Northern Territory Government

DEPARTMENT OF
NATURAL RESOURCES, ENVIRONMENT AND THE ARTS

Northern Territory

Cabomba Eradication Program 2005/06

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Cover photo: NRETA Weed Management Officers treating cabomba, Darwin River

1. Introduction

Cabomba caroliniana (cabomba) is a fully submerged, aquatic plant native to South America. Cabomba was first recorded in Australia in 1967, probably as a result of being introduced through the aquarium industry trade.

Since its introduction to Australia, cabomba has become established in various water storage facilities, farm dams and river systems in an area extending from Victoria to the Charters Towers/Townsville region in Queensland. Cabomba is often problematic in irrigation drains and channels where low flow rates facilitate rapid development and spread. Cabomba was first recorded in the Northern Territory (NT) in 1996.

Cabomba is a declared Weed of National Significance (WoNS species). The NT *Weeds Management Act 2001*, administered by the Department of Natural Resources, Environment and the Arts (NRETA), dictates that all plants within the genus *Cabomba* are declared Class A (to be eradicated) and Class C (not to be introduced to the NT).

Nationally, cabomba has proven to be a very difficult weed to effectively manage once established because of the rate at which it grows, the plant's ability to spread rapidly and the difficulty of managing off-target impacts.

The Cabomba Threat

Cabomba is a fast growing plant. Growth appears to positively correlate to increasing light, high temperature and elevated nutrients. These requirements indicate that most freshwater bodies in the Top End would be susceptible to infestations, including floodplains, backflow billabongs and water reservoirs including Darwin River Dam.

Infestations interstate have clearly demonstrated cabomba's capacity to reduce aquatic biodiversity and ecosystem functioning, adversely affect water quality, reduce water storage capacity of dams, block water distribution infrastructure, severely impede recreational activities, including fishing and boating and create suitable habitat for mosquito breeding.

Cabomba is a particularly easy plant to spread. Floating stem fragments, as short as one centimetre, with only a pair of leaves can take root and grow into new plants. Large infestations are also able to produce vast quantities of seed. Anything that moves through the water, including fishing lures, boats, trailers, outboard motors and animals, can act as vectors for the movement of either plant fragments or seeds.

As a result of these issues and associated costs, management programs in most jurisdictions are limited to targeting impact reduction rather than eradication. Given the currently limited range of cabomba in the NT, the enormous potential range and scope for extensive environmental, social and economic impacts (including the possible need to establish a drinking water supply treatment facility, in the event that Darwin River Dam became infested with cabomba), eradication was established as a priority.

Cabomba in the NT

Cabomba was first recorded in the NT in 1996 at Marlow Lagoon, Palmerston. After multiple unsuccessful attempts at physical control, over a period of several years, a single application of the herbicide, *Agricrop Rubbervine Spray* (active ingredient 2,4-D-n-butyl ester) resulted in the weed being eradicated in this isolated water source.

On 21 October 2004 the same species was reported and subsequently positively identified in the Darwin River area. Subsequent surveys identified cabomba at several locations along an 11 km stretch of the river. Herbicide management of the Darwin river infestation commenced in November 2004 and provided satisfactory 'knock down' control results. The germination of seed after the 2004/2005 wet season has, however resulted in the plant's re-establishment in multiple locations within Lok Landji Billabong, a section of Darwin River.

An awareness campaign was launched following the discovery of cabomba at Darwin River which resulted in a number of cabomba populations being identified in confined urban aquariums and ponds. Notably, in December 2004, a resident of Pine Creek reported that cabomba was regenerating from seed in a fish pond. Cabomba plants were persisting despite the pond having been drained the previous month and the weed removed. Weed Management Officers visited the property and found seeds attached to the roots of seedlings pulled from the soil. This was the first evidence of viable seed production in Australia.

The Task Force

When cabomba was discovered in Darwin River in 2004, a task force was formed to direct, coordinate and oversee the Cabomba Eradication Program. Other stakeholder groups, including the Amateur Fisherman's Association of the Northern Territory (AFANT), Local Government and the NT Environment Centre were also consulted. Table 1 indicates Task Force representatives.

Table 1: Cabomba Task Force

Agency	Area of Expertise/Association	Role
Dept. Natural Resources, Environment and the Arts (NRETA)	Biodiversity Conservation Unit	Monitoring riparian zone, aquatic fauna and flora
	Weed Management Branch	Survey, control, monitoring, landholder liaison
	Advisory and Regulatory Services	Water quality monitoring
	Communications and Media	Media management/contact/public awareness
	Environment and Heritage	Environmental monitoring and advice
Dept. Primary Industry, Fisheries and Mines (DPIFM)	Horticulture	Industry liaison
	Aquatic Pest Management Group	Industry liaison
	Fisheries and Aquaculture	Industry liaison
Dept. Health and Community Services	Environmental Health	Drinking water quality monitoring
Power Water Corporation	Power Water	Domestic water supply, dam quarantine
Kungarakany People	Traditional Owners of the area	Protection of registered sacred sites

Darwin River Quarantine

To minimise the chance of cabomba being spread further, the infested section of Darwin River was placed under quarantine, in accordance with Section 21 of the *Weeds Management Act 2001*, on 9 November 2004. The quarantine order will remain in place until 9 November 2008, or until it is revoked or extended by the Minister for Natural Resources, Environment and Heritage. The area quarantined comprises the section of Darwin River between Cox Peninsula Road and Leonino Road.

The quarantine order prohibits the movement of people or any object, including boats, vehicles and fishing equipment, into or out of this section of river and the five metres of land adjacent to the water's edge, unless an appropriate permit has been obtained from NRETA.

Vehicles are not to pass over causeways at Old Bynoe Road or Reedbeds Road if the river is flowing over these causeways. Non-compliance to this order is an offence with a maximum penalty of $50 000 for individuals and $250 000 for body corporate. Minimum penalties of $5000 or $25 000 respectively also apply.

Surveillance

Early detection of any new infestations is a vital part of the eradication program. NRETA Weed Management Branch regularly monitor susceptible water bodies in the region including:

- unaffected reaches of the Darwin River;
- sections of the Blackmore River;
- Berry Springs Nature Reserve;
- Howard Springs Nature Reserve;
- McMinns Lagoon;
- Fairway Waters;
- Girraween Lagoon;
- Darwin River Dam;
- Manton Dam;
- Marlow Lagoon; and
- Knuckey Lagoon.

2. Purpose of the Program

Overall the purpose of the Cabomba Eradication Program is to eradicate all known infestations of *Cabomba caroliniana* from the NT, and to prevent all future introductions of plants within the genus, to the NT.

Seven specific objectives have been identified which guide the project and provide an avenue for monitoring and evaluation. This report details how each of these objectives were addressed during the 2005/06 year.

Plate 1: Quarantine sign at Darwin River

3. Report Against Project Objectives

This section of the report is broken into four components which address prevention of further introduction of cabomba, the active control program, the seed research program and the various monitoring programs. Within these four sections, seven project objectives are reported against.

3.1 Prevention of Further Introduction

Objective 1: Prevent all future introductions of plants within the genus cabomba to the NT.

During 2005/06 NRETA Weed Management Officers visited and provided information to nurseries and aquatic plant retailers detailing the prohibition of import and subsequent sale of cabomba in the NT. It was noted that at this time no retailers were selling the plant. Significant effort was made with regards to increasing public awareness of cabomba (See 3.3 below).

3.2 Active Control Program

Objective 2: Eradicate all known infestations of the aquatic weed cabomba (Cabomba caroliniana) *from the NT, and to prevent all future introductions of the plants within the genus Cabomba to the NT.*

Objective 3: Prevent re-establishment of plants within the genus Cabomba *at all sites where it has previously been recorded and subsequently been treated and/or removed.*

Objective 4: Prevent the production of seed from all sites where cabomba is currently found.

Options available for reducing cabomba populations include biological control, water level manipulation, shading, physical removal of plants and herbicide application.

Water Level Manipulation and Physical Removal

To date, water level manipulation and physical removal have failed to eliminate major cabomba infestations in the NT or elsewhere in Australia. In the case of the Darwin River site, water level manipulation and physical removal were not viable options due to the size and location of the infestation and potential presence of saltwater crocodiles.

Biological Control

It takes many years to comprehensively assess the suitability of potential biological control agents for weed control in Australia. CSIRO are in the process of assessing the suitability of several host-specific insects for use in cabomba control. The need for immediate action in the NT did not allow for the time frames required for biological control research.

Herbicide Control

Application of *AF Rubbervine Spray* or *Agricrop Rubbervine Spray* (2,4-D n-butyl ester, 800g/L active ingredient) was the only herbicide control option available. 2,4-D-n-butyl ester functions as a systemic herbicide and is used to control many types of weeds. It is used internationally in cultivated agriculture, rangeland applications and to control aquatic vegetation. The successful reduction in the population of mature plants in Marlow Lagoon during October 2002 indicates that the application of 2,4-D-n-butyl ester is the most suitable management option presently available for the Darwin River situation.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is the national independent regulator of pesticides and veterinary chemicals. As 2,4-D-n-butyl ester is not a registered herbicide for cabomba, any usage of 2,4-D-n-butyl ester can only be made with the successful application of an off-label permit for use of the product, *Agricrop* or *AF Rubbervine spray*.

Comprehensive testing of 2,4-D-n-butyl ester has demonstrated that continued, direct exposure or ingestion can have negative implications for humans and animals. (See Table 6 for further explanation of possible off-target impacts). However, in aquatic environments, 2,4-D-n-butyl ester is broken down by micro-organisms. Increased nutrients, sediment load, high levels of oxygenation and dissolved organic carbon are conducive to more rapid breakdown (Australian Government – National Health and Medical Research Council and Natural Resource Management Ministerial Council, 2004).

2,4-D-n-butyl ester is listed in the 1996 Australian Drinking Water Guidelines (Australian Government, 2004), which contain specific recommendations for concentrations in potable water. The Guidelines state, “2,4-D should not be detected in drinking water. If present in drinking water, 2,4-D would not be a health concern unless the concentration exceeded 0.03mg/L. If detected then remedial action should be taken to stop contamination.” The Health Value of 0.03mg/L in drinking water is derived from the Australian ADI (acceptable daily intake based on daily lifetime exposure) of 0.01mg/kg/day for a 70kg adult with an average water consumption of 2 L/day.

The Task Force endorsed the continued use of 2,4-D-n-butyl ester as the preferred management option where suitable. As a result of this decision NRETA applied successfully for an off-label permit from the APVMA to continue use during 2005/2006. The permit for use of 2,4-D-n-butyl ester stipulates spot application directly into cabomba infestations. Submerged nozzles are used to apply a mixture of the product and diatomaceous earth. This light silica soil absorbs the herbicide and makes it less mobile. This method of application ensures that the control is as targeted as possible and the chance of herbicide spread is minimised. Herbicide is primarily applied in the Dry season (May–October) when water is clear and water flow is minimal. A high degree of sub-surface visibility is essential for targeted application and minimal flow means the herbicide will remain in the required area for as long as possible. Preferentially the herbicide should be applied prior to flowering, to prevent seed set.

2,4-D-n-butyl ester is not allowed to be used in potable water supplies. This fact is one of the main drivers for effective control of cabomba. If cabomba was to reach Darwin River Dam, this control method would no longer be an option. It is noted that when the herbicide was first applied in 2004 alternate water supplies were provided by the NT Government to those who depended on Darwin River for drinking water and for horticulture irrigation.

Effective dilution

12.5 L product + 5 kg diatomaceous earth mixed in 200 L water applied to a megalitre of water.
12.5 L X 800 g/L = 10,000 g/megalitre
This equates to 1g per 100 litres of water
This equates to 10 mg per litre of water

In 2005, herbicide management of the Darwin River cabomba infestation involved applying 2,4-D-n-butyl ester to limited infestations in the Lok Landji Billabong. An initial 36 litres of herbicide was applied on 24 May 2006, a further two applications were administered during the reporting period (see Table 2).

Table 2: Application of 2,4-D-n-butyl ester to cabomba populations – Lok Landji Billabong 2006

Date	24 May	8 June	21 June
Amount (volume)	36 litres	30 litres	27 litres

Note: herbicide volumes were in accordance with the off-label permit. Reducing amounts reflected decreases in cabomba occurrence.

All application of 2,4-D-n-butyl ester was in accordance with the standards imposed by the APVMA, with specific reference to location, concentration, application technique and frequency of application. The application regime at Darwin River, as determined by the off-label permit, was not expected to have a significant impact on the ecology of Darwin River, given the highly targeted mode of application. Precautions, including the provision of an alternate water supply where necessary and a comprehensive communication program, ensured no impact to human health or industry would eventuate.

On-site inspections estimated that infestation levels in Lok Landji Billabong were at a level less than 1% of those found in November 2004. This suggests that flower and seed production was prevented during 2006.

Shading and Booms

As well as applying herbicide to Lok Landji Billabong, NRETA Weed Management Officers established shades over all plants in infestations upstream to limit plant growth and prevent flower and seed production in areas where herbicide control could not occur due to water supply issues. Shading was not considered feasible in Lok Landji Billabong due to the extent of the infestation.

NRETA Weed Management Officers also constructed floating 'booms' to prevent viable fragments moving downstream into unaffected areas. These structures are essentially a floating net extending 30 cm below the water surface supported by a length of poly pipe.

Plate 2: Floating boom constructed to prevent spread of viable fragments

Capacity Building – NRETA staff and public

Staff training has been recognised as a vital component of addressing Objectives 2, 3 and 4. Constant communication has also been maintained with interstate government agencies to ensure NRETA staff have access to the most up to date information. The holistic approach to the NT Cabomba Eradication Program has meant staff have been involved in regular inspections of all previously recorded sites and in a seed research program (refer to Section 3.4 for further details).

All reported urban occurrences of cabomba (fish tank and pond) were destroyed. The exception is the Pine Creek site where the production of viable seeds on site has resulted in continual germination of seedlings. The number of accurate reports received from the public, demonstrates that continued public involvement in monitoring for cabomba is essential (see 3.3 on following page).

3.3 Public Awareness and Education Strategy 2006.

Objective 5: Educate the NT community as to the identification of plants within the genus Cabomba *and their potential negative impacts.*

NT Cabomba Eradication Communication Strategy

A Communication Strategy was developed in 2004 as an integral part of the NT Cabomba Eradication Program. This strategy was developed through significant consultation with all stakeholders. The NT Cabomba Eradication Communication Strategy aims to:

- ensure the public understands the implications of cabomba establishment and spread in the NT, and is consequently prepared to undertake measures required to eradicate the weed;
- enlist the public as the 'eyes and ears' to aid early identification of any spread or new outbreaks;
- educate the public about the danger of using species such as cabomba in private aquarium collections;
- reassure the public that authorities are dealing with the threat in an efficient and effective manner; and
- allay any concerns about the ramifications of treatment.

In 2006 the program included:

- the production of media releases communicating eradication efforts;
- the production of marketing material (see Table 3);
- TV advertisements;
- quarantine awareness advertisements;
- information sites at shows and field days;
- website information;
- on-site quarantine signage;
- the continued administration of the *Cabomba Hotline*, allowing members of the public to contact NRETA Weed Management Officers as required; and
- dissemination of water quality monitoring results (herbicide levels) in Darwin River, with particular reference to observed impacts on the Darwin River ecosystem and aquaculture establishments.

Figure 1: Cabomba information brochure 2006

How to identify cabomba

1. Small white flowers (2 cm wide) with a yellow centre, emerging a few centimetres above water.

2. Fan-like underwater leaves with leaf stalks that are in opposite pairs along the stem.

3. Small linear floating leaves at the surface.

Native fan-leaved aquatic plants do not have opposite leaves (instead usually in whorls) or linear floating leaves, while flowers are borne on emergent herb-like structures.

Cabomba *'opposite leaves'* **Native** *'whorls'*

How you can help

- Monitor local waterways and check household ponds and aquariums for cabomba.
- Do not enter the Darwin River quarantine area.
- Do not transport aquatic plant fragments along or between waterbodies.
- Do not discard aquarium contents near waterways.
- You must have a Section 16 permit issued by Fisheries to lawfully bring aquatic plants into the NT (this includes internet purchases from interstate).
- Seek advice before disposing of cabomba.

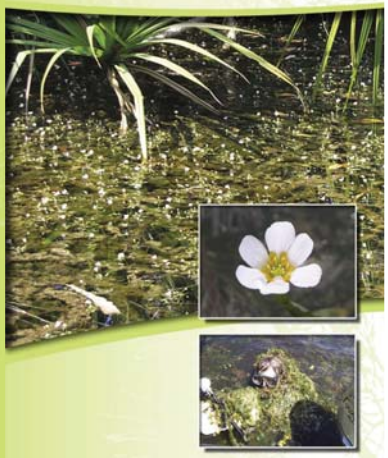
Report cabomba sightings immediately to the Cabomba Hotline on 8999 8954. Weeds Branch staff will remove and dispose of plants free of charge.

For more information call the Cabomba Hotline on 8999 8954 or visit the Cabomba website: www.cabomba.nt.gov.au

Cabomba

(Cabomba caroliniana)

aquarium plant now a weed of national significance



A choking weed of: water supplies; fishing and swimming holes; wetland ecosystems.

Northern Territory Government
Department of Natural Resources, Environment and the Arts

What is cabomba?

Cabomba is a submerged water plant with emergent white flowers introduced into Australia by the aquarium industry. It is usually rooted to soil but can survive free-floating for 6-8 weeks. It is an aggressive invader of shallow and deep, permanent freshwater bodies where it grows quickly to produce dense and often tall stands (e.g. 3 m) of underwater vegetation.

Weed status and potential impacts

Cabomba is a declared Class A and C weed in the NT, making it illegal to introduce, distribute or grow. It is considered a Weed of National Significance due to its potential to:

- reduce biodiversity and functioning of wetland ecosystems
- reduce water quality
- reduce water storage capacity of dams and block water distribution infrastructure
- severely impede recreational activities including swimming, fishing and boating
- create suitable habitat for mosquito breeding

Eradication and quarantine of Darwin River

Attempts to eradicate cabomba from Darwin River commenced after its discovery in October 2004. As part of this ongoing program, the section of Darwin River between Cox Peninsula Road and Leonino Road has been quarantined until November 2006. This prohibits the movement of people and other objects into or out of this section of river and 5 metres of land adjacent to the water's edge. The quarantine is designed to restrict the spread of cabomba and is a critical part of the eradication campaign.

Cabomba has the potential to invade most Top End permanent waterbodies, particularly in areas of slow-moving or stagnant water with silty soils.

Where is cabomba?

The only known infestation of cabomba in the NT is in Darwin River (downstream from Darwin River Dam). A previous infestation at Marlow Lagoon has been eradicated. Cabomba may also be present in some household ponds and aquariums. It is also present in Queensland, New South Wales and Victoria.

How is cabomba spread?

Cabomba spreads by fragmentation of the stem and movement of seed. Fragments as small as 1 cm can grow into mature plants, while seeds are 3 mm long and difficult to detect. Fragments and seeds may accidentally be moved in/on boats, motors and trailers, fishing gear, soil and other recreational equipment and clothing.

Table 3: Education and extension material summary 2006

Reporting Period: July 2005-June 2006			
Date	**Title**	**Objective**	**Description**
April 2006	Cabomba Legislative Assembly Brief	Provide draft briefing for update on cabomba	Update on cabomba management at Darwin River by Executive Director, Natural Resource Management
15 May 2006	Task force meeting	To discuss Cabomba Eradication Program	Discussed background, weed control program, water supply, monitoring program, community awareness program
21 May 2006	Cabomba eradication media release	To inform the public of the recommencement of spraying cabomba on Darwin River	To inform residents of where the quarantine remains in place and where spraying will occur along Darwin River
21 May 2006	Poster: Darwin River cabomba eradication recommences	Distribute poster throughout local community to inform them about eradication program for 2006	See above
20, 22, 27 May 2006	Cabomba eradication and quarantine awareness advertisements	To make public aware of re-commencement of eradication program	Advertisements run 20, 22 and 27 May 2006
2 and 9 June 2006	Cabomba eradication and quarantine awareness advertisements	To make public aware of re-commencement of eradication program	Two print advertisements 2 and 9 June for cabomba eradication recommencement and quarantine zone
14 June 2006	Update cabomba website	To provide the public with up-to-date information on the biology and management of cabomba	Plant description, distribution and weed status, potential impacts, eradication program, image library, similar species, *Agricrop rubber vine spray*, archive news, information sheet and distribution map
25 May – 10 June 2006	Cabomba eradication awareness campaign	To make the public aware of current Cabomba Eradication Program and quarantine restrictions	Cabomba advertisement running on Channel 9
25 May – 17 June 2006	Cabomba eradication awareness campaign	To make the public aware of current cabomba eradication program and quarantine restrictions	Cabomba advertisement running on Channel 7
Early July 2006	No Fishing, No Swimming Signs	To make the public aware that no fishing or swimming can occur in quarantine areas of Darwin River	Quarantine Area – No Fishing, No Swimming Caution – Herbicide Present in River, Do not Enter, Do not Drink Water

3.4 Seed Research Program 2005/06

Objective 6: Determine the viability and longevity of cabomba seed in the NT.

An increased understanding of cabomba reproduction in the NT's environments will greatly benefit continued management, eradication and monitoring programs.

Seed Production

The Cabomba Eradication Program at Darwin River in late 2004 was unsuccessful, despite the apparent destruction/removal of mature plants. In June 2005 NRETA Weed Management Officers began to investigate whether cabomba at Darwin River was producing seed.

On three occasions (June–August 2005), the top 25 cm of flowering cabomba plants were collected and put into containers filled with water in a shade-house. There was no soil in the container and the fragments simply floated on top. Flowering of the fragments was common for three to four weeks and these flowers were exposed to pollinators (older flowers were likely to have been pollinated at Darwin River).

A total of about 2000–2500 flowers were collected (excluding buds that did not flower). The flowers and fruits were examined for the presence of seed production but no seeds were observed. However after four to five weeks, the plant fragments were removed, the water was drained and seeds were collected from the bottom of the containers. A total of 453 seeds were collected. This suggests a rough average of one seed for every five flowers, although the number of flowers pollinated in the shade-house may be different to field conditions.

It is noted that well established areas in the field have been observed to have a flower density up to 50 flowers per square metre, which equates to 10 seeds per square metre. The occurrence of seeds in the field highlighted the need to undertake viability studies. These were undertaken in conjunction with the NT Department of Primary Industry, Fisheries and Mines.

Seed Viability

The Cabomba Eradication Program has also included the establishment of a number of experiments to determine factors which may influence germination. There have also been continued observations of known weed banks which have undergone various treatment methods, including the pond at Pine Creek.

Viability and germination following drying of seed and soil were tested to determine if cabomba can persist in ephemeral, as well as permanent water bodies. The findings of these tests will also give an indication of whether eradication by drawdown will be effective if plants have seeded within the past two years.

Seed viability, for different aged seeds, was tested over six months using tetrazolium tests. The tetrazolium test is a biochemical viability test for seeds. Hydrated and cut or pierced seeds are exposed to a solution containing the compound 2,3,5 triphenyl tetrazolium chloride (TTC). Initially colourless, TTC is converted to formazan red in the presence of live tissue. Seed analysts examine the stained tissues and determine if the seed is viable or nonviable (United States Department of Agriculture, 2008).

Some seeds were partially dried before testing by leaving them on an office window sill in air-conditioning for a number of days. Results are described in Table 4. The slow reaction time to the tetrazolium solution suggested that the seeds were dormant. Limited research since has supported this, see Table 5 on the following page.

Table 4: Viability of cabomba seeds collected from Darwin River, as determined by tetrazolium tests

Age of seed (months)	Drying regime	Viability (%)	Number of seeds tested
<1	None	100	30
4	None	76	30
4	Dried for 1 day	47	15
4	Dried for 5 days	40	15
6	None	33	30

Table 5: Summary - Seed germination experiments conducted on cabomba seeds to determine potential dormancy periods and ability to withstand varying environmental conditions

Manipulated environment	No. seeds added	No. of seeds germinated	Time until germination	Indicates
Soil (with nutrients added) Water (CO_2 added)	35	5 seeds (14%)	1, 2, 4, 6 and 9 months	Ionic balance in water (wet season rainfall) and available CO_2 may trigger germination
Soil (no nutrients) Water	60	0 seeds (0%)	NA	
1m^2 soil collected from infested area of Darwin River, stored in water under shade house conditions	unknown	2 seeds (Unknown%)	November and February	Viable seeds are being produced in the NT
Submerged soil 2 weeks Dried for two months (humid conditions) Resubmerged 2 weeks	15	1	6 months	Seeds can germinate after extended dry periods, indicating ephemeral water bodies are susceptible to infestation and draining may not be an effective control.
Observed environment	**No. seeds added**	**No. of seeds germinated**	**Time lapse until germination**	
Pine Creek garden pond	NA	unknown	12-16 months	Draining did not result in eradication

Note: Two minor germination-cabinet experiments failed to record any seed germination. Germination in the field has not been confirmed.

3.5 Monitoring potential off-target impacts

Objective 7: Monitor the impacts of all management activities and provide an 'early warning' mechanism in order to avoid potential off-target impacts to the environment, community and industries of the NT.

The significant economic, environmental, cultural and social implications of further cabomba infestations in the NT were key factors in the Task Force's decision to attempt to control cabomba with herbicide. The decision to use herbicide meant that a thorough monitoring program would need to be put in place in order to avoid impacts on the Darwin River environment, surrounding industry or on human health. Prior to the application of herbicide in 2004, a variety of monitoring programs were developed.

The following parameters and indicators were measured:

- Ground and surface water quality assessments included testing for 2,4-D-n-butyl ester and the by-products of this herbicide (4-chlorophenol and 2,4 dichlorophenol), dissolved oxygen and the bacterium, *Escherichia coli* (*E.coli);*
- Macro-invertebrates as biological indicators of river health;
- Fauna surveys – including birds, reptiles and fish; and
- Flora surveys – aquatic and riparian plants communities and species.

Results dictated the need to continue, discontinue or alter the sampling regimes. Table 6 (following page) provides a summary of the monitoring programs and findings.

Plate 3: Cabomba infestation at Lok Landji Billabong

Table 6: Risk assessment and monitoring programs associated with use of 2,4-D-n-butyl ester in Darwin River

Risk Area	Potential for impact	Monitoring	Conducted by	Results - 2006
Human Health	Contamination of water used for drinking, washing and irrigation. Any contamination of water used for these purposes would require an alternative water supply to be secured.	• 2,4-D-n-butyl ester • 4-chlorophenol (by product of 2,4-D) • 2,4 dichlorophenol (by product of 2,4-D) • Bacteria E.coli. Groundwater (bores) monitored during the 2006 control program. Surface water - weekly samples collected from 4 monitoring sites on Darwin River.	NRETA – Aquatic Health Unit	No detectable herbicide has been found in ground water. No detectable herbicide has been found in Darwin River surface water.
Environment	2,4-D-n-butyl ester is expected to kill cabomba and other plants in the immediate vicinity. The death of plants may deprive animals of food and cause anoxia in the water. Impacts on certain species can impact other animals, including higher order predators in the food web/chain. 2,4-D-n-butyl ester is also toxic to some animals, including fish. Macro-invertebrates are considered sensitive to certain chemicals and as such can be used as bio-indicators.	BACI design monitoring programs developed (Before-After Control-Impact), including: crocodile surveys using spotlight method; turtle surveys using baited crab traps before and after treatment; birds surveys in control areas and herbicide treated areas; and fish surveys using gill nets and electro fishing in control and treatment sites (04/05).	NRETA – Biodiversity Unit (Charles Darwin University – bird survey only) DPIFM – Fisheries	Crocodylus johnstoni (freshwater crocodiles) were observed before and after treatment. Turtle populations appeared unaffected. No significant variations in bird populations found. Fish surveys in 04/05 indicated no significant difference between treated and untreated sites. Lower herbicide applications did not warrant further surveys.
		macro-invertebrates surveys; and physico-chemical parameters, including dissolved oxygen (DO) were measured during sampling.	NRETA – Aquatic Health Unit	National methodologies did not indicate significant changes in macro invertebrate communities. DO levels did not fall below naturally observed minimums. *In 2004 low DO levels were detected and remediated using aerators.
	Native Flora (riparian and aquatic) The application of herbicide has the potential to impact off-target aquatic plant species. Riparian plants with roots in the water, such as Pandanus aquaticus are also susceptible.	28 separate 5 m x 5 m x 1 m deep, plots established. Depth, vegetation cover from bank, dominants, vegetation cover from the top of water column and floristics recorded before and after treatment.	NRETA – Biodiversity Unit	No major changes.
Industry	Possible impacts on aquaculture facilities on the Darwin River, where estuary water is routinely pumped into production ponds.	Water quality testing as described above. Monitoring sites set up up-stream from aquaculture farm intake areas.	NRETA – Aquatic Health Unit	No detectable herbicide has been found in the vicinity of aquaculture farms.

Water Quality Monitoring Program

Weekly surface water samples were collected from four sites, identified as Sites A-D, for analysis of the herbicide 2,4-D-n-butyl ester. Site locations are described below and depicted in Figure 2.

- Site A is in the lower freshwater reach of Darwin River below all infestations of cabomba.
- Site B is in the estuarine section of Darwin River just upstream of its confluence with the Blackmore River.
- Site C is downstream of the Darwin-Blackmore Rivers confluence adjacent to the intake for an aquaculture operation.
- Site D is the intake pond for that operation.

Three additional sites would be monitored if herbicide was detected at Site B.

It was predetermined that if the concentration of 2,4-D-n-butyl ester exceeded a 'trigger value' concentration of 1.0 mg/L at Site A, action would immediately be taken to prevent any further increase (e.g. reduce/cease application volumes) or spread to downstream areas. Action would also be taken if herbicide was detected at any of Sites B, C or D.

To expedite analysis, water samples collected from Sites A-C were analysed at a local NT Government laboratory where the detection limit, or minimum detectable concentration, is 0.02 mg/L. Samples from Site D were sent interstate to a National Association of Testing Authorities (NATA) accredited laboratory with a lower detection limit of 0.001 mg/L to provide additional reassurance that the herbicide was not affecting aquaculture operations.

No 2,4-D-n-butyl ester was detected at the Darwin River monitoring sites in the 2005/06 year. This result was expected given the relatively low volumes of herbicide used.

Table 7: Water monitoring schedule and results for 2,4-D-n-butyl ester testing at Darwin River monitoring sites, May 2006

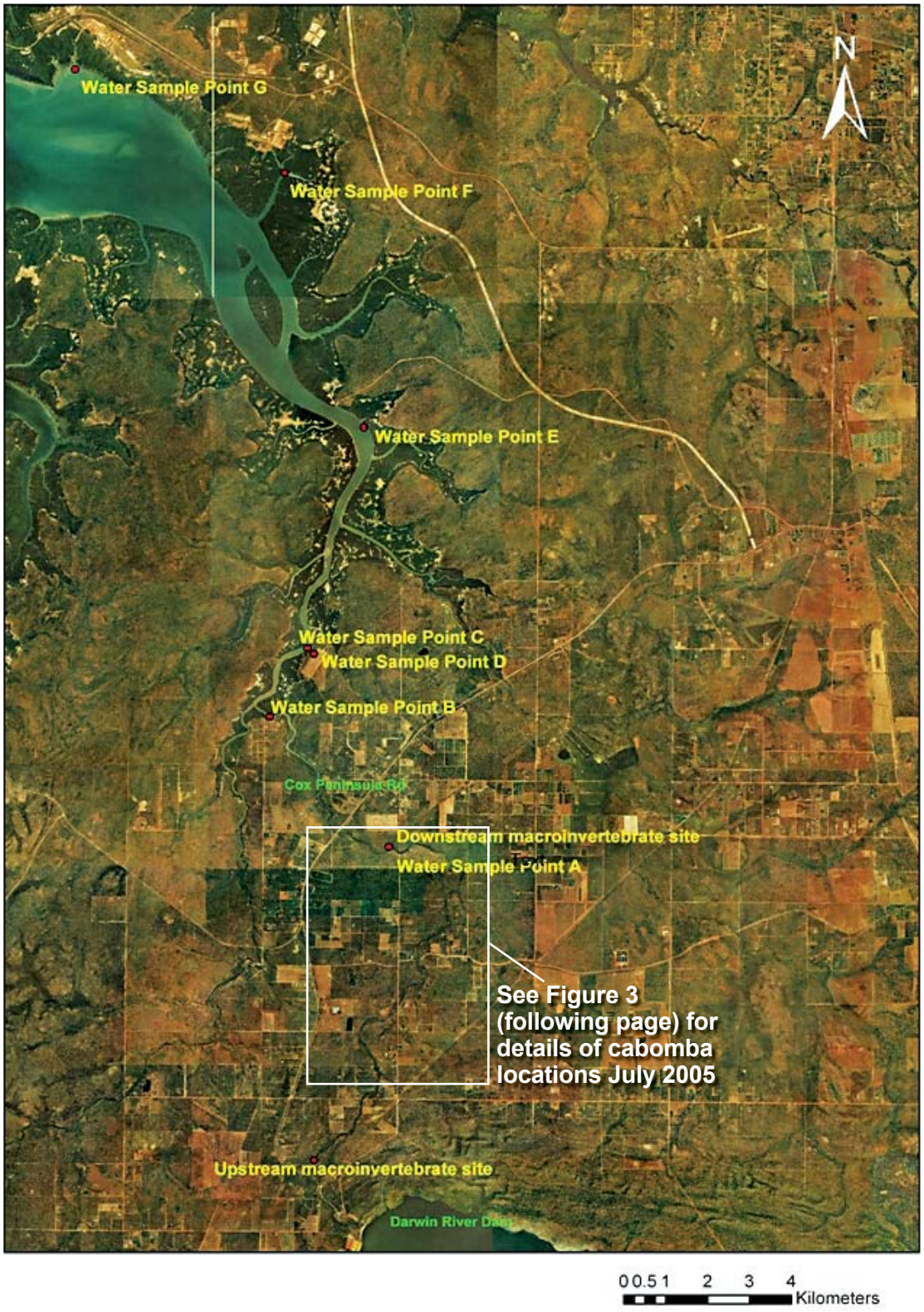
Sample date	Site A (mg/L)	Site B (mg/L	Site C (mg/L)	Site D (µg/L)
22/05	<0.02	<0.02	<0.02	<1
30/05	<0.02	<0.02	<0.02	<1
06/06	<0.02	<0.02	<0.02	<1
13/06	<0.02	<0.02	<0.02	<1
19/06	<0.02	<0.02	<0.02	<1
26/06	<0.02	<0.02	<0.02	<1

Notes: Sites A-C are analysed at Berrimah Farm DPIFM labs where detection limit is 0.02 mg/L. <0.02 mg/L means 2,4-D was below detection. Site D is analysed at Sydney where detection limit is 1 µg/L. < 1 µg/L means 2,4-D was below detection.

Volumes of herbicide being applied will be reassessed if Site A records 2,4-D > 1 mg/L of water, or if 2,4-D is detected at Site B, C or D.

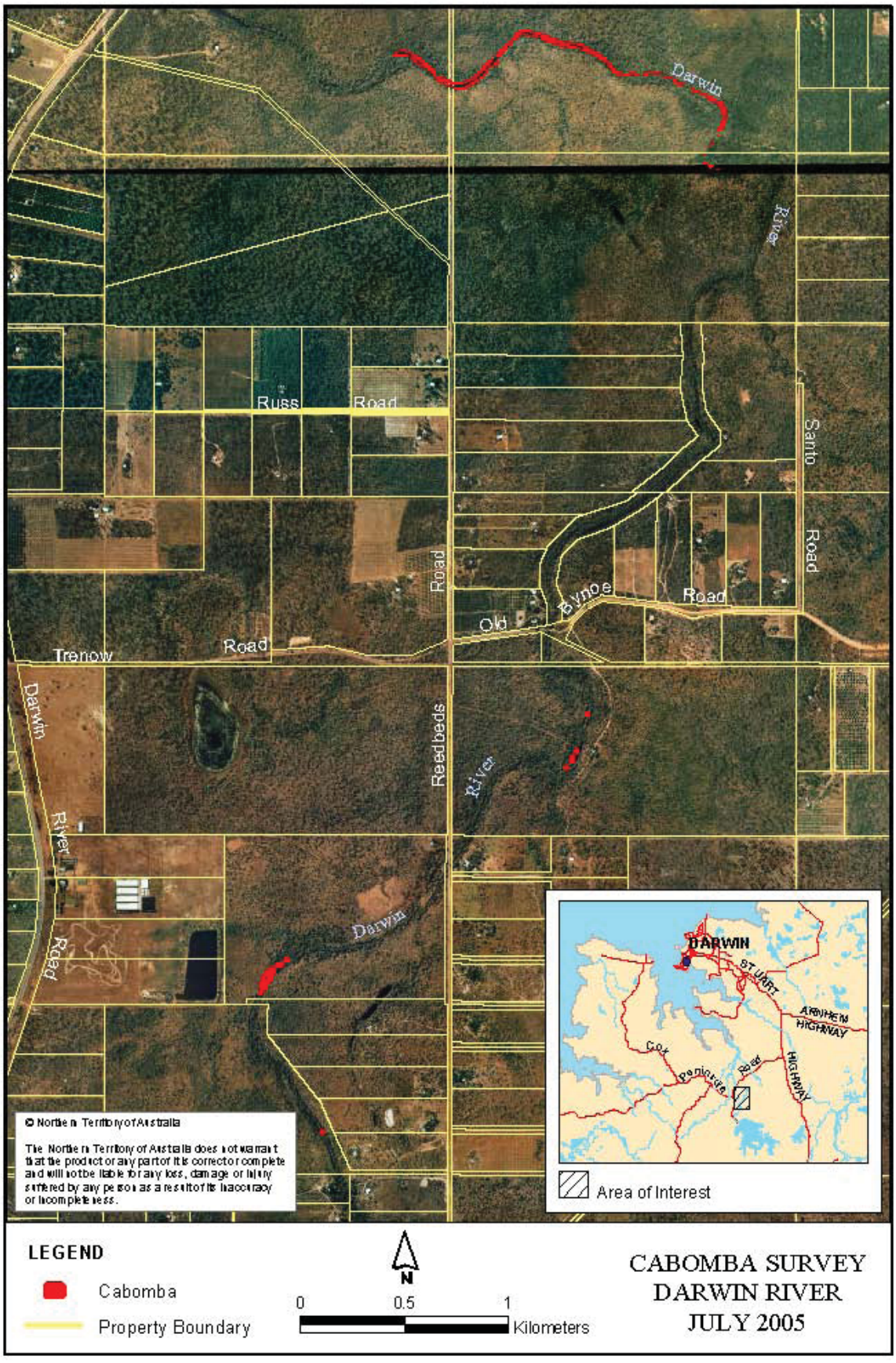
Lok Landji Billabong is a 2.2 km long section of Darwin River that is located 1.5 – 3.7 km upstream of the Cox Peninsula road and 0.5 – 2.7 km up stream of site A.

Figure 2: 2006 Water quality monitoring sites in Darwin River Catchment



Prior to the application of 2,4-D-n-butyl ester in 2004, bores along Darwin River were selected for monitoring. Samples from these bores were tested before treatment with 2,4-D-n-butyl ester (November 2004) and in February 2005. All samples were sent to Sydney for low level analysis of 2,4-D-n-butyl ester and the break down products, 4-chlorophenol and 2,4-dichlorophenol. In every sample, concentrations of all compounds were below detectable limits, meaning that the water was safe for drinking and use.

Figure 3: Cabomba survey July 2005



Macroinvertebrate Monitoring Program

Macroinvertebrates are animals without backbones, that are big enough to see with the naked eye. Macroinvertebrates form an integral part of the structure of most aquatic ecosystems, as they process and transfer organic material/nutrients and serve as a major food source for fish, water birds and other animals. Changes to macroinvertebrate community composition or populations can have significant implications for other organisms in the food web.

Many macroinvertebrates have limited mobility, meaning they are less able to avoid unfavourable environmental conditions. They are also sensitive to many environmental stressors. Consequently macroinvertebrate communities respond quickly to environmental changes. Monitoring of these communities can therefore tell us a great deal about the health of an ecosystem.

To evaluate whether the application of 2,4-D-n-butyl ester was having an impact on Darwin River health, a macroinvertebrate monitoring program was implemented by the Aquatic Health Unit of NRETA. The program involved sampling one site in the early dry season (a regular monitoring site since 2002), prior to the application of the herbicide 2,4-D-n-butyl ester and six sites being monitored at the end of the dry season, when a possible impact would be more evident.

The results of the early dry season sampling analysed with the Darwin-Daly family level AUSRIVAS* model revealed no significant change to the macroinvertebrate community at the monitoring site from 2002 to 2006. The sampling confirmed that the macroinvertebrate community of Darwin River had remained similar to other regional rivers and streams in the early dry season.

Plate 4 - Macroinvertebrate sampling. G. Lamche and R. Spry, Aquatic Health Unit, NRETA.

*AUSRIVAS (Australian River Assessment System) is a prediction system used to assess the biological health of Australian rivers. AUSRIVAS was developed under the National River Health Program (NRHP) by the Federal Government in 1994, in response to growing concern in Australia for maintaining ecological values. More information is available from http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/.

Fauna Monitoring Program

Crocodile surveys were initially undertaken in November and December 2004, pre and post treatment. Live crocodiles were observed in the treatment pools before and after treatment. Similarly trapping indicated yellow faced turtles were still present after the treatment. No further testing occurred in 2005/06.

A bird monitoring program, which was developed prior to the 2004 treatment, was continued. Staff and students from the Charles Darwin University's Parks and Wildlife Certificate course attempted to conduct dry season surveys. The surveys involved counting birds from four insectivorous or fish eating groups from a slowly moving boat in three control and three treated sites. Each site, a 200 metre reach, is assessed for bird presence four times over two days. Data was collected in September and November 2005.

Birds from all four groups were present at both the control and treatment sites. While the numbers were lower than those recorded during the 2004 surveys, this was most likely due to natural variation in numbers, since the numbers are low in both the control and treated sites. No statistical analyses have been conducted but preliminary assessment indicates that the eradication program is not impacting on any of the bird groups.

In 2004/05 the NT Department of Primary Industry, Fisheries and Mines conducted a series of fish surveys using gill nets and electro fishing techniques in both control and treatment sites. As no negative impacts were identified no further tests were deemed necessary in the 2005/06 period. No fish kills were observed during or after applications, despite extremely low levels of dissolved oxygen. As herbicide applications during the 2005/06 period were expected to be far lower than those initial applications no further monitoring was deemed necessary.

Incidental sightings during all site visits in 2005 included water monitors, water dragons, barramundi and rainbow fish. Crocodiles and turtles were also observed.

Flora Monitoring Program

The application of herbicide has the potential to impact off-target species. Riparian plants with roots in the water, such as *Pandanus aquaticus* are also susceptible. Surveys assessing the vegetation cover from bank, dominants, vegetation cover from the top of water column and floristics were recorded before and after treatment in 2004/05. While localised and short term impacts were observed, including the death of individual tress and banks of lilies, there was no indication that any irreversible impacts on the vegetation structure and ecosystem function would result.

The treatment areas are downstream of a four kilometre stretch of river which has not been impacted by cabomba or treated with herbicide. It is anticipated any aquatic and terrestrial plant communities harmed during the Cabomba Eradication Program will recover as native plant and seed material travels downstream and establishes in treated areas.

4. Conclusion

Public awareness, early detection, prevention of spread, prevention of seed production, prevention of establishment, the ability to manage with minimal off-target impacts, and targeted research are all components of an effective weed management program. Weed eradication may, as in this instance, require these components to be delivered concurrently.

The Cabomba Eradication Program will continue in the 06/07 period. Successes to date have already resulted in a refinement of techniques and further significant reductions in cabomba populations. Continued vigilance with respect to monitoring and surveillance will play a vital part in achieving eradication in the long term. The production of viable seed has provided a formidable challenge which has resulted in new investments in management and research. The extension of the quarantine order until November 2008 will play an important part in preventing spread of viable plant material and seeds.

During the 2005/06 reporting period all objectives of the NT Cabomba Eradication Program were met, with success being measured through the following observations:

No new infestations in the NT were identified

The implementation of the Education and Awareness Program, while resulting in a number of reports of potential new infestations did not result in new positive records for the NT.

The spread of populations of cabomba into new areas was prevented

Prevention of spread was effectively achieved through the implementation of quarantine restrictions in the project area, the establishment of floating 'booms' and also through active management of all sites where germination was detected.

Re-establishment at existing sites was prevented through management activity

Throughout the 2005/06 reporting period, all infestations were actively managed using either shades, herbicides, or a combination of both. These activities kept infestations to a level of at least 80% below those experienced in 2004. This reduced the potential for localised impact, further spread and subsequently reduced the requirement for herbicide application.

Seed production was prevented through the installation of shades

Once it had been determined that cabomba populations in the Darwin River were unfortunately producing viable seed every effort was made to prevent flower production, and therefore seed production, during the reporting period. The installation of shades limited infestation expansion and opportunity for seed transfer to into unaffected areas.

The viability and longevity of seed was determined

During the reporting period research into seed viability and longevity commenced. Results indicate a high level of viability for extended periods (at least 18 months). These results indicate that survey, monitoring and control efforts will need to continue for at least two to three years after flower production has been completely prevented.

Monitoring programs did not indicate negative off-target environmental or economic impacts as a result of the implementation of the management program

Programs monitoring the effects of herbicide application on aquatic macro-invertebrates, riparian fauna and riparian vegetation failed to detect any significant negative impacts resulting from management activities.

Water quality monitoring in both freshwater and saline ecosystems, did not indicate the presence of the herbicide 2,4-D-n-butyl ester at significant levels during the reporting period.

Plate 5: Cabomba flower

5. References

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Plate 6: Cabomba infestation, Darwin River