Factors influencing deoxygenation following an unintended whole of water body herbicide treatment of aquatic weed cabomba in a natural wetland in the Blue Mountains, NSW, Australia.

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Key Points

- The recently registered Shark™ Aquatic Herbicide (240g/L carfentrazone-ethyl) was used at Glenbrook Lagoon to treat an infestation of cabomba, one of the first applications of this scale in Australia.
- Water quality and ecological effects were monitored to determine the impacts of the herbicide on a large natural water body.
- To minimise impacts the herbicide was applied to 50% of the total water body volume. However, the application was effective in killing cabomba across the entire water body and resulted in deoxygenation and a fish kill.
- The oxygen depletion can be attributed primarily to the large decomposing biomass of cabomba, algae and other non-target aquatic weeds, combined with stratification and warm, calm prevailing weather conditions causing reduced mixing and high water temperatures.
- Attempts were made to re-oxygenate the lagoon using generators and pumps, with limited results. Re-oxygenation of a large water body, particularly without a power source, is difficult and expensive.
- One year later, monitoring programs show a return to healthy dissolved oxygen levels; a healthy population of native fish and turtles; and no evidence of cabomba or weed water lily.
- This case study highlights the challenges involved with planning and implementing a large scale aquatic weed control program and the importance of understanding and careful consideration of the current physical, chemical and biological conditions of the individual water body being targeted.

Abstract

Glenbrook Lagoon, an eight hectare natural escarpment wetland in the Blue Mountains of New South Wales, has a history of poor water quality and aquatic weed infestations because of the surrounding urban catchment. Until recently, the lagoon was densely infested with cabomba (*Cabomba caroliniana*), an invasive aquatic weed listed as a Weed of National Significance (WoNS).

In December 2012 the cabomba infestation was successfully treated using the recently registered Shark™ Aquatic Herbicide (240g/L carfentrazone-ethyl) (Shark). The application was intended to treat only 50% of the water body (as per label directions), but was found to be effective in controlling cabomba across the entire water body.

Oxygen depletion was observed across the entire water body following the rapid dieback and decomposition of weeds, together with other contributing factors including stratification and warm, still prevailing weather conditions. A fish kill of stocked Australian bass (*Macquaria novemaculeata*) occurred after a prolonged period of extremely low oxygen levels (0.04%; 0.4 mg/L). Attempts to re-oxygenate the 8 ha lagoon were largely unsuccessful.

Case studies of cabomba control in large natural water bodies in Australia using aquatic herbicides are rare and this paper seeks to outline some of the challenges involved, the lessons learned and make recommendations on how to implement a successful control program whilst minimising deoxygenation.

Keywords

Dissolved Oxygen Depletion, Deoxygenation, *Cabomba caroliniana*, Shark™ Aquatic Herbicide, carfentrazone-ethyl, aquatic weed control, thermal stratification, wind mixing, water temperature, Glenbrook Lagoon.

Introduction

Glenbrook Lagoon is a natural escarpment wetland in the Blue Mountains of New South Wales, Australia. The Lagoon has a history of poor water quality, aquatic weed infestations and occasional algal blooms. Blue Mountains City Council (Council or BMCC) embarked on a Glenbrook Lagoon restoration program and one of the top priorities was to address the aquatic weeds that were choking the water body and impacting water quality, biodiversity and habitat values.

In December 2012 an aquatic weed control program to control cabomba was undertaken in Glenbrook Lagoon using Shark. This was the first use of this herbicide for cabomba control in a natural wetland and in a water body of this size in Australia, with herbicide registration trials having taken place in farm dams and small ponds.

Cabomba is an invasive aquatic weed listed as a Weed of National Significance (WoNS). This infestation was ranked by the National Aquatic Weeds Management Group in the top 10 strategic priority sites nationally for control due to its outlier status, risk of spread to important aquatic assets and its feasibility to control.

When embarking on the cabomba weed control program utilising Shark, dissolved oxygen (DO) depletion and fish distress were identified as potential risks from the decomposition of large quantities of organic weed material (BMCC, 2012).

In order to minimise off-target impacts the herbicide registration for Shark includes a restriction to treat a maximum of 50% of total water body volume at one time, with a 3 month period between treatments (FMC, 2011). Other measures were investigated to minimise DO impact including reduction of weed biomass through harvesting and pre-treatments of non-target weeds. Despite following the label conditions and technical notes the herbicide spread and affected the entire water body. Thermal stratification of the lagoon water column is thought to have contributed to this lateral movement of the herbicide (Day *et al*. 2014).

Many existing examples of deoxygenation following aquatic weed control are from northern hemisphere temperate lakes and ponds pre-1980's (Cragg & Fry, 1986). Prior to commencing this weed control program, one study was found from New Zealand that showed no adverse impact to dissolved oxygen levels following total water body weed dieback of Hornwort (*Ceratophyllum demursum*) (Wells *et al*. 2012). To observe any effects of weed treatment on dissolved oxygen levels at Glenbrook Lagoon a comprehensive water quality monitoring program was implemented.

Day *et al*. (2014) provide a general overview of the methods, outcomes and off-target impacts of this cabomba weed control program. This paper provides a case study of deoxygenation following whole of water body weed dieback. It explores the factors that contributed to deoxygenation in Glenbrook Lagoon; provides an example of anoxia resulting from aquatic weed control using herbicide under Australian conditions; recommends a cautionary approach when following technical notes; and offers some recommendations to minimise the risk of deoxygenation in future cabomba control programs.

Field sites and methods

Site: Glenbrook Lagoon

Glenbrook Lagoon is an eight hectare 'shallow lake' or 'pond' (Wetzl, 2001) surrounded by an urban catchment in the Blue Mountains, New South Wales. It is one of three natural escarpment wetlands of this type in the Hawkesbury-Nepean Catchment area (Figure 1; Coordinates decimal Lat/Long: -33.7574; 150.6162). The Lagoon is managed by Blue Mountains City Council. It is highly valued by local residents and provides habitat to a range of aquatic and terrestrial plants and animals.

The lagoon is a flat bottomed basin bordered by wide shallow margins, with a total estimated water volume of 225,147 m^3, mean depth of 2.7 m and maximum water depth of 4.05 m (Keogh, 1996).

A single outlet from the lagoon flows via an unnamed creek to Lapstone Creek and then to the Nepean River approximately 3 km downstream. The lagoon is also within close proximity to the Blue Mountains World Heritage National Park and some of Sydney's drinking water catchment waterways and reservoirs.

Prior to December 2012 close to 100% of the lagoon water column was occupied by the submerged aquatic weed *Cabomba caroliniana*, with 37% surface cover of exotic water lilies (*Nymphaea mexicana* and *Nymphaea alba*). The shallower margins of the lagoon support dense native rush beds dominated by *Lepironia articulata* (grey rush) and in deeper water, *Eleocharis sphacelata* (spike rush). Native bladderwort (*Utricularia australias* and *U. gibba*) were found floating on the surface (AMBS 2012; BMCC, 2013).

Pre-treatment fauna surveys identified three species of fish (two native and one introduced). The introduced gambusia (*Gambusia holbrooki*) was abundant and the dominant fish species in the lagoon. Native flathead gudgeon (*Philypnodon grandiceps*) was uncommon in the survey (3 recorded) and an eel (probably *Anguilla reinhardtii*) was recorded. No threatened species were recorded or expected to occur (AMBS, 2012).

Herbicide treatment

On 3 and 4 December 2012, Shark was applied to 50% of the lagoons total water body volume (*c.* 209,000 m^3) at the label rate of 2ppm a.i. (active ingredient) (FMC 2011), using sub-surface injection from a boat-mounted boom with trailing hoses. 864 litres of Shark was applied. The application area (Figure 1) was chosen to target areas with actively growing cabomba and to avoid weed water lily cover to the north of the lagoon (which had been partially pre-treated using Glyphosate 360g/L, with plans to treat the remaining water lily prior to applying Shark to the untreated 50% of the water body volume three months later).

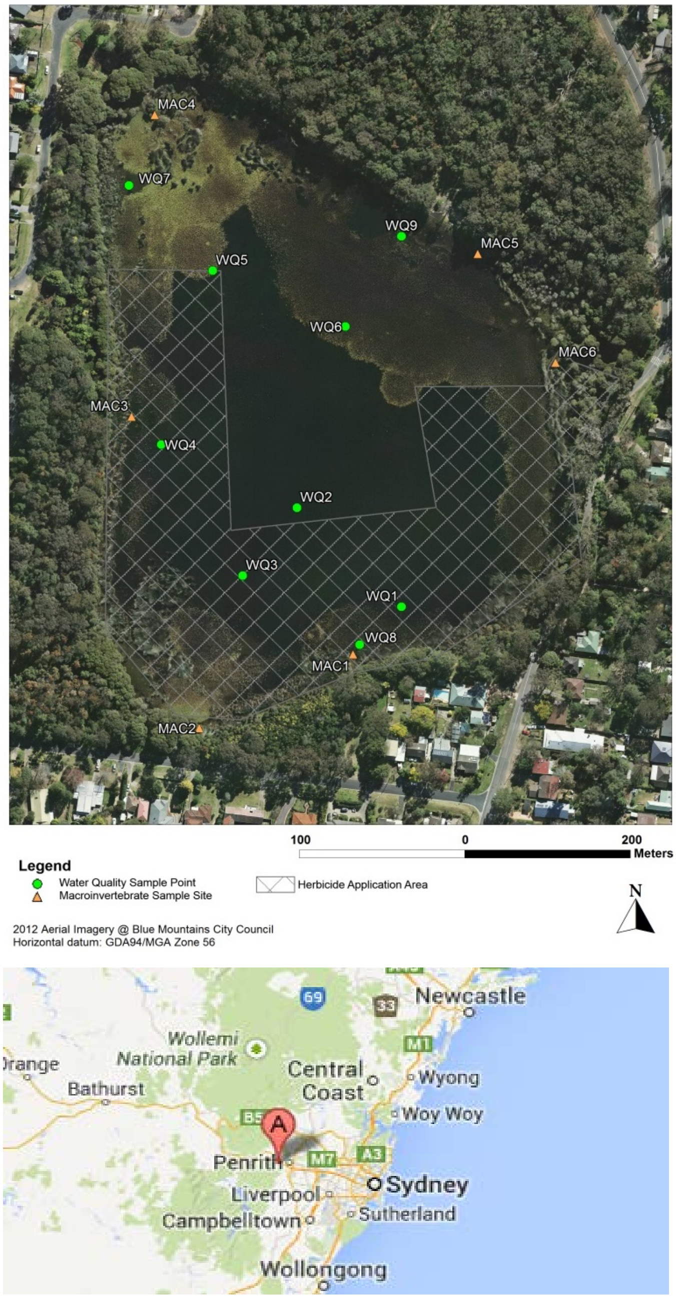

Figure 1. Top: Glenbrook Lagoon showing water quality monitoring sites (WQ1-9; MAC1-6) and herbicide application area (hatched) Bottom: Site Location (Google Maps, 2014).

Aeration

Following observations of declining dissolved oxygen in the lagoon two 6-inch diesel powered water pumps were installed at the north and south access points to the lagoon (WQ8 & 9) creating pockets in the lagoon with water circulation, surface agitation and fountains. During initial pump installation a boat was used to agitate and mix the surface of the lagoon.

Water Quality survey timing & variables

A monitoring program was implemented to assess the impacts of the cabomba weed control program on water quality, biodiversity and weed control outcomes in Glenbrook Lagoon prior to and immediately following treatment and over a three year period (AMBS, 2013; BMCC, 2013; Day *et al*. 2014).

Water quality sampling took place pre- and post-treatment at water quality monitoring sites (WQ1-9) and during macroinvertebrate monitoring (MAC 1-6), and results are reported to February 2015. A data logger was obtained on the second day of treatment (4 December 2012) and was placed at location WQ4 for two months post treatment (Figure 1). Parameters measured included: dissolved oxygen (mg/L & % Saturation), temperature (^{o}C), turbidity (NTU), pH, electrical conductivity (mS/cm); and salinity (pss).

In-situ water quality was measured using a calibrated hand held water quality meter (Quanta Hydrolab multi probe). The readings were taken at a depth of 0.5 m within the Lagoon at the sampling locations (WQ1-9 and MAC 1-6; Figure 1). The readings were taken pre, during and then daily for 1 month post treatment, then weekly for a further month; fortnightly for a further 6 weeks, monthly for two months and 6 weekly in summer 2013/14 (1 year post). Measurements were taken between 9:00 am – 11:00 am and recorded using a GPS enabled pocket pc electronic field data sheet. Maximum water depths at sampling sites ranged between 0.5 m – 3.5 m deep.

A single calibrated multi-parameter data logger (DS5X) was placed at site WQ4 at a depth of *c*. 0.7 m. The data logger was in place for 2 months, 4/12/12 – 5/02/2013. Measurements were recorded every hour. WQ4 was chosen as it was a core water quality monitoring site, was not easily accessible, was within the herbicide application area and had approximately average depth for the lagoon (*ca*. 2.7 m deep).

Water column profiles were measured pre, during and post treatment at one to six sites per sample period. In-situ water quality parameters were measured at 0.5, 1, 2, & 3 m depths, and at 1.5 and 2.5 m on occasion. This was conducted to assess changes in water quality associated with thermal stratification that was found to exist in the wetland during the first pre-treatment sample.

Data analysis

Water quality data was collected using 'PocketPC Creations' software on a GPS enabled pocket pc device, downloaded and exported to an excel spreadsheet and quality checked. Water quality measurements taken between 9:00 am and 11.00 am were collated from both hand-held and data logger probes from all sites and were then divided into date range categories representing key activities or water quality trends for analysis (Table 1).

Table 1: Time period categories for analysis of water quality measurements based on treatment events and dissolved oxygen trends (date ranges and Days after treatment (DAT) or Months after treatment (MAT) are given for each category)

Code: Category Description	Date/ Date Range	DAT	Code: Category Description	Date/ Date Range	DAT/MAT
Pre: Pre-treatment samples	26 & 30/11/2012	-	R2: DO Recovery Phase 2	26/01/2013 – 27/02/2013	53-84
Tx: Herbicide treatment period	4/12/2012 – 7/12/2012	0-3	R3: DO Recovery Phase 3	11/03/2013	97/3
Low DO: period of severe deoxygenation	8/12/2012 - 31/12/2012	4-27	Autumn: Stratification Graph only	23/04/2013	5 MAT
R1: DO Recovery Phase 1	1/01/2013 – 25/01/2013	28-52	1 Year: One Year after treatment	25/11/2013 & 15/01/2014	12&13 MAT

One way ANOVA was performed on each water quality parameter across seven time categories using Microsoft Excel software. ANOVA results and summary statistics for dissolved oxygen % saturation (DO% Sat.), dissolved oxygen mg/L (DO mg/L), pH, temperature ^{o}C (Temp ^{o}C), and turbidity (NTU) are presented in Table 2.

Graphing of Dissolved Oxygen % Sat. was achieved using Microsoft Excel software using combined in-situ handheld water quality probe data and data logger readings from 9-11 am, allowing for daily trends to be graphed over the 2 months following herbicide application, followed by approximately weekly for a further month, and then one year post treatment (Figure 2). Water column profile graphs were also achieved using Microsoft Excel (Figure 3).

Results and discussion

Following application of Shark to 50% of Glenbrook Lagoon, lateral herbicide drift resulted in complete dieback of cabomba and the remaining healthy water lily across the entire lagoon (photos in appendix). This was an unexpected outcome as the influence of stratification was not appreciated at the time and plans were in place for a follow up treatment 3 months later to treat the other half. The greater than expected dieback resulted in a more severe decline in oxygen levels than anticipated and was the likely cause of a fish kill. Rapidly declining dissolved oxygen (DO) concentrations were recorded at 10 am (+/- 1 hour) in the first four days and a minimum of 0.7% (0.07 mg/L) was recorded 4 DAT (days after treatment). This was followed by *c*. 23 days of extremely low DO (mean: 10.31%; 0.88 mg/L; minimum: 0.4%; 0.03 mg/L) before beginning to show signs of a slow recovery, reaching a maximum of 82.8% (6.4 mg/L) after more than 3 months. Pre-treatment DO levels average 92.35% (7.93 mg/L) with a range of 64 - 117.3% (5.48 - 10.05 mg/L) (Figure 2 and Table 2). A further drop in DO was recorded in April 2013 (5 MAT (months after treatment), believed to be related to autumn water column turnover (Figure 3). 13 MAT recorded DO levels were within ANZECC (2000) guidelines for ecosystem health.

Diurnal records of dissolved oxygen concentration showed periods where levels were close to zero for large portions of the day. On 15 December 2012 (11 DAT) the data logger recorded a period between 11 am to midnight of 0.4% DO saturation (0.03-0.04 mg/L). At some time during this period a fish kill of approximately 50 stocked Australian bass occurred. The maximum water temperature recorded during this period was 23.67^{o}C. Australian Bass had not been recorded in the lagoon during pre-treatment surveys (AMBS 2012) and stocking of this fish was thought to have ended decades earlier due to poor water quality in the lagoon making it unsuitable for recreational fishing.

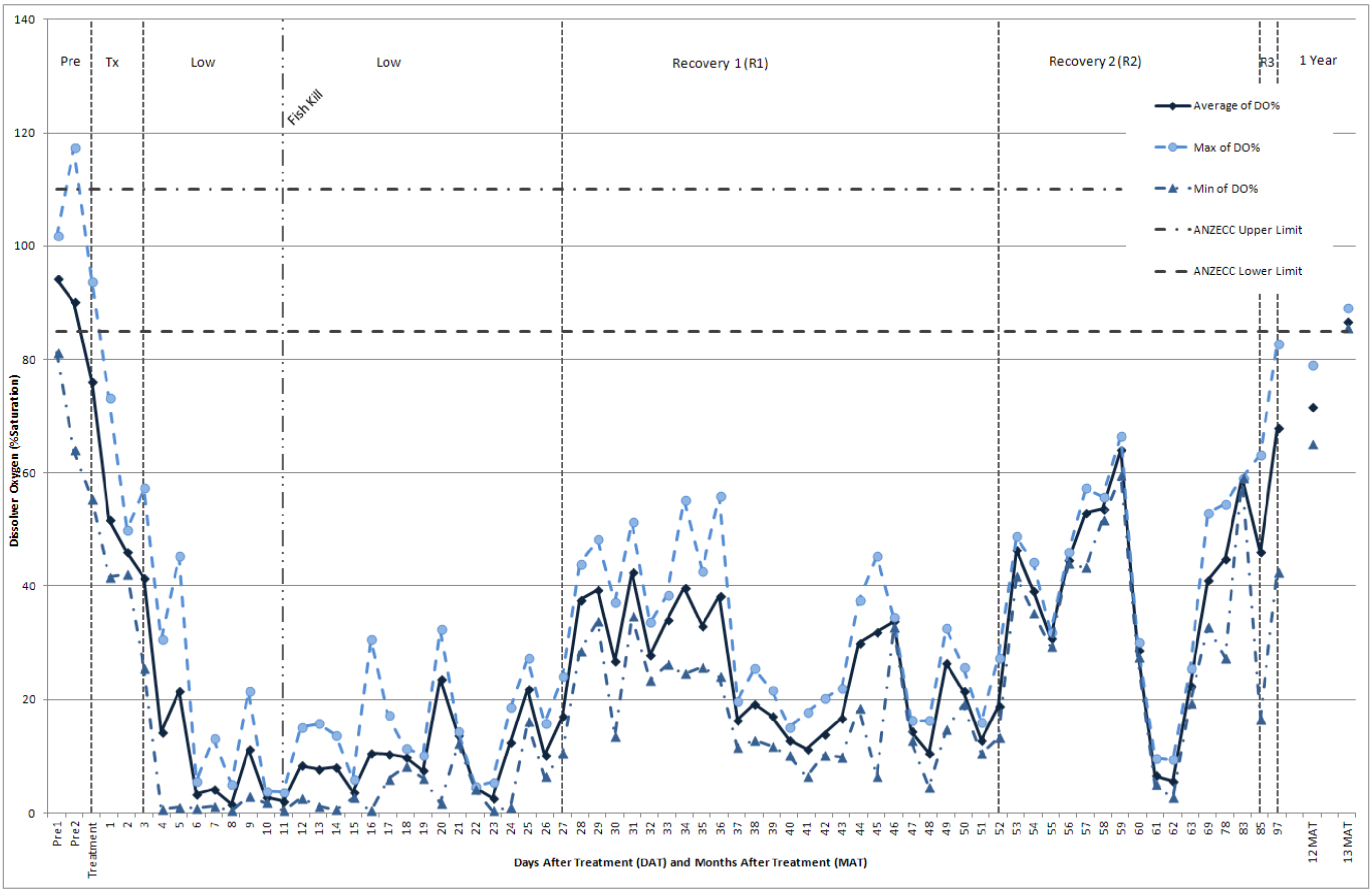

Figure 2: Average, Maximum and Minimum Dissolved Oxygen (% Saturation) recorded from Glenbrook Lagoon: 9-11am from 26 November 2012 to 15 January 2014. ANZECC (2000) upper and lower values indicated (85-110%). Vertical dashed lines indicate Categories: Pre-treatment (Pre); Treatment (Tx); Low DO (Low); Recovery phase 1 (R1); Recovery phase 2 (R2); Recovery phase 3 (R3); 1 Year After (1 Year). Vertical -..-..- line represents fish kill event.

Table 2. Summary of Glenbrook Lagoon water quality statistics (range, mean and ANOVA) from 26 November 2012 to 15 January 2014 by categories: Pre-treatment (Pre); Treatment (Tx); Low DO (Low: 3-27 DAT); Recovery 1 (R1: 28-52 DAT); Recovery 2 (R2: 53-84 DAT); Recovery 3 (R3: 97 DAT); 1 Year After Treatment (1 Year: 12 & 13 MAT (months after treatment)).

		Pre		Treatment (Tx)		Low DO (Low)		Recovery 1 (R1)		Recovery 2 (R2)		Recovery 3 (R3)		1 Year After (1 Year)	
	F Signif (p)	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
DO % Sat.	***	64 - 117.3	92.35	25.5 - 93.7	52.72	0.04 - 45.3	10.31	4.5 - 56	24.97	2.7 - 66.6	41.20	42.5 - 82.8	67.90	65.1 - 89.1	79.26
DO mg/L	***	5.48 - 10.05	7.93	2.05 - 8.15	4.52	0.03 - 3.76	0.88	0.37 - 4.3	1.95	0.24 - 5.28	3.25	3.26 - 6.4	5.31	5.52 - 7.37	6.62
pH	***	7.11 - 7.51	7.32	6.35 - 7.09	6.73	6.16 - 6.91	6.43	6.22 - 7.07	6.54	6.2 - 7.05	6.64	6.99 - 7.21	7.13	6.99 - 7.97	7.52
Temp ^{o}C	***	22.94 - 24.07	23.37	22.54 - 24.11	23.11	20.01 - 26.9	23.60	24.06 - 28.63	26.13	22.34 - 27.24	25.00	24.46 - 24.66	24.55	23.49 - 27.75	25.60
Turbidity NTU	***	2.2 - 15	5.01	4 - 64.3	14.20	0 - 27.1	7.11	0 - 33.5	6.21	0 - 8.3	2.53	4.4 - 7.1	5.12	1.3 - 7	3.64

*Significance: *p<0.05 **p<0.01 ***p<0.001 ns = not significant*

Principal cause of deoxygenation in Glenbrook Lagoon

The depletion of dissolved oxygen in a water body depends on the load of biodegradable organic material, microbial activity and the re-aeration mechanisms operating in the water body (ANZECC, 2000). Highly productive systems (e.g. tropical wetlands and aquatic weed infested wetlands) can naturally become severely depleted in DO, particularly when these systems are thermally stratified. However, of greater concern is the significant decrease in DO that can occur when a sudden increase in organic matter commences decomposition (e.g. from sewage effluent or dead plant material) (ANZECC, 2000).

The addition of a large biomass of rotting vegetation when cabomba, algae and other susceptible aquatic plant species died back across the whole water body following herbicide treatment undoubtedly triggered the severe oxygen depletion observed. However, the severity of deoxygenation can be further accelerated if there is reduced transfer of oxygen from the atmosphere to the water column resulting from thermal stratification and/or calm wind conditions as well as losses due to reduced photosynthetic oxygen production (Cragg & Fry 1986; Webster *et al*. 1996, in ANZECC, 2000).

Stratification and trophic levels

Glenbrook Lagoon has a history of low DO concentrations which were almost certainly the result of dense infestations of cabomba, algae and other aquatic weeds (BMCC, 2013). Immediately prior to herbicide application Glenbrook Lagoon was found to be thermally stratified, with a large drop in dissolved oxygen levels observed below 1-1.5 meters deep (Figure 3). Water column investigations from 1993 (Keogh, 1996) suggested the lagoon did not stratify and based on modeling, stratification was not expected in the lagoon (Stefan *et al.* 1996).

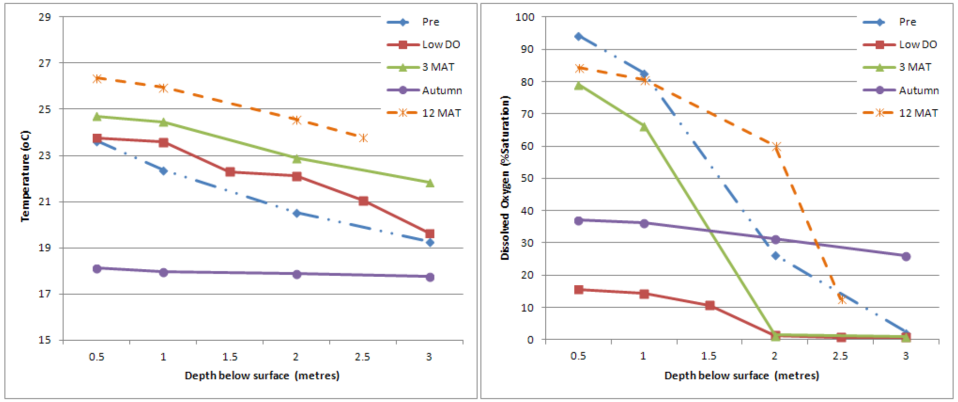

Figure 3: Left: Water temperature (° C) profiles and Right: dissolved oxygen (% Sat) profiles during 5 time periods (Pre; Low DO; Recovery phase 3 (3 MAT); autumn 2013; and 12 months after treatment).

DO observed below the thermocline suggest a significant volume of the lagoon was anoxic prior to the sudden addition of large quantities of dead plant material and this will have contributed to the severity of deoxygenation that occurred.

The eutrophic condition of the lagoon, with dense aquatic weed infestations and algal growth, may have contributed to the presence of a thermocline in the lagoon by affecting the depth of solar and thermal penetration (Stefan *et.al.* 1996; ANZECC, 2000), thus creating a thermal gradient. The thermocline recorded one year after treatment, during the 2013/14 summer, was weaker and occurred close to the lagoon sediment as opposed to the 1-1.5 m depth in summer 2012/13, supporting the possibility that cabomba may have been causing thermal stratification in the lagoon at the time of treatment.

Temperature and wind speed

Cragg & Fry (1986) determined the main factors controlling the extent or severity of deoxygenation following herbicide treatment to be water temperature and atmospheric diffusion. These factors are influenced principally by wind speed, with minima associated with high water temperatures (>25^{o}C) and low wind speeds (2-4 ms^{-1}). Additionally, Romero & Imberger (1999, in Davis and Koop 2006) observed downward deflection of the thermocline and deepening of the mixed layer following wind events.

In the weeks following herbicide treatment of cabomba in Glenbrook Lagoon, wind conditions were visibly calm (observation by author). The Bureau of Meteorology data for nearby Penrith supported this observation, with wind speeds below 20 km/h (<5.5 ms^{-1}) from commencement of the treatment to the end of December 2012. Some maximum wind gusts >10 ms^{-1} were recorded in the period. Recorded wind speeds were at their lowest for December around the day of the fish kill (approximately 2ms^{-1} with a maximum wind gust of 5.5 ms^{-1}) (BMCC, 2013).

During the three month period following cabomba treatment, water temperatures averaged between 23.11^{o}C and 26.13^{o}C (at 10 am +/- 1 hour) (Table 2). Additional recordings outside the reported time period (9am to 11am) detected afternoon water temperatures exceeding 25 ^{o}C in the weeks following herbicide application. Water temperatures greater than 30^{o}C were recorded over the following months. Cragg & Fry (1986) found a water temperature increase of 5^{o}C following herbicide use was enough to cause complete deoxygenation within 3 days.

Advisory panel discussions prior to treatment suggested that the large surface area and relatively shallow depth of the lagoon would provide sufficient oxygen transfer from surface diffusion to minimise the likelihood of oxygen depletion. However, the extremely calm and warm prevailing weather conditions at the time of and following herbicide application are believed to have contributed to both the decline and the slow recovery of dissolved oxygen concentration in the lagoon.

Comparison with NZ case study

A case study from New Zealand (Wells *et al.* 2012) showed a very different effect on DO following complete weed bed collapse of hornwort (*Ceratophyllum demersum*) after Endothall herbicide treatment in a wetland of similar size, depth and weed cover. Dissolved oxygen observed at 10 am did not fall below 62% throughout the water column following this weed treatment. Four notable differences can be seen between this example and Glenbrook Lagoon: in the New Zealand project, treatments occurred in winter and early spring when water temperatures were between 10 – 18.8^{o}C; there were frequent strong winds and white caps on the surface, allowing high oxygen transfer from the atmosphere; there was no water column stratification observed; and a Secchi depth between 2.5-3 metres suggests a more mesotrophic system may have existed in the New Zealand wetland (Stefan *et al*. 1996).

Conclusion & Recommendations

The control of the aquatic weed cabomba in this case study had far more extensive effects than were initially planned, which resulted in both positive and negative outcomes. Whilst this program proved very effective in the control of cabomba, a Weed of National Significance (WoNS) that is notoriously difficult to control and eradicate, it had the unintended secondary effect of contributing to an extended period of severe water deoxygenation that was the likely cause of a fish kill. Whilst the treatment was conducted in full compliance with the manufacturer's instructions, it may be prudent to re-evaluate the recommended application rates especially in more sensitive water bodies. Along with the unanticipated large percentage dieback of cabomba in the entire water body following the herbicide application, there were several other factors that contributed to the severity of the deoxygenation. Firstly, the water temperature (of >23°C) combined with the sudden increase in organic matter caused a very high degree of biodegradation and associated consumption of dissolved oxygen. Secondly, mild thermal stratification in the wetland restricted surface assimilation of oxygen into deeper sections of the water column and prior to treatment commencing this had caused severe oxygen depletion in the hypolimnion of the wetland. Thirdly, the very still prevailing wind conditions prevented wave action, reducing surface diffusion and circulation of atmospheric oxygen into the epilimnion. Finally, high water temperatures reduced the oxygen-holding capacity of the water.

Attempts to re-oxygenate the lagoon, particularly over a large water body without a power source, were found to be fairly ineffective and expensive. Fine bubble aeration would have been preferred but was not able to be achieved due to absence of an electrical power source, generator noise, site security issues and access to suitable equipment.

In warm climates the following recommendations are offered to minimise deoxygenation during aquatic weed control programs:

1. If practical, time programs to avoid the warm, still conditions experienced in summer.
2. Understand the seasonal physical, chemical and biological conditions in a wetland to allow an informed approach to managing potential impacts.
3. Use application methods that deliver herbicide both above and below the thermocline (where one exists) to reduce lateral movement and maintain the intended treatment area (in this case 50%).
4. In natural wetland systems or important fisheries where oxygen sensitive fish species are known or expected to occur a treatment of less than 50% of water body volume should be considered.
5. In dense aquatic weed infestations or sites with other susceptible plant biomass, consideration should be given to mechanical reduction of biomass prior to herbicide application and/or selective pre-treatment of the target weed or other susceptible weeds and vegetation in advance of Shark use.
6. Have sufficient mechanical aeration units should be kept on standby for timely deployment as required (with consideration given to the volume of water being treated).

Further recommendations for the control of cabomba using Shark are in draft as a supplement to the Cabomba Weed Control Manual (NSW DPI 2009, 2013).

Results from fish surveys in February and April 2014 suggest native fish (long-finned eel, freshwater catfish, southern smelt and flat-head gudgeon) and turtle (eastern long neck and Sydney basin) populations in Glenbrook Lagoon have not been adversely impacted by the weed control program (BIOSIS, 2014). As Australian bass were introduced stock and not naturally occurring in the lagoon, their loss was not as critical as the loss of an endemic species. Weed monitoring as of March 2014 has found no signs of cabomba, a very promising result for the potential eradication of this WoNS from Glenbrook Lagoon and an indicator that this has been one of the more successful cabomba control programs to date in Australia.

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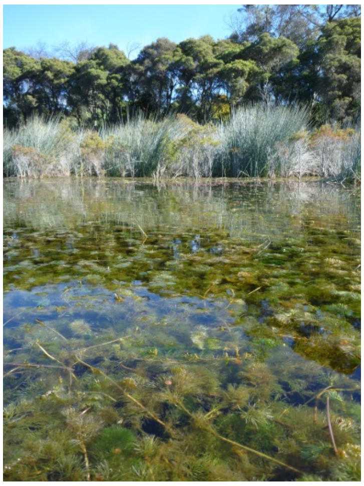
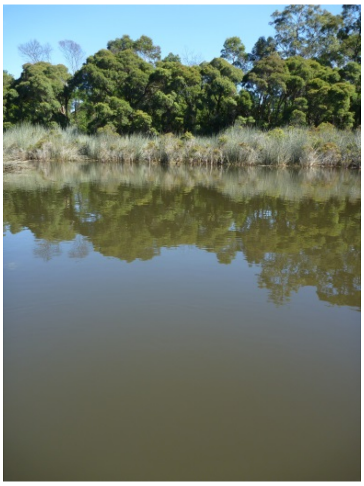
Appendix





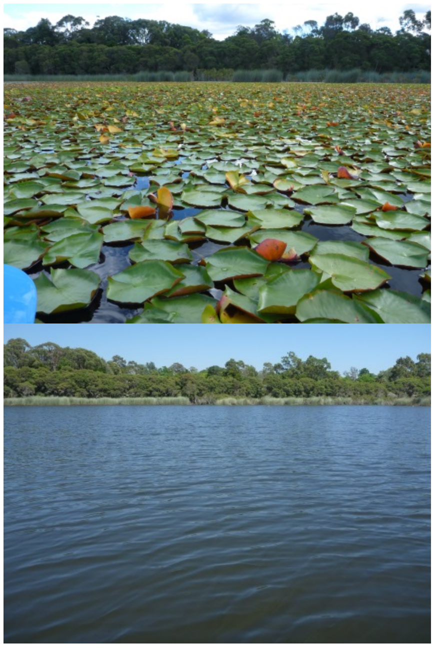


Photo plates: Glenbrook Lagoon showing: cabomba pre-treatment (left) and post-treatment (middle); water lily pre-treatment (top right) and post-treatment (bottom right).