Cabomba caroliniana eradication - integrated weed control success in the NT

Christopher Collins[1], Tony Dugdale[2] and Thomas Price[1]
[1]Northern Territory Government - Department of Environment, Parks and Water Security, Palmerston, NT, Australia
[2]Victorian State Government – Agriculture Victoria Research, Department of Jobs, Precincts and Regions, Victoria, Australia
(christopher.collins@nt.gov.au)

Summary Cabomba (*Cabomba caroliniana* A. Gray) is a submerged aquatic plant from the southern United States, is one of the world's most serious aquatic weed species. It is recognised in Australia as a Weed of National Significance. The species was first detected in the Northern Territory (NT) in 1996 and since that time the Northern Territory Government's Weed Management Branch has successfully eradicated three separate naturalised infestations. A fourth site, along a 2.2km stretch of the Darwin River, is presently on track for eradication. The success of the NT cabomba eradication effort is multi-faceted and predominantly sits with the integration and timing of multiple infestation stressors over time. These main stressors were natural annual flooding of the infestation area during the wet season, broad scale application of the herbicide carfentrazone and restriction of propagule spread. Importantly, cabomba programs in the NT have had consistent resourcing for over 20 years and the support of multiple agencies which enabled the NT Weed Management Branch to move past failures to achieve eradication.

Keywords aquatic weeds, carfentrazone-ethyl, eradication, integrated weed management.

INTRODUCTION

Eradication of *Cabomba caroliniana* (cabomba), a Weed of National Significance (WONS), from the wet dry tropics of Australia's Northern Territory (NT) has been the aim of the Northern Territory Government's Weed Management Branch (WMB) since first detection in 1996. Between 1996 and 2018 WMB has locally eradicated three naturalised cabomba infestations located in Palmerston's Marlow Lagoon, Pine Creek and upper Darwin River. Predominately combinations of hand pulling and applications of the herbicide 2,4–D n-butyl ester (2,4-D) resulted in local eradication of cabomba from these water bodies (Price and Collins, 2016). Although WMB applies a stringent requirement of ten years of no detection before eradication is declared, it was observed in each of the cases above that where a 12 month period of no detection of cabomba is achieved, cabomba does not return (14 plus years of subsequent nil detection at these sites has followed, as of 2021).

A fourth site that contains cabomba is the lower Darwin River (Lok Landji). It is currently in its fifth year of no detection, after an extensive eradication program, which began in 2004 (when the upper Darwin River eradication program began). It represents the only other known cabomba infestation in the NT.

This paper outlines the integrated weed management measures implemented by WMB in Lok Landji since 2016 that have resulted in this fourth site being on track for cabomba to be declared eradicated from the NT in 2027.

FIELD SITE AND INFESTATION

Darwin River Cabomba Infestation NT On 21 October 2004 cabomba was reported and positively identified in Darwin River. Subsequently cabomba was identified at multiple locations along an 11 km reach (Department of Natural Resources Environment and the Arts, 2006). The river itself stretches for a total of 16 km draining into Darwin Harbour. The management of the infestation was split between the top 8 km (Upper Darwin River) and a downstream billabong, Lok Landji, by shallow rocky anabranches. Lok Landji is a perennial water body located in the lower reaches of Darwin River. It is a 2.25 km long billabong with a variable width up to 40 m and depth up to 10 m (average 3 to 4 m). Its volume is ~170 ML and surface area ~6 ha.

METHOD

Cabomba Eradication Methods Lok Landji The active control program, 2016 to 2019, was modified with the following activities undertaken:

- Intensive surveillance.
- Booms installed.
- Four broad scale applications of Shark® Aquatic Herbicide (240 g L^{-1} carfentrazone-ethyl).
- Physical removal of plants (carried out as detected during surveillance).
- Quarantine area declared.

Intensive Surveillance Techniques Surveillance has been an integral part of the Program since 2004. From 2016 to January 2019 about 100 separate survey events have been carried out in Lok Landji, with surface surveys making up the bulk of the events. In the NT's Top End, entering the water is not recommended as the probability of a salt water crocodile encounter is greater than zero. Five salt water crocodiles have been found and removed from Lok Landji over the last eight years, the largest being a 3.25 m animal in September 2017.

Surface Surveys Surface surveys for cabomba in Darwin River were conducted from a vessel or from the bank on foot (where the river is unnavigable by vessel). The vessel is moved at idle speed adjacent to the bank with one observer surveying forward and down and the other looking between the vessel and the bank. It takes 28 days from flowering for cabomba to produce a seed (Tarver and Sanders, 1977). Weekly surveys were deemed necessary as surface surveys are not 100% effective, thus providing multiple chances for individual plants to be detected and removed before setting seed.

Benthic raking surveys Benthic raking involves a grapnel (two rake heads, fastened back to back) on the end of a length of metal chain which is attached to over 10 meters of rope. The grapnel is thrown into the water, allowed to sink to the bottom and then dragged along the river bed some few meters and then raised up. Cabomba fragments, if present, are readily snagged by the tines on the rake heads and able to be brought to the surface for inspection.
Benthic raking was used by Weed Officers in an ad hoc fashion at random and historic cabomba infestation sites only.

Boom Inspection Surveys Floating booms with curtains were used to reduce the ability of cabomba fragments to disperse up or downstream of infestations. The booms were strung up across the river at strategic locations to catch fragments that moved with the current or were windblown along the surface in any direction. In 2016 two booms were installed across Lok Landji. One was installed upstream of the most upstream cabomba location and the other at the junction of the carfentrazone treated and untreated areas. The booms were inspected weekly for the presence of fragments. The side of the boom the fragments were found on gave an indication of whether an infestation was present up or down stream of the boom. The upstream boom also reduced potential for movement of windblown floating fragments entering cabomba free areas of the billabong. Booms were typically removed from the river once a significant flow was experienced as a result of wet season rainfall.

Underwater camera survey The Director of Marine Ecosystems (NTG Flora and Fauna Division) developed a cabomba detection protocol for WMB after a pilot survey was conducted. The aim was to assess the effectiveness of the aquatic herbicide treatment in Lok Landji with a monitoring program using an underwater video camera and occupancy modelling framework.

The surface area of Lok Landji was divided up into 612 sites averaging about 10 m by 10 m (~100 m^2). To determine survey sensitivity prior to application of carfentrazone, 97 randomly selected sites were surveyed in August 2016 across Lok Landji. At each site a video camera was dropped to the river bed six times to determine the presence or absence of cabomba. Cabomba was found in 15 out of the 97 sites surveyed (naïve occupancy = 15.4%). The detectability was quite low (0.26) which means it often only turned up once or twice in the 6 camera drops per site. Based on this, we were 85-90% confident that we would find cabomba by dropping the camera 6 times per site, if it is present. To be 95% sure of detection it would require 10 camera drops per site (Griffiths, 2016).

eDNA Sampling In 2018 the Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) at James Cook University Queensland developed an environmental DNA (eDNA) assay for the detection of cabomba (Edmunds and Burrows, 2019). In late 2018 WMB collected surface and benthic water samples from Darwin River for Cabomba eDNA assay.

Herbicide application Two key factors drove the herbicide application technique. Firstly, eradication requires that all plants are controlled, and no surveillance program can detect every stem of cabomba in a 6 ha waterbody, even if it weren't inhabited by crocodiles. Secondly, submersed aquatic weeds such as cabomba require hours of exposure to herbicide to be killed (FMC Corporation, 2012). Broadscale application of the herbicide carfentrazone to the entire infested area (i.e. the sections of the billabong that were known to contain some cabomba) results in exposure at the target concentration (2 ppm a.i.) of the herbicide for a much

greater period (in contrast to spot applications, which result in rapid dilution and were used in the past with 2,4–D). Furthermore, it results in all plants in the infested area being exposed, even if they had not been detected by the surveillance program. This circumvents the necessity of needing to detect every plant of the target species to achieve control, a limitation known to cause eradication programs to fail.

Cabomba infestations were known to occur in the downstream section of Lok Landji and occupy 65% of the billabong volume. Given a maximum of 50% of the volume could be treated under the APVMA permit, the upstream-most infested part of this area, equating to 50% of the billabong volume, was treated. Upstream areas must be treated first to completely remove the risk of upstream reestablishment. The remaining 15%, at the most downstream part of the billabong, was left untreated.

Carfentrazone applications were carried out to coincide with ideal treatment conditions, those being healthy and actively growing cabomba, high light conditions with clear water and low water flow (FMC Corporation, 2012).

Seasonal Flooding – Impact on Cabomba Wet season flooding is not a direct action of the program managers but is a significant annual event that warrants consideration. Major flooding was experienced in Lok Landji between January and May 2017. The 2016/17 wet season for Darwin and surrounds was the third biggest on record. The resultant high flow rate of Darwin River coincided with the Darwin River dam reaching capacity and the dam spillway flowing for an estimated 68 days, with high river flows well into the early dry season. This high river flow and subsequent high turbidity resulted in a period of around five months where cabomba growth would have been supressed due to suboptimal growing conditions (low light caused by high turbidity and high flow).

RESULTS

Application and monitoring In total four 50% by volume treatments of cabomba with carfentrazone were carried out annually in Lok Landji in September or October between 2016 and 2019. A significant water quality monitoring protocol was implemented for each application as a requirement of the Northern Territory Environment Protection Authority.

Cabomba abundance Between 2004 and 2009 cabomba had been present in an estimated 340 out of the 612 camera survey sites and in August 2016, before carfentrazone was applied in October 2016, cabomba was present in 86 of the 612 sites.

Three months post-first application (Jan 2017) no floating cabomba fragments could be located in either the treated or untreated infestation areas, however, in the untreated area a single, healthy 10 cm fragment was retrieved via benthic raking. This healthy stem indicated that targeted management would be required once the river stopped flowing in the 2017 dry season. In May 2017, seven months after application, no cabomba was detected in any of the camera survey sites. The herbicide application had effectively controlled the whole infestation. This result supports the findings in Glenbrook Lagoon, NSW (Day, *et al*. 2014) where half of the waterbody was treated but very effective control was achieved over the entire waterbody.

Multiple integrated surveys were undertaken throughout the 2017 dry season months with nil cabomba detected. In mid-September 2017, the second 50% by volume treatment for cabomba using carfentrazone was completed as a follow up application relative to the detection of the fragment in January 2017 and to treat any other undetected cabomba.

In 2018 and 2019 multiple integrated surveys were undertaken throughout the dry season months, cabomba was unable to be detected. However, cabomba DNA was detected in water samples collected in 2018, mostly from benthic samples (Edmunds, *et al*. 2019). The positive detection is, in itself, not a direct indication of live of viable cabomba plants or propagules being present. TropWATER advised that the eDNA assay cannot distinguish between eDNA from viable cabomba and eDNA from dead or decaying cabomba, legacy eDNA. It is believed that it is possible for eDNA of aquatic vegetation to be present and detectable some years post the death of the last viable plant or propagule (Edmunds, *et al*. 2019). This information was reason enough for program managers to carry out a third (September 2018) and fourth (September 2019) 50% by volume treatment for cabomba using carfentrazone.

Not a single cabomba plant or fragment has been detected since January 2017, as of December 2021. Cabomba is likely to be declared eradicated from Lok Landji and the NT generally in 2027.

DISCUSSION

The NT cabomba eradication program has adapted and overcome the challenges that had seen the

progression towards eradication falter in Lok Landji prior to 2016.

Reintroduction of cabomba or establishment of new infestations in the NT cannot be ruled out. The aquarium industry trade cannot wholly be prevented and poses a risk. It is also probable that cabomba is currently present in ponds and aquariums in the NT with release into the environment possible. It is also possible that viable cabomba seed is present in Lok Landji, although this seems unlikely given that regeneration has not occurred in any of the other three NT sites where eradication has been declared.

With detection of dormant cabomba propagules being almost impossible, a lot of weight has been placed in the supporting evidence that cabomba has not returned at any other location in the NT where a nil detection period of 12 months has occurred. It is noted, for Lok Landji, that it has been over four years since last detection but only 30 months since active control ended though natural flooding continues unaided.

Annual wet season flooding is likely to have contributed to the long-term control observed after the 2016 application. Similar long-term control has been observed in Lake Benalla, Victoria, where drawdowns were used to control cabomba. Sampling of the cabomba at the end of the drawdowns demonstrated that cabomba was still viable and capable of rapid regeneration, however, severe flooding in the lake after the drawdown (and associated turbid water) is thought to have resulted in long term control, although cabomba returned several years later (Author's pers. obs.).

Another risk to the NT cabomba eradication goal is the potential decline in political and departmental will to continue investment in weed eradication programs. Having seen, across all NT cabomba infestation, 25 years (and counting) and almost $5 million invested so far, there is a possibility of support being withdrawn given competing priorities for government resources. The opportunity cost of not eradicating cabomba is the realisation of the threats the weed possess to the NT lifestyle, tourism and economy. Rough costings to build a water treatment plant, should cabomba enter Darwin River Dam (Darwin's main potable water supply), was estimated to be $40 million in 2004 and up to $100 million in 2016.

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