps to differentiate pond apple from plants with a similar appearance. The leaves emit a distinct smell (similar to the smell of green apples) when crushed—another feature that can distinguish pond apple from mangroves. In the dry season, the more mature leaves yellow and this distinctive feature can aid in detecting infestations by aerial surveillance at that time.

Ian Holloway

▲ A multi-stemmed appearance often results when seedlings germinate together

Ian Holloway

▲ Young plants often have swollen bases

The flowers, short-lived and rarely noticed, are 2–3 cm in diameter, are pale yellow to cream and consist of three leathery outer petals and three inner petals. The inner base of the flower is bright red in colour.

During summer and autumn, pond apple produces roughly spherical fruit, 5–15 cm in diameter, with the appearance of a smooth-skinned custard apple (*Annona cherimola* x *Annona squamosa*). The ripe fruit falls from the tree when yellow or orange, and turns black on the ground. The flesh turns orange at maturity. Each fruit contains 100–200 seeds that are similar in size and shape to pumpkin seeds.

Dan Skean Jr

Dan Skean Jr

▲ Although flowers are inconspicuous on the tree they have a colourful inner base

M&S Setter

◀ Pond apple petals, leaves, fruit and seed

Reproduction and spread

Trees begin to flower and produce fruit when they are around two years old. The main flowering period is from December to February, with fruit formation following in January to March. From February to April, the fruit falls from the tree and matures on the ground. Sporadic flowering and fruiting can also occur at other times of the year.

Pond apple's massive seed production allows it to rapidly form dense thickets. In some infested areas, seeds have been found to form a 20 cm-thick carpet on the ground (CRC for Australian Weed Management 2003). Studies have shown that, in areas where movement of water has caused debris accumulation, the seed bank holds over 20 million potentially viable seeds per hectare (Brookes 2001). Pond apple seeds are, however, relatively short-lived and when conditions are suitable, seed banks can be rapidly depleted through mass germinations within six months of fruit fall (Setter et al 2004). Trials have proven that few pond apple seeds survive for longer than one year in the soil, with the seed bank being completely depleted within three years, provided that no new seed input occurs.

Ian Holloway

A thick carpet of seeds may be found in infested areas

M&S Setter

Research is currently being undertaken into the role of ocean currents in seed dispersal

Pond apple seeds are spread mainly by water. Both the seeds and fruit float and remain viable for many months in fresh to saline water, and germination can occur in fresh or brackish situations. The success of seed dispersal can be attributed to the fruiting period coinciding with the wet season when flooding is common. New infestations occur when flowing water and floodwater transports seeds and fruit downstream. In addition, flooding can cause water to backup in rivers and streams causing infestation of upstream areas and floodplains. Generally, infestations resulting from flood events are characterised by patches of similar-sized trees, whereas infestations in tidal areas tend to range in size due to the constant tide ebb and flow (Holloway 2004). Pond apple is dispersed most efficiently in river systems that have a broad floodplain.

Ocean currents also play a role in the dispersal of pond apple. Infestations are often found on the northern peripheries of bays and inlets-indicating that seeds have been transported northward along the coast from river mouths. Seeds often germinate above the high tide level on the beach when deposited during flood events, king tides, or tidal surges. Seedlings may germinate below the high tide level; however, they generally do not survive subsequent high tides. Survival to maturity on beaches tends to be isolated; however, these individual plants could contribute to further pond apple spread.

Animals also spread pond apple seeds, as the fruit provides a food source for the endangered southern cassowary, feral pigs and possibly flying foxes. Research into seed dispersal by animals found that cassowary droppings contained up to 842 seeds and feral pig droppings contained up to 288 seeds (Setter et al 2002). While this study suggests that most of the ingested seeds are passed from the animals while they are still in the vicinity of the infested area, it also indicates that feral pigs may distribute seeds up to 10 km away and cassowaries up to 1.2 km away. Cassowaries and feral pigs can therefore contribute to accelerating the increase in density of existing infestations, and may disperse seeds to areas where water cannot, such as upstream from infested areas and beyond the infested catchment. There appears to be strong evidence that flying foxes may also transport the seeds of pond apple. While no research has been done to determine a positive link between pond apple dispersal and flying foxes, it is considered worthy of further investigation.

Ian Holloway

▲ Animals such as feral pigs disperse seeds in their droppings

Ian Holloway

▲ Cassowaries feed on the fruit of pond apple

M&S Setter

▲ The role of the flying fox in seed dispersal is currently being studied

Ian Holloway

▲ Pond apple thrives in both fresh and salt water

History of spread

Pond apple is native to the swamplands of tropical North, Central and South America and to West Africa. It was first recorded in Australia in 1886 at the Cooktown Botanic Gardens; however, it was not until 1912 that the weed was imported into Australia as grafting or root stock for the commercial production of custard apple. Pond apple was considered useful as grafting stock due to its salt and water tolerance. A large number of existing infestations can be traced back to farms, orchards and domestic gardens.

Pond apple has become naturalised in areas of Asia including Sri Lanka, Thailand, Vietnam, the Malay Peninsula and possibly China.

Distribution and potential spread

The 2000 hectares of the Wet Tropics bioregion in North Queensland currently covered by pond apple includes areas from Ingham to Cooktown. Pond apple has also been found as far south as Bushland Beach near Townsville and as far north as Cape York Peninsula and Horn Island in the Torres Strait. Major infestations occur in the Murray, Tully, Johnstone, Russell and Mulgrave catchments, and the Daintree and Cooktown lowlands. Individual plants have been reported in northern New South Wales and in gardens in Darwin. To date, pond apple has invaded 14 protected areas and 10 Wetlands of National Significance (ARMCANZ et al 2001).

▼ Figure 1: Current distribution of pond apple in North Queensland

Predictive modelling programs have identified that areas most at risk of invasion by pond apple include the estuaries and floodplains on the north-eastern side of Cape York Peninsula, Gulf of Carpentaria river systems, the wetland areas of the Top End (including Kakadu), and the coastal strip from Cape York to Bundaberg. Limited data means that, in reality, pond apple may successfully grow in more areas than currently predicted. While temperature does not seem to be a critical factor in pond apple survival, the plant requires temperatures of above 25 °C for seed germination. Further research into the temperature ranges for germination will improve predictive modelling.

Pond apple requires moist soil with regular inundations of fresh to brackish water. It can withstand periods of flooding, with its roots under water for weeks at a time; however, it does not appear to survive permanent inundation. Areas particularly susceptible to infestation by pond apple are disturbed habitats, such as areas affected by cyclones or flooding.

Ian Holloway

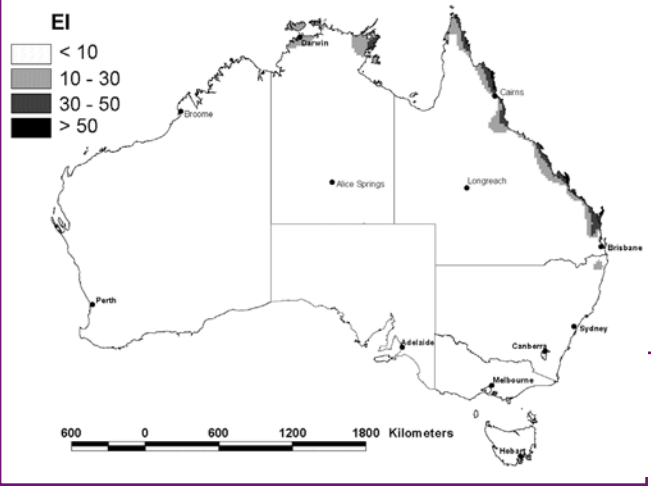
▲ Pond apple trees and seedlings in a melaleuca forest

In Australia, infestations have been found in:

- creeks, river banks and floodplains
- wetlands, including melaleuca and pandanus swamps and sedge lands
- mangrove communities and beach high tide litter zones
- rainforest areas
- agricultural drainage systems.

In particular, melaleuca wetlands and *Heritiera littoralis* mangrove communities are at risk.

Although pond apple is opportunistic and tends to establish in disturbed areas, it can also establish itself in relatively undisturbed environments. Pond apple can germinate in semi-shaded conditions where the seedlings lie dormant until a gap in the canopy is created.



◀ Figure 2: Potential distribution of pond apple in Australia

(Data is splined from a CLIMEX prediction. EI = Ecoclimatic index: EI < 30 potential for permanent population low, EI > 50 potential very high).

The impacts of pond apple

Pond apple is considered to be the most serious threat to the Wet Tropics bioregion (Werren 2001). Already, pond apple has caused a number of the wetlands to become endangered or restricted bioregional ecosystems.

Pond apple forms a dense understorey or subcanopy, competing with ferns, grasses, shrubs and sedges, and preventing regeneration of native species. Dense infestations can result in the replacement of mature stands of melaleuca with a monoculture of pond apple. The invasion of pond apple into native communities creates an undesirable habitat for wildlife by replacing food, breeding sites and shelter. Many infested ecosystems are habitat for rare and threatened flora and fauna, including the vulnerable ant plants (*Myrmecodia beccarii*) that host the larval symbionts of the endangered Apollo jewel butterfly and endangered orchids (ARMCANZ et al 2001).

▼ Thickets of pond apple outcompete native vegetation

Ian Holloway

Peter Van Haaren

▲ Monocultures of pond apple can shade out the understorey

Seed dispersal by animals makes locating new infestations difficult, particularly as pond apple can establish in areas where little or no disturbance has occurred. Seed may be dispersed within and between catchments, and germinations and survival of seedlings to maturity may remain undetected in remote areas or infrequently visited sections of a property. Infestations in these areas act as a seed source for the further spread of pond apple.

While pond apple is primarily considered an environmental weed, it is becoming a threat to the cane and cattle industries as it thrives along fence lines, farm drains and creeks. In the past, landholders have allowed self-seeded pond apple to grow to stabilise creeks and riverbanks and to suppress weeds in cane drains. Invasions of low-lying agricultural land may occur from these areas during flood events.

Pond apple affects the tourism industry by spoiling outlooks and degrading visual amenity by creating muddy monocultures in creeks and intertidal areas. It also destroys ecosystems, particularly in national parks and conservation areas. Thickets of pond apple restrict access and the movement of animals, humans and vehicles, and its control can be costly.

Ian Holloway

▲ Pond apple is also commonly found along fence lines

▼ Drainage lines are susceptible to infestation

M&S Setter

M&S Setter

▼ A mass of pond apple seedlings can result in many pond apple trees

M&S Setter

Ian Holloway

Section 2

Managing pond apple

A national approach

To tackle the current and potential threat of pond apple, a national strategy was launched in 2001 with the vision that in 20 years the weed will be eradicated from Australia. The aim is to deliver four desired outcomes:

1. The community becomes aware, committed and skilled to take action against pond apple.
2. The current distribution of pond apple is mapped and its potential spread is prevented.
3. Pond apple infestations are removed using environmentally safe best practices resulting in restored sustainable ecosystems.
4. Pond apple management is coordinated and maintained nationally.

The strategy, documented in the Weeds of National Significance Pond Apple Strategic Plan, is led by the Pond Apple Management Group. This group comprises agency and community representatives and is responsible for overseeing and monitoring the implementation of the national strategy.

Planning

Any control program should be planned well to ensure that the best possible results are achieved with minimal cost and effort. To do this, it is necessary to have a realistic view of how pond apple impacts on overall property management. Planning takes place at a number of levels: from paddock to property level; at local government level through the development of local government pest management plans; at catchment level; and at a regional level through regional strategy groups. To help create a greater sense of involvement, it may be advantageous to involve others who are directly affected by pond apple.

A successful plan cannot be developed in isolation from other property operations and must be integrated into the overall property management plan. The management principles suggested in this manual for the control and eradication of pond apple can be applied to other weeds on a property and, ideally, strategies for management of all weeds should be included in a single plan. It is recommended that a weed control plan have at least a 5–10 year time frame and be reviewed annually.

A range of planning processes can be adopted to develop a weed control plan. The following suggested control and eradication plan has six steps.

Step 1: Identify and prioritise problem areas

- Use a map of the property to identify problem areas. This can be a satellite image or an aerial or hand-drawn map. The more accurate and current it is, the easier it will be to calculate control costs, and to track the long-term effectiveness of control programs.
- Use separate transparent overlays when developing maps—one to indicate property improvements, one for vegetation types and natural features, and another devoted solely to weed infestations. Using different overlays can make each section of the map easier

to interpret and can also be helpful when making management decisions (e.g. determining the best place to put fences).
- Outline all natural features, improvements and property boundaries on the map, then indicate areas of pond apple, noting the size and density of each infestation.
- Prioritise the areas for control or eradication at the property level and at a paddock-by-paddock level, keeping in mind features outside the property such as seed sources, seed dispersal routes or vulnerable areas.
- Start controlling small, isolated outbreaks before tackling the main infestation. This may be the best approach when confronted with a large infestation.
- Consider all legal or ethical responsibilities (e.g. the threat of pond apple to neighbouring properties).
- Consider relevant local government, catchment or regional priorities and plans.
- Focus initial control efforts on isolated outbreaks to help prevent infestations from spreading. A rule of thumb is to start with the area that will be easiest to control and then gradually work towards the thicker patches.

Ian Holloway

Step 2: Determine the control options

- Identify what resources are already available or affordable, such as spray equipment, machinery and labour. This will indicate which control methods will be the most economic and beneficial.
- Decide which methods will be required at all phases of the program—initial control, follow up and ongoing monitoring.
- Decide which method of pond apple control is most appropriate in the given situation. It may be necessary to use a combination of methods to complete the job effectively.

Step 3: Develop a financial plan

- Estimate the cost of the management strategies and control options.
- Evaluate the costs of the chosen methods in relation to those of other operations currently occurring on the property to ensure that they are economically viable.
- Integrate these costs into short and long-term property budgets.
- Find out if there are any financial incentives available to assist with control programs.
- Consider all costs (including the hourly running costs of machinery and labour). If necessary, seek advice from local government or departmental weeds officers before committing a large amount of money.
- Take into account the cost of future control—this is frequently underestimated.

◂ Focus initial efforts on isolated outbreaks

Step 4: Schedule activities

- Consider how effective various control methods will be at different times of the year and balance this with the time available for carrying them out.
- Try to integrate weed control with other property management activities (e.g. combining a routine burn with the control of pond apple).
- Schedule any weed control activities for the year.
- Make pond apple control a regular part of property management. When developing a plan, allow for monitoring and follow up after the initial treatment, and ensure that follow-up occurs within a year.

Step 5: Monitor progress—an integral part of any control program

- Monitor to check how a treatment worked, identify areas of regrowth and find out where follow-up treatment is required.
- Use the property map as a starting-point record of the problem before any control work has commenced.
- Show any new or previously treated areas of infestation on the map.
- Take several photographs from the same point over time to show any changes resulting from control work.
- Document control costs and resource requirements.
- Incorporate monitoring activities into the yearly timetable.

Step 6: Follow up what was started

- Use appropriate control methods to follow up previous pond apple control. This is necessary as not all control methods result in 100 per cent kill. Also, some seed germination and regrowth is likely.
- Identify areas, from the monitoring sites, where follow up is needed.

Helpful tips

- As there is no 'quick fix' for weed control, developing a management plan and implementing it are essential for the long-term effectiveness of pond apple control.
- Any control plan is useless without implementation. If the problem area is large or the land manager lacks weed control experience, planning may be difficult. It is therefore advisable to seek professional advice or start on a smaller scale.
- While the plan must be structured, it needs to be flexible enough to allow for changes brought about by uncontrollable external influences such as drought and fluctuating commodity prices.
- The plan must be reviewed annually to assess the effectiveness and efficiency of the control options and strategies implemented.

Section 3

The toolbox

Pond apple control considerations

The two most cost-effective methods of managing pond apple are the prevention of infestation and early intervention. Although in the long term, prevention is the best way to control weeds, this is not always possible. In the case of pond apple, natural means—water and animals—easily disperse seeds. New infestations must therefore be identified quickly and controlled before they become widespread.

Large, mature specimens, often found in remote and undisturbed locations upstream from infestations, pose a major challenge to managing pond apple. These isolated trees act as a seed source for future infestations or can reinfest treated areas.

As identified in the national strategy, community awareness of the impact and seriousness of pond apple is essential. When community members can identify pond apple, the detection rate of presently unknown infestations increases. As pond apple may be confused with some mangrove species, positive identification should be sought prior to undertaking any treatment. If unsure about the identification of pond apple, contact the local government weeds officer.

Access to infestations presents another challenge to pond apple control. Infested areas often include crocodile habitat; isolated and inaccessible upper reaches of catchments; muddy, inaccessible intertidal areas; and infrequently visited areas of a property.

Ian Holloway

▲ Yellowing of leaves can help to locate infestations

The best time of the year to undertake control is during the dry season (August to November) when access to waterways and wetlands is easier. This is the ideal time to remove all plants that have germinated from the previous fruiting cycle, as it will maximise the amount of seed taken out of the system. The control of mature trees before they fruit will also reduce the amount of seed added to the seed bank (Holloway 2004).

Control work should start at the top of the catchment or the uppermost section of the river, creek or waterway. This will prevent seeds being transported into previously treated areas downstream. Reinfestation of downstream areas is best prevented through a coordinated catchment effort.

In North Queensland coastal situations, the role of ocean currents in the transport of seeds northwards along the coast suggests that control efforts should begin at the southern end of the infestation (Setter et al. 2002).

The environmental integrity of the infested area must be considered when choosing control methods, as pond apple is often found in mangroves, rainforest and riverine areas where the use of herbicides, heavy machinery or fire may not be appropriate. The least disturbance of sites and the establishment of native vegetation soon after weed control will minimise the risk of erosion and invasion by other weeds.

In some areas, pond apple has become an important cassowary food during the fruiting season. In these situations, it may be appropriate to stagger treatment over time and to revegetate with native cassowary food plants that can provide food throughout the year (Setter et al. 2002).

Experience in controlling pond apple in melaleuca woodlands has shown that, once the weed is controlled, the natural vegetation is able to regenerate on its own.

Ian Holloway

▲ Access to infestations may be a control constraint

Ian Holloway

▲ Consider the risk of erosion, as some trees may help stabilise banks

The use of fire, biological, chemical and mechanical methods of control are outlined on pp. 20–30. It is common for land managers to trial various methods and assess the results in a particular situation and, in effect, learn by experience. Instances of this are described in the case studies where several landholders discuss how they have tried different approaches, have adopted some for wider-scale control, have modified some, and have abandoned others.

Ian Holloway

▲ Consider how cost-effective and practical chosen control methods are for the control of pond apple

Choosing control methods

When choosing control options, factors to consider include:

- size and density of the infestation
- location in relation to other pond apple infestations
- accessibility
- safety hazards such as crocodiles
- preferred method for applying chemicals
- resources available
- presence of non-target species
- life cycle stage of the plants
- time of year
- landscape features such as slopes and waterways.

It is important to consider how cost-effective and practical the chosen methods are. As the objective is not just to control pond apple, but also to restore the vegetation community to its original condition, the effect of control methods on other plants and on the soil after the pond apple has been killed must be taken into account.

Effect of plant density

The density of plant infestations will help determine the choice of control method.

Low density

Low-density infestations have a minimal effect on the environment, but there is still a real threat of the weed spreading. If left uncontrolled, these infestations can rapidly develop into medium or high-density infestations.

There are many cost-effective options available for control at this stage; however, locating the infestations may be time consuming.

Control methods should be chosen according to site topography, site access, and surrounding vegetation (particularly sensitive habitats).

Medium density

Medium-density infestations have a greater effect on the environment, competing with the native vegetation for space, light and nutrients.

Several cost-effective control options are available at this stage.

Depending on the vegetation community and the availability of fuel, infestations can be burnt and then followed up with appropriate methods.

High density

High-density infestations have an extreme effect on the environment and these dense areas provide seeds that spread into new areas.

To stop seeds spreading, small, selected parts of the infestation, located upstream, must be treated first.

Treatment can be more effective if infestations are divided into smaller, more workable areas.

Table 1 outlines recommended control options for various situations. Further details for these methods of control are outlined in this section.

Table 1: Guide for control methods

Tree size	Dense stands	Medium stands	Isolated trees
Seedlings (up to 1 m high)	Foliar spray Fire*	Hand pull Fire*	Hand pull Fire (to maintain area free from pond apple)
Small trees (stem diameter less than 10 cm)	Cut stump Foliar spray (smaller trees in clumps) Basal bark	Cut stump Fire*	Cut stump Fire (to maintain area free from pond apple)
Medium trees (stem diameter greater than 10 cm but less than 20 cm)	Stem injection Basal bark application Machinery	Stem injection Fire*	Stem injection
Large trees (stem diameter greater than 20 cm)	Cut stump	Cut stump	Cut stump

Adapted from Holloway (2004) and CRC for Australian Weed Management (2003)
*depending on available fuel loads

Control methods

Control methods for pond apple currently include chemical control, mechanical control and fire. Often, a combination of methods can be used to achieve effective control. For example, an infestation of mature trees may be treated using stem injection of herbicide, then followed up with hand pulling or a foliar application for subsequent seedlings. Follow-up treatment is essential to identify missed plants, regrowth and any problems with the initial control method.

To date, no studies have been undertaken in Australia for the biological control of pond apple. Other species in the same genera as pond apple are produced commercially in Australia. These include the custard apple (*Annona cherimola* x *Annona squamosa*), bullock's heart (*Annona reticulata*) and sweet apple (*Annona squamosa*). Also, the Wet Tropics region contains native rainforest species in the same family as pond apple. Any biological control agent would need to specifically target pond apple to ensure there are no impacts on commercially important or native species.

The control of blackberry, another Weed of National Significance, faced similar problems; however, a suitable species-specific agent was found. In the future, and after extensive research and investigation, biological control may be a tool in the control of pond apple.

Ian Holloway

Ian Holloway

▲ In this situation in the Eubenangee Swamp, control using the cut stump method provided access for stem injection

Chemical control

Herbicides can be applied to pond apple in a number of ways:

- into the stem (stem injection)
- to the stump immediately after cutting (cut stump)
- on the leaves (foliar)
- to the stem and bark on the lower stem (basal bark).

Table 2 lists the chemicals permitted for use on pond apple in 2006. The recommended herbicides require a 'minor off-label use' permit (permit number PER8297, valid Queensland only). This permit is in force from 28 April 2005 to 30 June 2010. Pond apple can also be controlled by chemicals prescribed under the environmental weeds permit (permit number PER7485, valid Queensland only) which is in force from 1 July 2004 to 30 June 2009. These chemicals are also listed in Table 2.

Table 2: Herbicides registered for use on pond apple

Application method	Chemical	Rate	Comments
Stem injection	Glyphosate (e.g. Roundup® Biactive)	500 mL/1 L of water mix	Apply to actively growing plants
	Triclopyr (100 g/L) + picloram (50 g/L) (e.g. Tordon* timber control herbicide)	200 mL/1 L of water mix	Do not apply to stressed plants
Cut stump	Triclopyr (240 g/L)+ picloram (120 g/L) (e.g. Access* Herbicide)	1.67 L/100 L of diesel	Do not mix with water; cut close to the ground and treat immediately
	Glyphosate (e.g. Roundup® Biactive)	Undiluted to 1L per 12 L water	Apply immediately after cutting
Basal bark	Triclopyr (240 g/L)+ picloram (120 g/L) (e.g. Access* Herbicide)	1.67 L/100 L of diesel	Do not mix with water; do not treat wet or charcoal-coated stems
	Fluroxypyr (e.g. Starane* 200 Herbicide)	1.5 L/100 L of diesel mix	Do not apply to stressed plants; do not apply if rain is likely within one hour; do not treat wet stems
Foliar	Imazapyr (e.g. Arsenal® Herbicide)	800 mL/100 L of water mix	See permit for critical comments
	Glyphosate (e.g. Roundup® Biactive)	1 L/100 L water	Spot spray for wetland/ aquatic areas

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For other states, refer to the relevant local government pest management officer or state agricultural or primary industries department (see Contacts on page 52).

Herbicides must be used with care; therefore, before use:

- ensure all permit conditions are met
- read the instructions and conditions for use on the label
- consider the possible impact on non-target vegetation and the surrounding environment.

It is important that all methods of chemical control comply with the relevant state and local government native vegetation legislation, and it should be noted that causing even accidental death of native vegetation could be a breach of this legislation.

In Australia, the Australian Pesticides and Veterinary Medicines Authority controls and regulates the use of pesticides, including herbicides. Chemical products are assessed for toxicity, efficacy, environmental impact, residues and any implications for occupational health and safety. By law, herbicides must only be used in accordance with label instructions or off-label permits.

Personal protective equipment (such as protective clothing, eye protection and respiratory protection) must be used, also in accordance with manufacturers' recommendations.

Ian Holloway

▲ Where pond apple trees are made up of fused multistems, all stems must be treated for effective control

Stem injection

Injecting herbicide into the stem of pond apple minimises herbicide run-off and subsequent impacts on the surrounding ecosystem. Stem injection is the recommended method for aquatic areas such as wetlands and mangroves, as it minimises off-target impacts.

There are two main methods of stem injection: axe cut (or frilling), and drill and fill.

The axe cut method

The axe cut method (also known as frilling) has proved to be a particularly effective and popular method to control pond apple in the Wet Tropics of Queensland. An axe, tomahawk or machete is the best tool for this method; however a 3/4 length axe with a curved blade of 5–7 cm is particularly suitable. Herbicide, usually carried in a 2.5 L or 5 L backpack, is injected using a low-volume drench gun.

To use the axe cut method, make horizontal cuts into the sapwood, 13 cm apart, around the circumference of the stem, as low to the ground as possible. While still in the cut, lean the axe or tomahawk out to make a downward angled pocket which will allow herbicide to pool. Then, immediately inject herbicide into the pocket. This is necessary because the plant can seal the cut quickly, preventing the herbicide from penetrating into the sap stream. A double row of cuts, with the second row placed under the spaces created by the first row, is recommended to achieve maximum kill rate. During spring, when the plant is actively growing, a single row of cuts may suffice; however, due to the effort required to re-treat, it is recommended that a double row is always used. Where low branches are encountered, place a cut immediately below the branch.

The drill and fill method

The drill and fill method consists of drilling downward angled holes using a powered drill. These should be 5 cm apart around the stem circumference. The herbicide is then immediately injected into the holes. Although more time consuming than the axe cut method, the drill and fill method has less potential for spillage of herbicide.

Ian Holloway

▲ Stem injection using the axe cut method

M&S Setter

▲ Stem injection using drill and fill

The requirement for a battery-powered drill and a ready supply of batteries or a suitable field recharge facility may render this option unsuitable since many infested areas are remote and only accessible by foot.

One of the challenges of treating pond apple by stem injection is that when stems fuse, or when individual trees form a multi-stemmed appearance, each separate stem requires treatment. Care should be taken to ensure each stem is sufficiently injected. Monitoring and follow-up work should be undertaken to ensure that treatment has been effective.

Stem injection is not suitable for large trees, since a large number of cuts are required for a successful kill. In addition, large trees are often made up of several plants fused together, with the stem of each plant requiring treatment.

Ian Holloway

▲ Equipment required for the axe cut method includes a brush hook, axe, injector gun and herbicide backpack

For herbicide application via stem injection, ensure that:

- cuts are made as low as possible
- cuts are deep enough to allow herbicide contact with sap wood
- herbicide is added immediately after the cut has been made
- an applicator, fitted with a tree injector kit that can be easily calibrated, is used
- herbicide does not run out the side of the cut when treating trees with stem width less than the width of the axe. Use the corner of the axe to make a pocket in the stem.

▼ Stem injection has been successful along drains

Ian Holloway

▼ All stems of multi-stemmed plants need to be treated

Ian Holloway

Ian Holloway

▲ Cut stump method is useful for multi-stemmed and large plants

The cut stump method

The cut stump method is an effective way of killing pond apple, and the risk of killing non-target species is low. Also, this method is efficient in the use of herbicide and is suitable for use along watercourses. However, it is costly in labour terms as it requires two people—one to cut the stems and one to apply the herbicide to the cut surface. The cut stump method is most suitable for use on large plants, scattered plants or plants in small, easily accessible infestations.

To use this method, cut horizontally through the stem as close to the ground as possible and apply herbicide immediately to the clean cut surface of the stump. For smaller trees, suitable cutting implements include a brush hook or machete but for larger trees, a chainsaw is required. Spray applicators or paint brushes are suitable for applying the herbicide, and placing a dye in the herbicide will mark which stumps have been treated. Ensure that the cut surfaces of felled portions of trees do not remain in contact with water, as resprouting can occur.

Young trees of up to 10 cm diameter are particularly suited to the cut stump method, as the soft timber makes them easy to fall. The method also suits larger trees over 20 cm diameter, as stem injection is not viable for this size tree. For large plants consisting of multiple fused stems and for multi-stemmed plants, applying herbicide to the cut surface will treat all individual stems.

Subsequent weed growth of the treated area is minimised if the pond apple trees are left to die in situ. The removal of cut or felled trees can result in destruction of suppressed native seedlings and disturbance of soil, which encourages weed germination.

▼ Ensure monitoring for resprouting and rerooting occurs following control using the cut stump method

David Phillips

David Phillips

Basal bark application

The basal bark method involves spraying or painting a herbicide and diesel mix around the circumference of the stem, from ground level up to a height of 50 cm. Suitable equipment includes a backpack spray unit with a directed nozzle.

This method is useful for dense infestations of pond apple plants that are not growing in or near water. Experience has shown that basal barking can be an effective, rapid method with more trees able to be treated per day in comparison with other methods.

After treatment, the trees remain standing and disintegrate quickly on site due to the low density of the wood and humid conditions. As a result, good regeneration of native vegetation often follows this method of treatment as soil disturbance and damage of suppressed native seedlings is minimal.

▼ For basal bark application, spray the plant around its entire circumference

Brendan Malone

M&S Setter

▲ Pond apple killed by basal bark spraying

Keys to successful basal bark application include the following:

- Apply the herbicide when the plant is actively growing.
- Follow the permit and only use on plants with stems up to 20 cm basal diameter.
- Ensure that all stems on multi-stemmed plants are treated.
- Spray thoroughly around the bark of the plant to a height of 50 cm.
- Ensure that the bark is thoroughly wetted so that the spray soaks in.
- Remove obstructing vegetation, debris or soil from around the stem so that enough chemical reaches the plant to kill it. This is important as pond apple-infested areas are often subject to flooding.
- Keep the spray pressure low and use a nozzle with a directed, rather than a fan pattern. If the spray droplets are too fine and misty, insufficient chemical will reach the plant.
- Do not apply to wet stems, as water can repel the diesel mixture.
- Do not apply to trees standing in water.
- Use a marker paint or dye to indicate which plants have been treated.
- Follow up.

Foliar application

Foliar application of herbicide is particularly useful for dense monocultures of young plants up to 1 m tall where there is no risk of damaging native vegetation. The method is not suitable for trees growing in water or near sensitive habitats due to the potential for contamination.

The appropriate equipment for foliar application will depend on the size, height, density and extent of the infestation. Hand-held or backpack spray units will be sufficient for the majority of pond apple infestations; however, quad bike or tractor mounted spray units with extension hoses may also be appropriate in some situations.

Important factors to consider for using foliar application include the following:

- Spray when plants are actively growing.
- Avoid spraying when the plant is stressed or fruiting.
- Spray plants thoroughly to the point of run-off, wetting every leaf. Do not spray past the point of run-off.
- Do not apply to trees greater than 2 m in height.
- Check weather conditions to ensure that spray will not drift onto wetlands, natural surface waters, soil, neighbouring properties or other sensitive areas.
- Use appropriate spraying equipment to prevent chemical drift.
- Do not spray if rain is expected within 48 hours. Rain may cause herbicide run-off and reduce the effectiveness of the application.
- Monitor and follow up.

If Arsenal herbicide is used for foliar application, care must be taken around off-target vegetation. A condition of the 'minor off-label use' permit is to notify the National Registration Authority for Agricultural and Veterinary Chemicals of any off-target contamination or damage associated with the use of Arsenal® herbicide for foliar application.

▾ Foliar application of herbicide is suitable for dense seedlings

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Ian Holloway

▲ The shallow root system of pond apple aids mechanical control.

Ian Holloway

▲ Mechanical control is particularly suitable for flat areas

Mechanical control

Mechanical options for clearing pond apple infestations include hand pulling, chain pulling and dozer pushing. Mechanical control is generally not suitable for areas such as creeks, gullies, wetlands or inundated areas; however, it may be suitable for flat country and for areas free of sensitive vegetation where machines can manoeuvre easily.

Pond apple has a shallow root system, so trees up to 1.5 m tall can be hand pulled, especially in damp conditions. Ensure the roots of pulled plants do not have contact with the soil after pulling, otherwise the plant may resprout. One way to prevent resprouting is to hang the pulled plants upside down in remaining vegetation.

The use of machinery to push dense monocultures into windrows can be a cost-effective solution. Windrows should then be burnt to prevent the resprouting of stems lying in contact with the soil. Monitoring and follow-up are essential after control using machinery, as clearing creates an ideal seed bed for germination of weeds.

Native vegetation can be damaged, either intentionally or accidentally, with mechanical methods. Persons undertaking mechanical control of pond apple must comply with the relevant state and local government native vegetation legislation.

In addition, mechanical methods of control may cause soil erosion. The impact of mechanical weeding must be considered and steps taken to minimise the likelihood of erosion, particularly around agricultural drains and ditches.

Fire

Fire can be a cost-effective method of controlling pond apple, although it is not appropriate in many situations. Its use is frequently limited by a lack of fuel load and concern about non-target environmental effects, particularly in rainforest and mangrove habitats. In addition, fire is highly dependent on the presence of suitable moisture and weather conditions. It is most effective for removing regrowth in sclerophyll communities following control of larger trees by one or more of the other methods.

For control using fire, sufficient fuel is required; however, this is often not available in pond apple infestations. Experience has shown that a mild fire will kill small trees but an intense fire is required for larger trees. Generally, thickets of larger pond apple trees shade out the understorey, preventing growth of sufficient fuel needed for a successful fire. Also, pond apple thrives in wet areas that will not sustain fire, such as intertidal zones and drainage lines.

Fire is best used to control pond apple in the following situations (Holloway 2004):

- to maintain melaleuca woodlands
- to remove pond apple regrowth in woodlands
- to remove pond apple seedlings in sedge lands
- to destroy pond apple following mechanical control (i.e. burning windrows of felled plants), or chemical control.

Providing the entire circumference of the plant is burnt, fire will effectively kill pond apple and the plant will not resprout. Depending on its intensity, a fire can destroy seeds lying on the ground; however, seeds that have fallen into cracks or are lying on moist soil where the fire cannot burn can remain viable. Follow-up work is therefore generally required to control seedlings that germinate following fire, or to control any patches that did not burn. Hand-pulling, foliar herbicide application or reburning are useful follow-up control methods for subsequent pond apple germinations. Note that reburning depends on the presence of suitable conditions.

▾ Pond apple following fire

David Phillips

Ian Holloway

▲ Lack of fuel means many infestations cannot be burnt

Using fire to control pond apple can alter the land's natural fire frequency. This can have a significant impact on the native vegetation that landholders are trying to protect or save by controlling the weed. The consequences of using fire must therefore be carefully considered. For example, sedge lands have a longer fire cycle than grasslands and therefore should not be burnt as often. Frequent fires can alter pasture and understorey compositions, increase soil erosion, lead to loss of nutrients and favour fire tolerant species that may be other weeds.

Other important questions to ask when planning to control pond apple with fire include the following:

- What is the desired outcome?
- When is the best time to burn?
- What is the seasonal weather outlook? (Check the Southern Oscillation Index.)
- What fuel load is required? (Remember that the greater the fuel load, the higher the potential for a high-intensity fire.)
- Is it possible that non-target vegetation may be killed? Ensure you comply with government vegetation management legislation.
- What safety precautions are required (e.g. firebreaks)? Remember that the risks associated with fire can continue for some days after a controlled burn.
- When will follow-up operations be required?
- Has a permit to burn been obtained from the fire warden?
- Have the neighbours been notified?

M&S Setter

▲ Future research is planned to investigate the effect of fire temperature on pond apple seeds

Monitoring, follow-up and revegetation

Although the methods of control detailed previously have achieved good results in the right situations, monitoring and follow-up treatment are essential for any weed control project. Sometimes plants are missed, errors occur during the mixing or applying of chemicals and other factors may reduce the overall kill achieved. Returning to the site after initial treatment or follow-up work will reveal areas where treatment has been ineffective. Also, subsequent seedling germinations or reinfestations will be seen. Follow-up treatment will then be required to prevent new seedlings from maturing.

Monitoring and follow up are particularly important for pond apple, as each stem of multi-stemmed plants can survive independently and subsequently produce fruit. In addition, it is possible for whole trees or patches to be missed during treatment, particularly in very dense infestations and in areas that are difficult to traverse.

Given pond apple's maturity age and seed longevity, it is recommended that monitoring and follow up be undertaken within at least 2 years of treatment. It is also recommended that monitoring continue for a further 5 years to prevent reinfestation of the treated areas from other sources. More frequent monitoring and follow-up over a longer period will result in more effective control. Careful management of funds is necessary if a suitable monitoring and follow-up program is to be implemented.

Hand pulling, foliar spraying and fire are useful follow-up methods for controlling seedling germinations after treatment. Fire, in the right situation, is a particularly useful tool for following up after chemical and mechanical control. After the death of pond apple trees treated with herbicides, the newly opened canopy allows for the regrowth of native grasses and understorey species. This provides sufficient fuel for a fire to burn subsequent pond apple germinations, or any surviving trees.

Foliar application of herbicides and hand pulling are particularly useful to control seedling germinations after fire.

Where seedlings or juveniles of native vegetation, particularly melaleuca, have been suppressed by the canopy of a pond apple infestation, replanting or reseeding may not be required. Removing pond apple trees and seedlings can result in successful re-establishment of native vegetation through natural means. Rapid control of pond apple is imperative in these areas to prevent the native vegetation from being out-competed and unable to re-establish itself naturally.

Leaving treated plants to die in situ can assist in revegetation by minimising the destruction of remaining native vegetation. Pond apple's low wood density, combined with the warm, humid climate of the wet tropics, causes treated plants to rapidly disintegrate. Dead stems can degrade within 2 years, and after 4–5 years of treatment there is often no sign of the weed having infested the site.

Where sites are prone to erosion and weed establishment after treatment (e.g. after mechanical control), areas should be replanted using local native plant stock. This is particularly important along drainage lines and in agricultural areas where pond apple may have been retained to prevent soil erosion. If the previous native vegetation of a treated site is unknown, some suggested species include (Holloway 2004):

- *Acacia celsa*—Brown salwood
- *Archontophoenix alexandrae* —Alexandra palm
- *Cyperus* spp—Sedges
- *Hibiscus tiliaceus*—Coast cottonwood
- *Melastoma affine*—Blue tongue
- *Melaleuca viridiflora* —Broad-leaved tea tree
- *Pandanus* spp—Screw palm.

Pond apple has become an important food source for some populations of cassowaries at certain times of the year, especially in areas where the weed has replaced their native food source. It is important to include cassowary food plants in a revegetation program in these areas.

M&S Setter

▲ Further germinations may occur following treatment

Section 4

Case studies

Pond apple control in North Queensland is mainly undertaken by local shires and government organisations such as the Queensland Parks and Wildlife Service. Few landholders have been involved in the treatment of pond apple to date, largely because the weed does not generally impact on normal farming practices.

The following case studies highlight the problem of pond apple in North Queensland, include accounts of various control methods, and explain why these methods were used. One common theme in all case studies is the difficulty of access to pond apple infestations and the hazards faced by operators when treating pond apple.

Not all North Queensland shires are featured in the case studies but most employ similar practices. It is interesting to note that some shire councils, such as the Johnstone Shire Council, have incentives for landholders to control pond apple by offering free native trees under 'pond apple replacement programs'.

The case studies are the result of consultation with people who have been involved in controlling pond apple and who have generously donated their time and photographs for this publication.

▾ Pond apple is able to germinate and grow in unfavourable conditions

Ian Holloway

Ian Holloway

Slow and steady progress throughout the catchment

Cardwell Shire Council

Background

The Cardwell Shire, between Cairns and Townsville, is part of Far North Queensland's coastal region. Over 60 per cent of the shire is protected by its location within World Heritage listed areas, National Parks, state forests and other environmental reserves. High rainfall has made this area ecologically diverse and forest types range from thick lowland rainforest and wet sclerophyll forests to permanently inundated swamps and wetlands. It is thought that pond apple was planted around 1915 on Bellenden Plains, just west of the highway on the Murray River, as a rootstock for the commonly cultivated custard apple. Since then, pond apple has spread towards the coast, up to 20 km further inland, and into neighbouring creeks and rivers.

The threat

Pond apple is found extensively throughout the Upper Murray wetlands and throughout the entire Murray River area. Its spread is aided by water movement, when the whole region between the Tully and Murray rivers (the Tully–Murray floodplain) is inundated. Pond apple is also spread by cassowaries, fruit bats and feral pigs in areas not reached by flood waters. At present, pond apple is thought to have invaded at least 1500 hectares of native bushland, but further surveying may show a greater area. Most of the infested country consists of permanently wet melaleuca swamps and riparian zones.

▾ Very large multi-stemmed trees have been found in the Cardwell shire

Damon Sydes

Pond apple control

Prior to 2003, the only control of pond apple was carried out on council reserves. Following a successful bid in 2003 for Australian Government Weeds of National Significance (WONS) funding, council staff were trained by the Queensland Parks and Wildlife Service to map, detect and control pond apple.

Pond apple treatment has since commenced in the upper catchment and is being conducted in conjunction with surveying and mapping of the region. The aim of the shire is to first eradicate any upstream sources of pond apple before looking at the lower catchment. To date, over 500 hectares of land in the Cardwell Shire have been cleared of pond apple.

Control is undertaken on a catchment basis and is not limited to council land, although these areas are a priority. Infestations on private land are also controlled to prevent the reinfestation of other treated areas.

▼ Stage 1 of cutting down large trees

Damon Sydes

Damon Sydes

▲ Stage 2 of cutting large trees—final cut is made much lower on stump

Control methods

Initial control involved stem injection using the herbicide Tordon* and the axe cut method (frilling). Only 70–80 per cent kill was achieved, mainly due to difficulties in achieving enough overlap of axe incisions around the stem. This method required skilled operators and was not suitable for the many multi-stemmed trees encountered.

Operators expressed concerns about Tordon*, including distortion of surrounding vegetation and the length of time it took for this herbicide to kill large trees—in some cases two or three months. This allowed the trees to complete a fruiting cycle and potentially reinfest other areas.

The shire now uses the cut stump method for pond apple control and has replaced Tordon* with glyphosate, which is cheaper and considered safer, thus making it more acceptable for use in the environment.

The Cardwell Shire claims effective control when using glyphosate with the cut stump method. Cardwell Shire pest management officer Damon Sydes considers this method the most reliable. He says, 'a down tree is dead—or at least it won't fruit again this year'.

The cut stump method involves cutting down large trees with chainsaws and smaller trees with axes, cane knives or lopping shears. Operators carry 5 L injector packs and the cut surfaces are treated immediately. Cardwell Shire plans to trial the herbicide gel Vigilant* (active constituent 43 g/kg picloram) as a safer and cleaner method of control for both operators and the environment.

It was often necessary to cut the very large multi-stemmed trees twice; firstly to cut down individual trees, and secondly to cut lower down on the trunk. The second cut was then treated with herbicide.

All treated areas are followed up regularly; however, little weed regeneration is found in treated areas. Seedlings are generally pulled out by hand. Currently, fire is being considered as a follow-up control method in certain areas once the established infestation is removed.

The shire has also tried basal barking pond apple, using a Starane* and diesel mix or glyphosate. Trials resulted in poor control of multi-stemmed trees, and the use of diesel posed a serious safety issue for operators and was not deemed acceptable in environmentally sensitive areas. Therefore, basal barking is no longer practised in the shire.

Working conditions and hazards

The main problem in the Cardwell Shire is accessing infested sites. Pond apple infests areas surrounding fringe lagoons, located in virtually impenetrable country due to thigh-deep mud and head-high bulkuru sedge. Other hazards include snakes, crocodiles, mosquito-borne diseases and Weil's disease (leptospirosis). Paper wasps, scrub itch, insects and spiders are frequently encountered. High temperatures, extreme humidity and rough terrain make this a physically demanding and arduous job, especially as the worker needs to carry chainsaws and axes.

A down tree is dead—or at least it wont fruit again this year

The Cardwell Shire Council uses the services of Conservation Volunteers Australia (CVA), local Indigenous volunteers and landholders in its battle against pond apple. These volunteers provide the much needed additional labour to control the weed in the shire.

The challenge

The Cardwell Shire Council is gradually and steadily controlling pond apple within the catchment. While they have made good use of current resources by combining surveys with pond apple control, the full extent of the pond apple threat and the funding needed to combat it are currently under review.

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Large multi-stemmed trees on Ron's property will take time and resources to control

Kate Charleston

A cane farmer's approach

Ron has observed pond apple seedlings germinating in both cassowary and pig dung in his ratoon cane

Ron and Val Zamora have been farming sugar cane on the Tully–Murray floodplain since 1964. Their cane farming enterprise expanded in 1994 when they acquired a second property adjacent to the Murray River. With this purchase, they inherited a major pond apple problem.

Most of the pond apple on the newly acquired property occurs in the riparian zone and does not interfere with normal cane farming practices. However, Ron has observed pond apple seedlings germinating in both cassowary and pig dung in his ratoon cane.

'These do not survive due to farm management practices, which include weed control', Ron said.

Pond apple has also germinated in farm drains, which Ron controls with glyphosate as part of his drain management program.

In October 2003, Ron attended a pond apple workshop organised for landholders and council staff by the Department of Natural Resources and Mines, Queensland Parks and Wildlife and the Cardwell Shire. Ron wanted to learn about pond apple control as he was aware of the serious nature of the weed infesting large sections of native vegetation along the river.

Ron has since sprayed smaller trees with glyphosate and slashed some of the pond apple along the edges of bush that make up the riparian zone. Although continued slashing has proven effective, it does not kill large trees. He believes basal barking to be the best and most cost-effective way to eradicate large trees. As a cane farmer, Ron has the equipment and skills to implement basal barking, but understands that as many of the trees are multi-stemmed, basal barking may not provide 100 per cent control.

Ron wants to eradicate pond apple to preserve the bush for future generations. 'I believe it can be done but it will take time as well as resources', he said. Ron encourages other landholders to control pond apple on their properties. Unless they do, all Ron's hard work will be compromised when the next flood spreads a new seed bank throughout the area.

Kate Charleston

Ron Zamora surrounded by young pond apple plants

Pond apple control helps preserve the natural heritage of Eubenangee Swamp National Park

Background

The Eubenangee Swamp National Park, near Innisfail, forms part of the coastal floodplain fed by the Russell and Alice rivers and Canal and Dinner creeks. The national park covers approximately 2000 hectares and provides important habitat corridors linking the park to the nearby Graham Range and Wet Tropics World Heritage Area. The Eubenangee Swamp has international significance as a unique example of a high rainfall wetland developed on nutrient-rich basalt deposits. A number of rare and threatened plant species are found within this ecologically sensitive area.

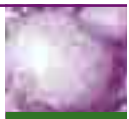
The threat

Wetlands are highly susceptible to weed invasion when disturbed. The park lies within a heavily developed agricultural landscape and was disturbed by former land uses. Poor understanding and inadequate management of the wetlands prior to 1977, when this area became a national park, contributed to a vast infestation of pond apple (and other weeds).

Pond apple grew in all open habitats of the park, including grasslands, melaleuca-dominated swamps and along the edges of rainforest. The Eubenangee Swamp is part of the lower catchment and remains subject to infestation of pond apple seeds from rivers that flow into the swamp.

Fire management in Eubenangee Swamp

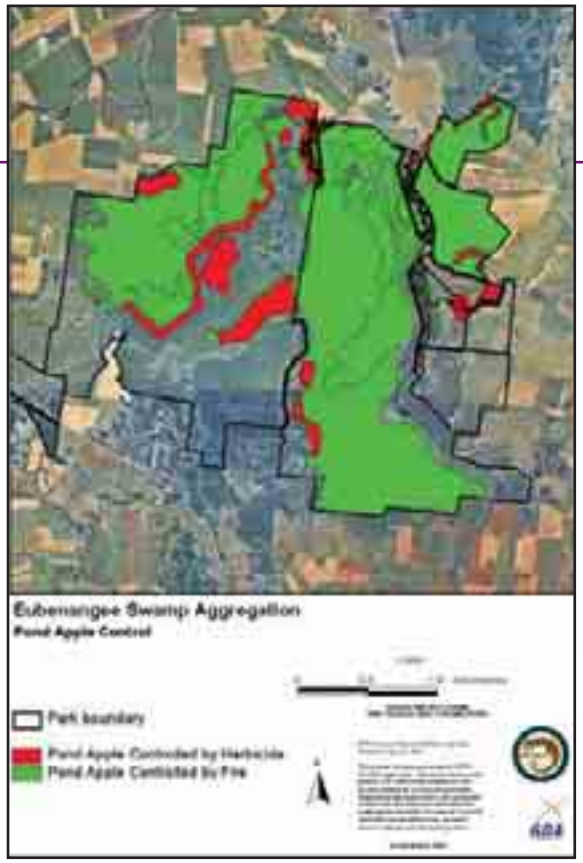
Controlled burning in the Eubenangee Swamp was first carried out in 1984, making it the first national park in North Queensland to implement a fire regime. Maintaining an established fire regime is now a vital part of land management in the park as it helps maintain ecological processes and protect threatened communities and species. The native grasslands in the swamp begin to decline after 3 years, but fire, used every 3–5 years, is a catalyst for regeneration in these highly sensitive grasslands. Areas that contain native sedges and melaleuca are burnt every 6–10 years.



Fire is the most economical means of controlling pond apple. Figure 3 shows the large areas controlled by fire. A medium-intensity fire will kill juvenile pond apple without destroying native vegetation such as melaleucas. Large pond apple trees can only be killed by a high-intensity fire, and such fires can only be used where they do not threaten native vegetation. Any pond apple trees that survive a fire will need to be treated by chemical means. The use of fire in the park has the additional advantage of opening up areas that are difficult to access.

Unfortunately, it was found that long-established thickets of pond apple were largely resistant to fire because their dense shade had prevented growth of ground cover that could carry a fire. These dense stands of pond apple had to be controlled by chemical means.

Fire as a means of weed control in the park often required rapid decision making and actions, to take advantage of the weather conditions suitable for fire. For example, burning could not be undertaken in wet conditions; however, provided there was enough dry fuel, the presence of some surface water was desirable as very dry conditions resulted in peat burning.



Dave Phillips and Les Jackson

▲ Figure 3: Map of pond apple control in Eubenangee Swamp National Park

▼ Fire in the Eubenangee swamp

Les Jackson

▼ Pond apple with fruit after fire

Dave Phillips

Chemical control

Pond apple was not found in rainforest areas of the park due to low light levels, but its presence along the edges of these forests meant that it could only be controlled by chemical means.

Chemicals used were Access*/diesel, Tordon* and glyphosate. Methods of application included stem injection (axe cut method), cut stump and some basal barking.

Stem injection was predominantly used where it was difficult or dangerous to fell trees, but this proved to be the slowest method of treating pond apple in the national park. Trained operators had to ensure that every cut was treated to achieve 100 per cent kill.

Les Jackson

▲ Pond apple being checked after fire

Most pond apple was controlled with the cut stump method, which resulted in 100 per cent kill. This two-person operation involved cutting the tree and immediately applying the chemicals to the stump. The operators used mainly Tordon* or Access*/diesel on large trees and glyphosate on the smaller trees. They observed that a small timeframe exists when glyphosate can also kill large trees. This timeframe occurs soon after leaf drop, when new leaves are forming. It was during this time of active sap flow that even straight diesel was shown to kill the trees.

Basal barking was tried, but with a lower success rate of around 50–70 per cent control. While this was the fastest (and cheapest) method of chemical control, and the most efficient when dealing with single-stemmed trees, it had a number of disadvantages. Operators had to take care not to contaminate the surrounding vegetation. Also, with many multi-stemmed pond apple trees, control was generally only achieved on the outside stems and coppicing was common. A red dye was mixed with the chemicals to show which trees had been treated. Follow-up work consisted of using fire to control any remaining seedlings and trees.

Trained operators had to ensure that every cut was treated to achieve 100 per cent kill

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Working conditions

As with most pond apple infestations along the Wet Tropical coast, access to sites was difficult. The centre of the swamp could only be reached during the dry season and, even then, it could take up to an hour on a quad bike to get there. Access roads and tracks were limited and operators had to be careful not to disturb the ecosystem, as this could have created a situation where the infestation could re-establish or spread.

Operators had to wade through water and traverse uneven terrain, often through tall vegetation that offered poor visibility. Other hazards included sharp sedges and vines that cut through clothing and skin, and mosquitoes, march flies, snakes and crocodiles. It was often difficult to find trained and dedicated operators who were willing to work in these difficult conditions.

Revegetation

The control of dense thickets of pond apple left numerous bare areas in the park. These were vulnerable to further weed infestation and therefore needed to be revegetated. In places where pond apple had existed for many years, the original native vegetation was not always known. However, a 50-year archive of aerial photos provided evidence of the original vegetation. Successful revegetation has been achieved at the walking track along the Alice River. This track winds through a beautiful native rainforest, all of which was replanted after a pond apple infestation was eradicated.

Conclusion

Pond apple has now been controlled in the Eubenangee Swamp National Park. This successful management is attributed to early intervention, systematic work throughout the whole park and meticulous follow-up work. Good land management practices in the park will assist in detecting any further infestation and controlling pond apple.

Attempting to keep pond apple out of a World Heritage Area

Douglas Shire Council

Background

The Douglas Shire, north of Cairns, incorporates the towns of Mossman and Port Douglas as well as the Daintree National Park. Over 80 per cent of the shire is World Heritage listed. The Daintree National Park is renowned for its rich diversity of plants and wildlife with low and upland rainforests, mangroves, swamps and heath lands.

The threat

Pond apple infestations in the Douglas Shire occur along the Mossman and Daintree rivers and tributaries as well as in melaleuca swamps and intertidal mangrove communities. The latter are directly adjacent to the Daintree National Park and, when infested with pond apple, threaten the diversity of the lower Daintree catchment.

Pond apple is primarily spread by water, especially during flood events. However, the occurrence of infestations in areas that do not flood suggests that the weed is spread by cassowaries and feral pigs who feed on pond apple fruit.

▾ Pond apple control in accessible areas

Peter Logan

Control strategies

Extensive control of pond apple in the Douglas Shire started in 2000 when external funding became available. Mapping and aerial surveys of the Douglas Shire revealed major infestations in the Baileys Creek area (approx. 300 hectares) and at the mouth of the Daintree River (approx. 20 hectares), with more isolated areas along the Daintree and Mossman rivers.

The shire trialled various control methods before finding that the cut stump method was the best for this situation

The Douglas Shire Council's control strategy initially targeted reasonably accessible areas with the aim of slowing the rate of spread by reducing the weed's fruit production as much as possible.

Control methods

The shire trialled various control methods before finding that the cut stump method was the best for this situation.

In 2002, the Douglas Shire Council compared the methods of basal barking (using Starane* and diesel) with stem injection (axe cut method) using glyphosate. Factors compared were:

- cost
- time taken to control
- risks to off-target vegetation
- practicality of use.

The shire found that:

- basal barking was faster than stem injection, making it cheaper in labour terms
- herbicide for basal barking, which included diesel, was more expensive
- basal barking posed a higher risk to native vegetation due to herbicide drift (this does not occur with stem injection).

Despite basal barking being significantly faster than stem injection, the risk of contaminating native vegetation made this method suitable only for the central parts of dense monospecific stands of pond apple. The high volumes of chemical needed for basal barking also limited the use of this method to infestations in easily accessible areas.

After trialling both methods, basal barking and stem injection are no longer used to control pond apple in the Douglas Shire. It was found that, although stem injection worked well when done correctly, poor overlap of cuts or cuts not deep enough resulted in some trees regrowing. Also, poor herbicide coverage resulted in a number of basal barked trees reshooting.

The cut stump method has proved to be the most successful method for the Douglas Shire. Trees are cut as close to the ground as possible and the cut surface is immediately treated with glyphosate at a rate of 1:1 (equal parts chemical to water). Not only is cut stump easier on the operator than stem injection, but its use greatly improves morale among operators because the results are immediately apparent.

* Trademark of Dow AgroSciences LLC

Peter Logan

▲ Treatment of cut surface with glyphosate

Controlling pond apple is very labour-intensive and many infested areas are remote and difficult to access. Workplace injuries, heat fatigue, mosquitoes and crocodiles are constant hazards when treating pond apple.

Where pond apple occurs on the water's edge, access can be difficult and dangerous. The shire has bought a small boat so that operators can safely treat pond apple along watercourses.

Achievements to date

Infestations along the Mossman River were few and scattered, and some very large trees were found. The river system has now been cleared of pond apple, and treated areas are followed up and any reinfestations controlled. Seedlings are generally pulled out by hand, allowing native seedlings to regenerate.

Pond apple treatment is continuing along the Daintree River and its tributaries, but numerous small outbreaks have been eradicated along creeks on private property.

Pond apple has been eradicated in the accessible parts of Baileys Creek where infestations had dramatically altered the native landscape. Where pond apple stands once stood, the original vegetation of melaleuca and sedges have re-established—an encouraging sight.

▼ Baileys Creek area before pond apple control

Peter van Haaren

▼ Baileys Creek area after pond apple control

Kate Charleston

Involving Indigenous groups

The Douglas Shire Council Pest Management Unit employs two full-time staff and two Indigenous staff on a casual basis. They have also trained 13 Indigenous students and traditional landowners (Kuku Yalangi people) to identify and control pond apple on their land.

Involving Indigenous groups in weed control and revegetation with native plants encourages a sense of responsibility for the problem and ownership of the land. While large areas of pond apple were controlled on traditional land, some small stands have been retained. These remaining trees will be used for training and identification purposes prior to control.

Indigenous communities are generally not in favour of using chemical control on weeds, but, after seeing the successful effects of using glyphosate on pond apple, there is now a greater acceptance of herbicide use.

There are numerous infestations of pond apple along the east coast of Cape York. Including the efforts and values of traditional owners in the control program will be a major contribution to eradicating the weed from this region.

Public awareness

The Douglas Shire raises public awareness of the pond apple threat in local print media and radio campaigns and during Weedbuster Week, held in October each year. Information packs about pond apple have been distributed to the public, as well as to tour guides, river guides and rangers. Most sightings of pond apple are made by Daintree River guides who see the weed along the river and creeks.

The shire has developed a cooperative relationship with the Queensland Parks and Wildlife Service. Together, strategies have been aligned to control pond apple on both local shire land and in national parks. Control of pond apple is now a collaborative effort between the two agencies.

The challenge

With many of the smaller infestations along rivers and creeks now under control, the Douglas Shire is yet to face the major challenge of eradicating pond apple from Baileys Creek and the mouth of the Daintree River. Access to these low-lying areas is often restricted by tides and these melaleuca and mangrove swamps are home to saltwater crocodiles.

Public awareness helps control pond apple in Mareeba Shire

Background

The Mareeba Shire, on the Atherton Tablelands, is 60 km west of Cairns and ranges in altitude from 600–1100 m above sea level. The presence of pond apple in the Mareeba Shire indicates that its distribution is not restricted to the coastal lowlands and lower catchment areas. In the 1990s, pond apple was found in both rainforests and dry sclerophyll forests of the upper Barron catchments.

The threat

Although pond apple is generally spread by water, its initial spread in the Mareeba Shire was due to its use as rootstock for custard apple. This use is now prohibited, although it is possible that older trees on this rootstock still exist in managed orchards. It was in neglected or abandoned custard apple orchards that pond apple rootstocks were able to regenerate from suckers and bear fruit. It is thought that seeds were spread by animals such as cassowaries, pigs and possibly fruit bats. The location of some infestations, especially in the drier sclerophyll forests where flooding is not known to occur, supports this theory. The establishment of pond apple in drier areas means that this pest can also survive in areas of low moisture.

▾ Pond apple in dry sclerophyll forest

Sid Clayton

Aerial surveys were conducted in winter when pond apple leaves were characteristically yellowing.

Public awareness

In 1997, after numerous sightings of pond apple and concerns about its ability to spread, the Mareeba Shire Council declared pond apple as a noxious weed under the *Local Government Act 1993*. A public awareness campaign was conducted. Information and photos of pond apple were distributed to the public via letterbox drops and published in local shire papers. The information was also sent to landholders, fruit grower associations, gardening groups, the local nursery industry, Ergon Energy, Telstra, skyrail, and birdwatching and bushwalking groups.

The council, together with EnviroCare, a Kuranda-based Landcare group, organised meetings with landholders to discuss pond apple identification, management and control. Samples of pond apple plants and fruit were displayed at these meetings allowing participants to become familiar with the plant.

The awareness campaign proved highly successful and the public reported many pond apple locations within the shire. Greater awareness of the threat of pond apple and the importance of its control assisted council staff in gaining entry to landholders' properties.

Finding pond apple

While the council relied on public feedback, it also used surveys to detect infestations in the catchment. Aerial surveys were conducted in winter when pond apple leaves were characteristically yellowing.

Surveys indicated that pond apple infestations were larger than originally thought and there were not sufficient resources to control all areas in the catchment immediately.

In 2001, the council obtained Australian Government funding under the Weeds of National Significance (WONS) project, to undertake surveys and eradication work to destroy all infestations of pond apple. The aim was to eradicate pond apple in the Mareeba Shire. Funding was used to:

- survey custard apple orchards and nurseries to determine the use of pond apple as rootstock and to provide advice on pest management issues
- conduct on-ground property inspections and, with landholder assistance, systematically search waterways and drainage gullies to eradicate all infestations found
- employ a dedicated team to conduct on-ground work
- follow up and re-treat as required ensuring 100 per cent kill.

Strategic surveys identified infestations of pond apple at Paddys Creek, occurring in dry sclerophyll forest at elevation (1000 m). These infestations were patchy and not widespread. Larger infestations were found in the Jumrum Creek area; 27 km of creek line were inspected and treated. This area included numerous farm dams with pond apple along the shores.

Sid Clayton

▲ Pond apple along fence line in Mareeba Shire

Control methods

Pond apple control in the Mareeba Shire was carried out in the drier winter months from June to August. Eradication work started at the top of the creek tributaries before working downstream to the main creek systems.

Two control methods were used—the stem injection (axe cut method) and the cut stump method. The chemical used for both was glyphosate at a rate of 1:1 (equal parts chemical to water).

For the axe cut method (also known by council workers as frill backing) workers used tomahawks to make a double row of downward cuts into the stem, around the circumference of the tree, at axe blade lengths apart. Herbicide was then injected into the row of pocket cuts with the use of a stem injector (Tordon* gun). Glyphosate was not always successful on larger trees with only a 70 per cent success rate.

(Note: As glyphosate is not always effective on large trees, it is better to use Access* or Tordon*.)

The cut stump method involved the application of herbicide onto the stump surface immediately after the tree was cut with an axe or chainsaw. This generally required two people. It was essential to ensure that cut stems did not fall into creeks or onto the ground in a way that allowed them to propagate.

Seedlings that had germinated after the wet season floods were pulled out by hand. This was preferable to spraying, which frequently killed the native seedlings essential for revegetation after the pond apple was removed.

▼ Workers have to ensure that pond apple plants are not moved downstream where they can regenerate

Sid Clayton

* Trademark of Dow AgroSciences LLC

The Mareeba Shire Council believes that they have now successfully eradicated all known infestations of pond apple. The annual follow-up work indicates excellent control, with few seedlings found downstream of treated areas. With the eradication of all reproductive trees and the relatively short seed life of pond apple, the weed should no longer pose a problem in this shire.

Working together

Mareeba Shire worked closely with the neighbouring Cairns Shire (located in the lower Barron catchment) and other adjacent councils to map pond apple infestations. Cairns City Council was warned that seed may spread into their area, especially below the Barron Falls, and that pond apple was likely to establish in ponded areas such as Lake Placid.

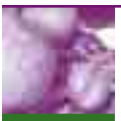
Controlling pond apple was a joint effort between Mareeba Shire, landholders and members of the local Landcare group. The control program faced a number of obstacles, including dense bushland, difficult access, lost workers (temporarily disoriented), mosquitoes and swollen creeks.

Key successes

The success of pond apple control in the Mareeba Shire can be primarily attributed to the extensive public awareness campaign.

Without public assistance, many of the infestations would have been overlooked and their regeneration would have resulted in a more widespread problem.

The shire continues to receive occasional calls from the public or from Telstra workers reporting new pond apple sightings. Immediate response and control will ensure that the Mareeba Shire remains free of this noxious weed.



Section 5

Further information

Pond apple information sheets can be obtained from the following agencies.

Table 3: General contacts

Organisation/department	Contact details
Queensland Department of Natural Resources, Mines and Water	Phone: 1800 803 788 Website: www.nrm.qld.gov.au
Weeds Australia	Website: www.weeds.org.au
Cooperative Research Centre for Australian Weed Management	Phone: 08 8303 6590 Email: crcweeds@adelaide.edu.au Website: www.weeds.crc.org.au

Enquiries about declared weeds should first be referred to your relevant local government, shire council or state government department.

Table 4: State and territory contacts

Organisation/department	Contact details
New South Wales	
Department of Primary Industries	Phone: 02 6391 3100 Email: dpi.nsw@dpi.nsw.gov.au Website: www.dpi.nsw.gov.au
Department of Infrastructure, Planning and Natural Resources	Phone: 02 9762 8044 Email: information@dipnr.nsw.gov.au Website: www.dipnr.nsw.gov.au
Northern Territory	
Department of Natural Resources, Environment and the Arts	Phone: 08 8999 2020 Email: weedinfo.nreta@.nt.gov.au Website: www.nt.gov.au/nreta
Parks and Wildlife (for information on prohibited entrants)	Phone: 08 8999 5511 Website: www.nt.gov.au/ipe/pwcnt
Queensland	
Department of Natural Resources, Mines and Water	Phone: 1800 803 788 Website: www.nrm.qld.gov.au
South Australia	
Department of Primary Industries and Resources	Phone: 08 8226 0222 Website: www.pir.sa.gov.au
Tasmania	
Department of Primary Industries, Water and Environment	Phone: 1300 368 550 Website: www.tas.gov.au
Victoria	
Department of Primary Industries	Phone: 136 186 Email: customer.service@dpi.vic.gov.au Website: www.dpi.vic.gov.au
Western Australia	
Department of Agriculture	Phone: 08 9368 3333 Email: enquiries@agric.wa.gov.au Website: www.agric.wa.gov.au

Reference list

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Setter, S, Setter, M and Campbell, S 2004, 'Longevity of pond apple (*Annona glabra*) seeds and implications for management' in SM Sindel and SB Johnson (eds), Weed Society of New South Wales, *Proceedings of the 14th Australian Weeds Conference,* Wagga Wagga.

Stanton, P 1998, 'Environmental weeds' in Jeffery, PL and Lindsay, AM (eds), *Proceedings of the 5th Queensland Weed Symposium: Paradise lost—will you let it happen?* Queensland Weeds Society, Cairns.

Werren, G 2001, *Rainforest weeds and their ways: the need for vigilance*, Cooperative Research Centre for Tropical Rainforest Ecology and Management, viewed 5 July 2006, <http://www.rainforest-crc.jcu.edu.au/publications/infosheets/rainforestWeeds.pdf>.

Declaration details in Australia

The following information on the declaration details of pond apple has been extracted from the respective state government websites. Nationwide declaration is required, to ensure that pond apple is not grown, traded or distributed from states in which it is not declared. For further information, please refer to the relevant website (see Contacts, page 53).

ACT
Not declared

New South Wales
Declared Class 1: Ban on sale, introduction and use; eradication is required

Northern Territory
Declared as prohibited entry

Queensland
Declared Class 2: Ban on sale, introduction and use; control is required

South Australia
Restrictions on sale

Tasmania
Not declared

Victoria
Declared Restricted Weed: Ban on sale and trade

Western Australia
Declared as prohibited entry