Integrated Management of Alligator Weed [*Alternanthera philoxeroides* (Mart.) Griseb] at Botany Wetlands, Sydney- A Case Study

Nimal Chandrasena[1] and Leonard Pinto[2]

[1]GHD Pty Ltd, 10, Bond Street, Sydney, NSW 2000, Australia

nimal.chandrasena@ghd.com.au

[2]Sydney Water Corporation, 51, Hermitage Road, West Ryde, NSW 2114, Australia

Abstract: Sydney Water provides drinking water and wastewater services to over four million people in Sydney. This case study addresses the difficulties and costs associated with the control of Alligator Weed at Botany Wetlands, which is a key natural resource owned by the Corporation. This pond system is ecologically significant, and historically important, as they served as a drinking water supply for early settlers in Sydney. First noted as occasional patches in the ponds in 1985, Alligator Weed infestations became extensive by 1996, posing a significant threat to the Wetlands.

Since 1996, Sydney Water has implemented an integrated weed management (IWM) plan to manage Alligator Weed. This combines (a) systematic monitoring, (b) regular application of herbicides (™Biactive Glyphosate and Metsulfuron-methyl), (c) manual removal of floating masses, (d) lowering of water levels to allow better control, (e) controlled burning of sedges in infested areas, (f) large scale planting of native macrophytes in treated areas, and (g) exploiting the feeding by bio-control agents. Minimising the potential impact of chemicals, herbicides are not applied on patches where Alligator Weed flea beetles *Agasicles hygrophila* are most active. Herbicides are applied as spot-treatments at monthly intervals during cooler months, but more frequently in warmer months. New infestations are treated with herbicides or are manually removed, preventing downstream spread. Disposal of collected material is by burial in sand, after desiccation and treatment with herbicides. It is estimated that, on average, 90– 95% of the previous Alligator Weed infestation has been controlled over the past 10 years. The costs of control and amounts of chemicals used have declined. Although this is a relatively successful result, the current gains made on Alligator Weed management at Botany Wetlands have been achieved only through diligent action, continual assessment and persistent management intervention, on a yearly basis.

Keywords: Alligator Weed, Management

Introduction

Alligator Weed (*Alternanthera philoxeroides* (Mart.) Griseb.) is one of twenty Australian Weeds of National Significance (WONS), and is a declared noxious weed in New South Wales (NSW). Alligator Weed was accidentally introduced to Australia from ship's ballast into Newcastle harbour and Botany Bay around 1944. The weed has since spread in many areas of NSW, and is also present in south-east Queensland and Victoria. It has the potential to spread much further and threaten agriculture, wetlands, waterways and properties over much of Australia, with potential losses of many millions of dollars to agricultural, tourism and extractive industries (NWSEC 2000; Chandrasena *et al* 2004).

The Botany Wetlands are the largest coastal freshwater lakes in the Sydney Region. The Wetlands comprise of 11 interconnected ponds and dams (Figure 1), which stretch over a 4 km corridor in Sydney's eastern suburbs, north of Botany Bay. The ponds are an integrated surface and ground water system, fed by the Botany sand aquifer and surface runoff from 20 Km^2 of urban catchment. The Wetlands are ecologically valuable because they constitute an extensive aquatic habitat assemblage, supporting aquatic biota in a highly urban area. They are historically significant, because the ponds served as a drinking water supply to early Sydney settlers during 1858 to 1886 (Chandrasena *et al* 2002). Sydney Water Corporation owns and manages Botany Wetlands. Minor infestations of Alligator Weed at this historic location were first noted around 1985; limited control action commenced in early 1990s, but the infestations increased in size and spread over the next few years. By 1996, infestations were extensive, posing a significant threat to the Wetlands. The purpose of this article is to discuss the results of an integrated Alligator Weed management program at Botany Wetlands.

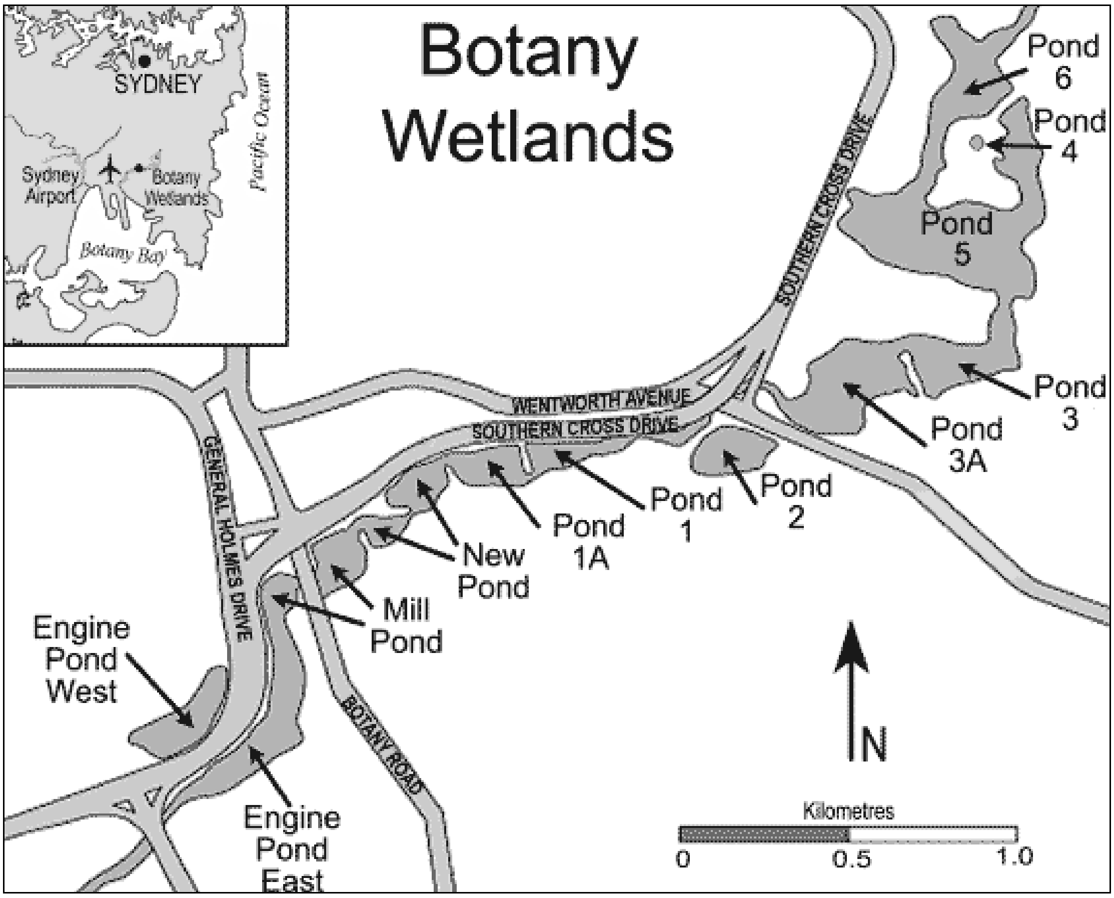

Figure 1. The Botany Wetlands pond system, Sydney, NSW, Australia

Integrated Weed Management

Broadly, integrated management involves the integration of a number of weed control options to achieve the most favourable economic (cost-benefit ratio), sociological and ecological outcomes for managing an invasive organism like Alligator Weed. IWM is based on a logical approach, system understanding, planning and implementing a control program, which is often ‘site-specific’. The broader goal would be to arrest the spread of an invading weed, and reduce or eliminate the threat posed by the invader. Understanding the various factors that influence weed invasion of a site is a key to planning and successfully implementing IWM (Figure 2). IWM also includes monitoring of performance against nominated criteria and critical analysis of success.

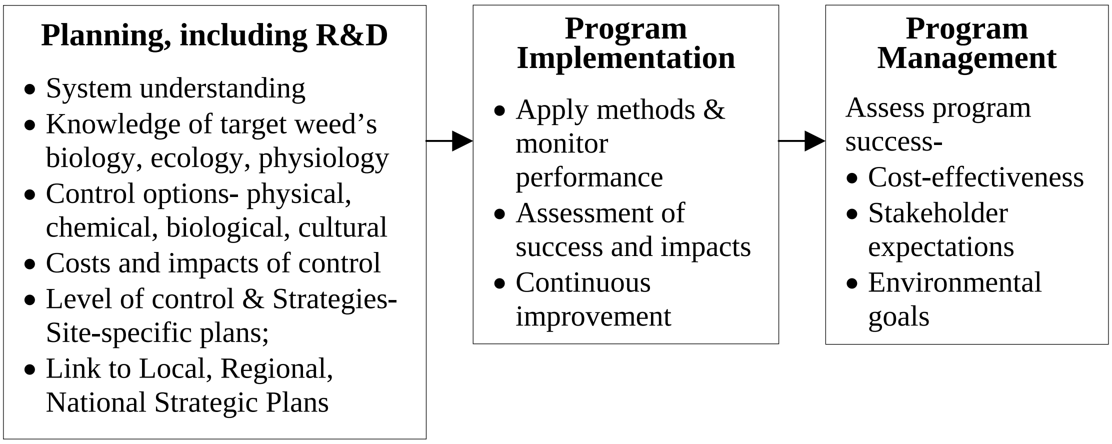

Figure 2. Components of an integrated weed management (IWM) program

IWM Methodology

The IWM approach applied to manage Alligator Weed infestations in Botany Wetlands has the following elements: (1) Setting up of specific sites and zones for monitoring the weed’s spread and treatment effectiveness; (2) Establishment of performance criteria (nil, minor or low-level occurrence, within the pond system) (3) Systematic monitoring and recording, to detect and treat new infestations; (4) Scouting to check potential upstream sources of new inoculum from the catchment; (5) Regular spot applications of herbicides- ™Bi-Active Glyphosate, 1% v/v, on aquatic infestations; Metsulfuron-Methyl (™Brush-Off) on terrestrial infestations; frequency of treatments, on average, was once per month during cooler months, and twice per month from September to May each year; (6) Water level management, to better access to persistent patches for herbicide treatments; (7) Manual removal of floating masses or loosely attached plants, caught up in snags and debris, treatment with Glyphosate, before disposal by burial in sand; (7) Controlled burning of weed infested pond shorelines occupied by macrophytes; (8) Adjustment of treatment regimes to allow bio-control agent (Flea Beetle: *Agasicles hygrophila* Selman & Vogt) to do maximum damage (mainly in January-February), so that the overall herbicide loads applied are reduced; (9) Large-scale planting of native macrophytes in riparian zones, cleared of entrenched Alligator Weed; and (10) Annual review and critical assessment against the performance criteria.

Results and Discussion

When the IWM program commenced in 1997, Alligator Weed (total estimated area ≈ 5000 m^2) was largely restricted to upstream Ponds 4, 5 and 6 (Figure 1). With intensive herbicide spot treatments (total herbicide load applied- 24 Kg a.i in 1996-97), this area was reduced to less than half within one year (Figure 3). However, treatments were often only partially effective, because of access difficulties in slushy mud for spraying. Inadequate uptake of herbicide by a few leaves of the weed exposed above water was a probable cause of ineffective treatments. Inadequate uptake was also probably due to the lack of a surfactant in ™Bi-Active Glyphosate, which caused poor retention of spray on leaves. Incorporation of a biodegradable additive, even a simple vegetable oil, increases the effectiveness of Glyphosate on Alligator Weed substantially (data not presented). This may prevent sub-lethal treatments from causing fragmentation, and consequently, increased spread. Metsulfuron-Methyl is highly effective on 'terrestrial' Alligator Weed, but this herbicide has not yet been tested on infestations 'in water'.

The ability to lower the water level in the largest water body- Pond 5 was important, as this allowed more effective treatments with Glyphosate. Slushy mud and snags in the ponds were major obstacles, as they prevented boat access. Where access was possible by boat and by shoreline walking, removing any loosely attached clumps was essential to reduce downstream spread of the weed. A high inspection and spot treatment frequency included time spent on scouting to find new patches, both within Botany Wetlands and in upstream channels that drain stormwater into the Wetlands. Figure 3 shows how the overall herbicide load applied decreased over the first few years of IWM implementation, to ≈12 Kg a.i. by 1999-2001.

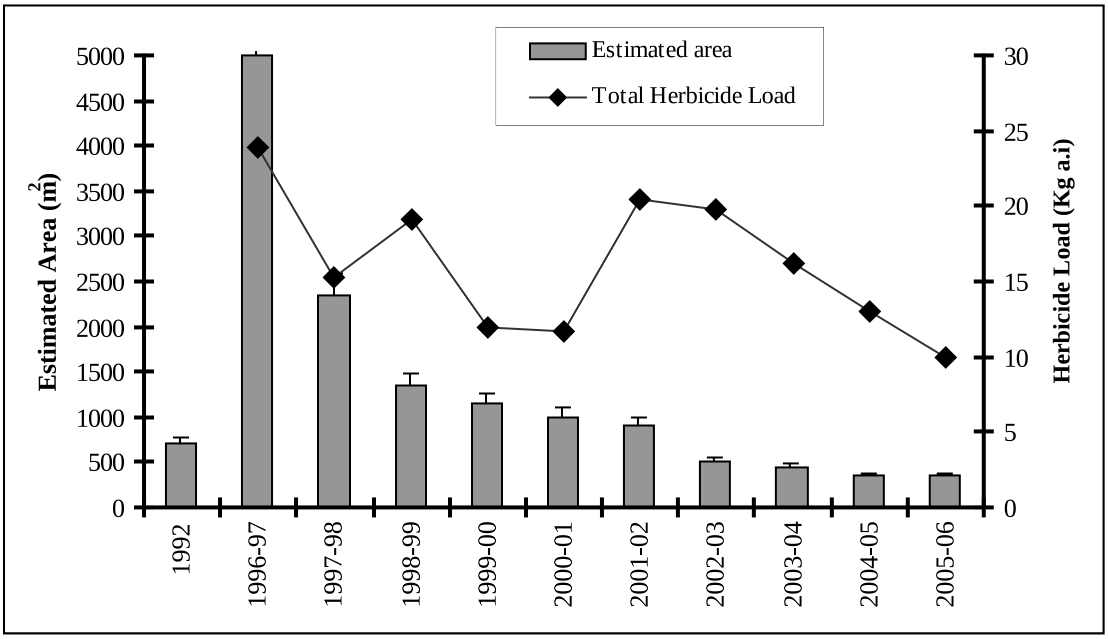

Figure 3. Estimated extents of Alligator Weed infestations and annual herbicide loads used to control weed spread in Botany Wetlands, Sydney, 1996-2006.

Preventing the entry of new 'inoculum' from upstream sources is essential in managing Alligator Weed in Botany Wetlands, within its large urban catchment. Scouting to find potential upstream sources, and treatment to eradicate those, was an integral part of IWM. Successful control in some ponds can also be attributed to burning of sedges and rushes, such as *Bolboschoenus fluviatilis* (Torrey) Soják, and *Typha orientalis* Presl, carried out several times during their winter-dieback. The clearing after burning allowed re-emerging, persistent Alligator Weed patches to be effectively treated. Macrophytes grew back after burning, because their rhizomes and bulbs were unaffected by fire.

Annually, the Alligator Weed flea beetle (*Agasicles hygrophila* Selman & Vogt; Coleoptera: Chrysomelidae) becomes active during January to April; its foraging strips the shoot system of leaves, sometimes as much as by 90%. We avoided treating these patches during this period, allowing the flea-beetle to do as much damage as possible. However, the control achieved by the flea-beetle appears limited in the Sydney basin, because adults do not survive or breed well under temperatures below 13 ^{0}C (Stewart *et al* 1999), which are common during winter in Sydney. Like sub-lethal Glyphosate treatments, flea-beetle foraging may cause disintegration and spread of the weed.

The control of vast infestations of Primrose Willow (*Ludwigia peruviana* (L.) Hara) in the ponds during 1996-2000 (Chandrasena *et al* 2002) was followed by large-scale revegetation of shorelines with wetland plants, which were once dominant in Botany Wetlands. Shoreline revegetation did not directly prevent these areas from being re-infested by Alligator Weed, as entangled weed fragments grow among macrophytes. However, the benefits of revegetation are indirect- possibly through the stabilisation of degraded, muddy and peaty shorelines and general environmental improvements.

Removal of Primrose Willow infestations in downstream ponds increased the water flow through the system (Chandrasena *et al* 2002). This caused Alligator Weed to spread downstream in major storm events. Significant patches were found growing in downstream Pond 3 and 3A in 1999-2000 and in Ponds 1 and 1A in 2001-02. Preventing wider spread became a high priority. Inspections were increased, as well as spot treatments. During 2001-03, scouting to detect new patches increased; spot-treatment frequency, and overall herbicide load used (Figure 3) also increased, mainly to arrest this spread. During the drought years (2002-06), water levels in all ponds decreased, allowing more shoreline access for treatments. Exposed ‘terrestrial’ Alligator Weed could also be treated with the selective herbicide- Metsulfuron-Methyl. The overall reduction of Alligator Weed at Botany Wetlands is about 90% of what existed prior to 1996 (Figure 3). Reduction of upstream infestations in Ponds 4, 5 and 6 is >95%. The decline in overall management cost, over time, is shown in Figure 4.

Conclusions

The inability to eliminate Alligator Weed from Botany Wetlands reflects its resilience to current control measures in a nutrient-enriched environment. Our experience of the past 10 years of implementing IWM is that without more effective herbicide treatments or new biological control agent(s), complete eradication of Alligator Weed from the Wetlands may not be achieved. The chances of some minor amount of weed existing within the nutrient-enriched substrata in the macrophyte-dominated system are high. However, the Case Study shows that by implementing a well-managed IWM program, with dedicated funding and resources, backed up by strong project management, it is not impossible to reduce its threat to a low level. Sydney Water’s commitment to the above has protected the integrity of natural ecosystems in this historic wetland system, where uncontrolled growth of Alligator Weed could have had serious repercussions. The lessons learnt from Botany Wetlands are replicable elsewhere.

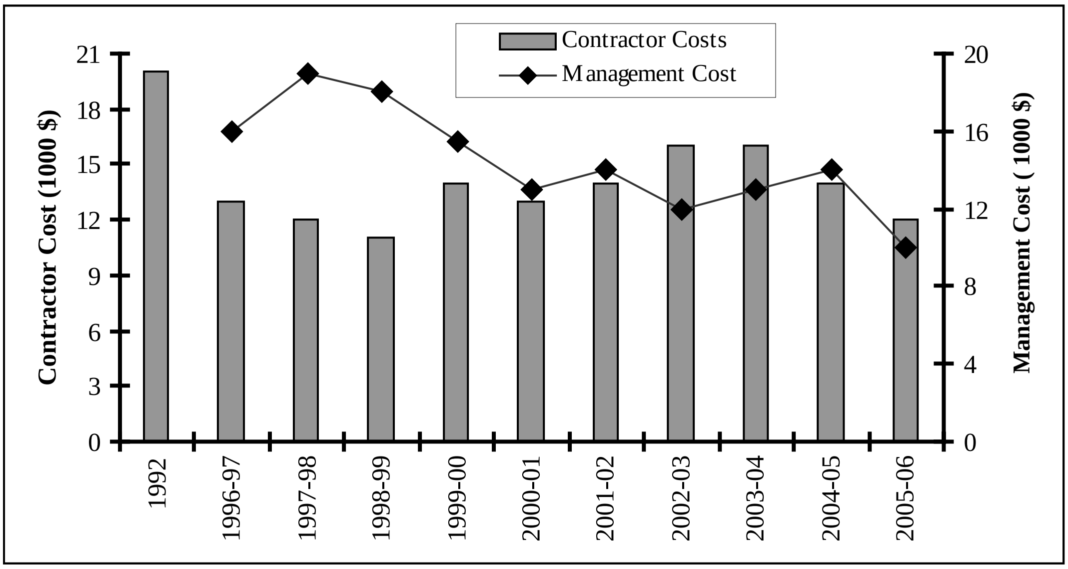

Figure 4. Contractor costs and management costs for the IWM program, 1996-2006.

An interesting research study would be to determine whether partial killing of the weed by sub-lethal Glyphosate treatments increase the palatability of the leaves to flea-beetle foraging. Another study that could improve the overall management effort is to investigate the possibility of incorporating a commercially available hormone (such as Na salt of 2,4-D at 500 ppm; 1-Naphthyl Acetic Acid, NAA or Amino ethoxy vinyl glycine, AVG at 100-250 ppb) into herbicide treatments, to prevent disintegration of patches. Given that the flea-beetle's capacity to damage the weed is limited, it is also necessary to develop other bio-control agents, for integration into future management.

Acknowledgements

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