

Water Hyacinth Control

Insight into Best Practice, Removal Methods, Training & Equipment

| **Guideline** Document |

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Image overleaf: Bangladeshi man in river infested with Water Hyacinth (AP Images)



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ACRONYMS, ABBREVIATIONS & SYMBOLS

CARA	Conservation of Agricultural Resources Act (Act 43 of 1983)
CEBA	Community Ecosystem-based Adaptation Programme (under EPCPD)
CESCM	eThekweni Coastal Engineering Stormwater Catchment Management Department
DAEA	Department of Agriculture and Environmental Affairs (Provincial)
DAFF	Department of Agriculture, Forestry and Fisheries (National)
DEA	Department of Environmental Affairs (National)
DUCT	Duzi-uMngeni Conservation Trust
DWA	Department of Water Affairs (National)
EHS	eThekweni Environmental Health Services
EM	eThekweni Municipality
EMA	eThekweni Municipal Area
EMIAS	eThekweni Municipality Invasive Alien Strategy
EPCPD	eThekweni Environmental Planning and Climate Protection Department
EKZNW	Ezemvelo KwaZulu-Natal Wildlife
EWS	eThekweni Water and Sanitation Services
GIS	Geographic Information System
IAP	Invasive Alien Plant
IAS	Invasive Alien Species (plants and animals)
IASP	Invasive Alien Species Programme (Provincial, under DAEA)
IUCN	International Union for the Conservation of Nature
NEMA	National Environmental Management (Act 107 of 1998)
NEMBA	National Environmental Management: Biodiversity Act (Act 10 of 2004)
PLCD	eThekweni Parks, Leisure and Cemeteries Department
PPE	Personal Protective Equipment
RSWM	eThekweni Roads and Stormwater Maintenance Department
SANBI	South African National Biodiversity Institute
WFE	Working for Ecosystems Programme (Local, under EPCPD)
WFW	Working for Water Programme (National, under DEA)
WFWet	Working for Wetlands Programme (National, under DEA)



CARA Category



Herbicide



Biocontrol



Hand Pulling



Aerial Spraying



Foliar Spraying
by Boat



Foliar Spraying with
Knapsack



Mechanical
Harvester



EXECUTIVE SUMMARY

Water Hyacinth, *Eichhornia crassipes*, is an aquatic invasive alien plant (IAP). It spreads rapidly, being able to double its biomass in as little as a week. It degrades the ecological systems of rivers and dams, chokes up watercourses causing flooding and affecting people's ability to access and use water resources. It has been included in the IUCN's report on "100 of the World's Worst Invasive Alien Species". Nutrient pollution of rivers, in particular nitrogen and phosphorous from human settlement and agriculture, is considered to be the main contributing factor to the rapid proliferation of Water Hyacinth.

In terms of Section 4(2)(a) of the National Environmental Management: Biodiversity Act (NEMBA), all municipalities are required to manage and conserve biological diversity. This includes taking steps to control and eradicate Invasive Alien Species (IAS) – such as Water Hyacinth – in areas that they own or manage. This guideline thus aims to assist eThekweni Municipality departments such as Water and Sanitation Services, Environmental Health Services, Roads and Stormwater Maintenance, Coastal Engineering Stormwater Catchment Management, Parks Leisure and Cemeteries and the Environmental Planning and Climate Protection Department, by providing information on best practices in Water Hyacinth removal methods, equipment, and personal protective equipment (PPE) that is required.

Integrated control, meaning the implementation of a combination of control

"The cost of managing and controlling IAPs once they are firmly established, i.e. reproducing and spreading, can be enormous."

methods together, has been shown to be the most effective and cost-efficient approach. To design an effective integrated control programme, divide the entire catchment into management units and look at each unit separately to see which control methods will suit each best. Before a control plan is prepared, test the nutrient levels in the waterbody. If they are high, find the source of the problem and reduce this first. If the source of nutrient input to the waterbody is not identified and addressed, continuous re-infestation will result and resources will be wasted.

1 WHAT IS WATER HYACINTH?

Water Hyacinth, *Eichhornia crassipes*, is South Africa's worst aquatic weed. It is a highly invasive species that originates from the Amazon Basin in South America and is believed to have been introduced into South Africa as an ornamental aquatic plant.



Top: Water Hyacinth Above: Water Hyacinth roots;
Opposite: Water Hyacinth flowers

Water Hyacinth can live free-floating on the water surface, or may be anchored by bunches of long, feathery, hanging roots.

Adult plants usually grow to 10 – 20cm high, but may be as tall as 1m when the plants are clustered together in dense mats on the water surface. The flowers, which are approximately 5cm wide, are pale blue or violet and the upper 'petal' of each flower has a prominent dark blue patch with a yellow centre. There are 8 – 10 flowers clustered together on each "flower spike" produced by the plant.

Water Hyacinth can reproduce vegetatively by budding, which occurs when parts of the plant break off and develop into new plants. Each plant also produces thousands of seeds several times a year following flowering. Seeds germinate on moist sediments or in warm, shallow water; flowering can occur 10 – 15 weeks thereafter. Under optimal conditions, Water Hyacinth has an exceptionally high growth rate – doubling its size in as little as a week. Seeds can remain viable in aquatic sediments for 15 – 20 years, highlighting why this is such a problematic species to control.



2 HAZARDS OF WATER HYACINTH

If left uncontrolled, Water Hyacinth can disrupt water abstraction facilities, destroy fishing grounds, disable water sports areas, block up irrigation channels and watercourses causing siltation and flooding, and obstruct hydro-electric turbine intakes. The plants also provide

breeding grounds for mosquito larvae and habitat for disease vectors such as the bilharzia snail. The resulting health risks are obvious. Water Hyacinth also devastates aquatic biodiversity.

The financial cost of controlling Water Hyacinth can be significant. However, the negative ecological, economic and social costs that result from the uncontrolled spread of this species can be severe. This highlights the important role that the eThekweni Municipality needs to play in controlling this problematic plant species.

UNDERSTANDING WATER HYACINTH INVASION

South Africa is not the only country struggling with this plant's invasiveness. Water Hyacinth has become established in most tropical and subtropical countries around the world. There have been many clearing operations documented from all over the globe, some more successful than others. This plant has now invaded more than 50 countries and is listed in the IUCN's report on "100 of the World's Worst Invasive Alien Species". With the optimum temperature for Water Hyacinth growth being 27.5 °C, rising global temperatures as a result of climate change will allow for an expanded range of distribution for this species and perhaps quicker growth.



Above: Cows attempting to drink from a waterbody infested with Water Hyacinth

3 MAKING PRODUCTIVE USE OF CLEARED PLANT MATERIAL

There are some potential positive gains to be had from the harvesting of Water Hyacinth during clearing operations. The plants can provide significant volumes of biomass, which when dried can be used for the creation of bioenergy, as well as the production of furniture, rope and other products.

"Water Hyacinth can provide significant volumes of biomass."



Above: Collection of Water Hyacinth biomass during a clearing operation

4 WHAT CAUSES WATER HYACINTH INVASIONS?

Water Hyacinth may spread into rivers and dams from windblown seeds, plants and seeds washed down from upstream areas, or may be introduced by boats, birds and animals inadvertently carrying seeds from water resources where Water Hyacinth is present.

Rivers and dams that suffer from nutrient pollution, in particular nitrogen and phosphorous, are optimal places for the rapid proliferation of Water Hyacinth. Discharge of effluent from domestic waste-water treatment works, industrial effluents, leaking or overflowing sewers and use of fertilisers on agricultural lands all contribute to excesses of nitrates and phosphates entering aquatic systems, which in turn can significantly increase the growth rate of Water Hyacinth.



Above: Water Hyacinth choking the iSiphingo River



Above: Inspection of Water Hyacinth menace at the Winam Gulf in Kisumu, Kenya



Unsuccessful case study

iSiphingo River (eThekweni Municipality)

Observations at the iSiphingo River have shown that soon after clearing dense mats of Water Hyacinth, it again proliferated remarkably fast and formed dense mats. Therefore, any plan for controlling Water Hyacinth must address nutrient levels in the river system, as well as ongoing follow-ups and monitoring.



Successful case study

Nseleni/Mposa River (uThungulu District Municipality)

This river system was heavily invaded with Water Hyacinth up until the mid-1990s. At that time, the Nseleni sewerage works on the Mposa River was upgraded, and the effluent quality improved dramatically. Before upgrading, the ammonia (NH₃) discharging into the river was measured at 14.2 ppm and the chemical oxygen demand (COD) at 130 ppm. After the works upgrade, the ammonia dropped to 1.2 ppm and the COD to 53 ppm. This was a vast improvement, which resulted in a dramatic decrease in the rate of Water Hyacinth proliferation. Together with a suitable programme to control the Water Hyacinth plants, it was then possible to clear the river to an acceptable level.

5 LEGISLATIVE AND POLICY FRAMEWORK GOVERNING WATER HYACINTH CONTROL

5.1 The Conservation of Agricultural Resources Act (CARA)

The Conservation of Agricultural Resources Act (Act 43 of 1983), lists Water Hyacinth as a Declared Weed (Category 1), which means that this species of plant:

- Is prohibited on any land or water surface in South Africa;
- Must be controlled, or eradicated, where possible.

This implies that any organ of state or private land-owner that owns or is responsible for a waterbody, must implement control of Water Hyacinth in that area. This includes municipalities where they are responsible for the management of reservoirs, dams, rivers and estuaries.

5.2 The National Environmental Management: Biodiversity Act (NEMBA)

In terms of Section 4(2)(a) of the National Environmental Management: Biodiversity Act (NEMBA) (Act 10 of 2004), all organs of state (including municipalities) are required to manage and conserve biological diversity. This includes taking steps to control and eradicate Invasive Alien Species (IAS) in areas that they own or manage.

In terms of Chapter 5, Section 76(2)(a) of the NEMBA, all organs of state in all spheres of government must prepare an invasive species monitoring, control and eradication plan for land under their control. This plan must form part of a municipality's environmental plans, and be part of a municipality's Integrated Development Plan.



Water Hyacinth is listed as a Declared Weed (Category 1) in terms of CARA.

5.3 The eThekweni Municipality Framework Strategy and Action Plan for the Control of Invasive Alien Species

In response to the requirements of NEMBA, the eThekweni Environmental Planning and Climate Protection Department (EPCPD) has drafted a Framework Strategy and Action Plan for the control of Invasive Alien Species (IAS). The strategy's mission is to establish a cooperative means for preventing the establishment of new IAS and for the effective control of IAS already established in the eThekweni Municipal Area. The complexity and difficulty of managing Invasive Alien Species requires that a strategic and collaborative approach be adopted to boost and co-ordinate efforts to control invasive species.

This strategy and action plan aims to direct Invasive Alien Species control in the municipal area towards achieving faster, more efficient outcomes and sets realistic targets that can be measured and

assessed. It promotes the need for Invasive Alien Species control to become a more integral part of the ongoing sustainable management practices that the eThekweni Municipality is already engaged in. This approach aims to ensure that public funds are used effectively and that municipal investment in Invasive Alien Species control supports the well-being and health of residents through securing a healthy and functional natural environment. The strategy and action plan clarifies the responsibilities of various municipal departments and provides direction on how they can co-ordinate their efforts with respect to IAS control. The strategy and action plan forms part of the eThekweni Municipality's Integrated Development Plan (IDP) for 2012/2013.



DOWNLOADABLE RESOURCES

The Strategic Action Plan provides an immediate operational, practical outline of how the Strategy is to be implemented, and will be updated as needed. The full document is available online at www.invasives.org.za and www.durbaninvasives.org.za



6 WHO IS RESPONSIBLE FOR IMPLEMENTING WATER HYACINTH CONTROL?

In terms of the Legislative and Policy framework governing Water Hyacinth control in South Africa, there are a number of actors that have a role to play:

- At a national level, the Department of Water Affairs (DWA) has been mandated to co-ordinate control efforts of Water Hyacinth and to execute measures of control where the weed threatens state water works.
- At a local level, municipalities are required to address water quality and use, and as such have a key role to play in managing river water quality and Water Hyacinth infestations where these threaten local water use and aquatic ecosystems.
- All private land-owners who have dams or rivers running through their properties are required to control Water Hyacinth infestations in these areas.

This Guideline has been prepared specifically to assist eThekweni Municipality departments that are responsible for managing areas that are infested with Water Hyacinth to meet the legal requirement for control. Departments that may benefit from its use include eThekweni Water and Sanitation, Environmental Health Services, Roads and Stormwater Maintenance, Coastal Engineering Stormwater Catchment Management, Parks Leisure and Cemeteries and the Environmental Planning and Climate Protection Department (EPCPD).

"Municipalities have a key role to play in managing river water quality and Water Hyacinth infestations."

7 GUIDELINE FOR CONTROL OF WATER HYACINTH

7.1 The benefits of an Integrated Approach

In order to control Water Hyacinth successfully, the entire catchment should be considered and key stakeholders in the catchment need to be engaged in the control efforts – both in terms of addressing water quality in the system and in terms of controlling Water Hyacinth infestations. A lead agency can play a significant role in ensuring co-ordination, management and ongoing documentation of all control efforts. The eThekweni Municipality is an example of a lead agency in many Water Hyacinth control endeavours. The eThekweni Environmental Planning and Climate Protection Department (EPCPD) often acts as the lead department, though this responsibility does often shift to other departments that might have a stronger presence in a particular area. The lead agency should always ensure that a thorough plan is compiled for control of Water Hyacinth which incorporates funding considerations and short, medium and long term objectives.

A good approach for controlling Water Hyacinth in an integrated way within a catchment – where there is more than one land-owner, manager, or user – is to seek buy-in and participation from all the stakeholders in the catchment, including various government departments and the public. This includes increasing the synergies between different eThekweni Municipality departments, as well as with partner organisations such as the KZN Department of Agriculture and Environmental Affairs (DAEA), Department of Environmental Affairs (DEA), Department of Water Affairs (DWA), Ezemvelo KwaZulu-Natal Wildlife (EKZNW), Department of Agriculture, Forestry and Fisheries (DAFF), South African National Biodiversity Institute (SANBI), Duzi-uMngeni Conservation Trust (DUCT¹), Working for Ecosystems (WFE), Working for Water (WFW) and Working for Wetlands (WFWet).



¹DUCT is a not-for-profit organisation that controls and eradicates IAPs on the river banks and in the waters of the uMsunduzi and uMngeni River systems. It works in partnership with other organisations and has had many successes over the years. More information and contact details for DUCT are available online at www.duct.org.za

"The eThekweni Municipality is an example of a lead agency in many Water Hyacinth control endeavours."



Above: A team of workers involved in the manual control of Water Hyacinth

Case study The uMbilu River catchment CEBA partnership

The EPCPD and Parks, Leisure and Cemeteries Department (PLC) are co-ordinating the clearing of IAPs in the uMbilu River catchment as part of the Durban Community Ecosystem-based Adaptation (CEBA) initiative. In addition, the Wildlands Conservation Trust (an NGO contracted by the eThekweni Municipality to implement aspects of the project) has built relationships with and sourced funds from local businesses in order to undertake a range of activities in this catchment, such as IAP control, tree planting, waste collection and recycling. A successful result attributed to effective collaboration!



Above: Cross-section of Water Hyacinth stems

For private land-owners and businesses, forming a “Conservancy” can be a very successful way of gaining the participation of multiple parties in a specific location. In the River Horse Valley area local businesses have established a Conservancy, which has partnered with DUCT and the eThekweni Municipality to try and tackle IAPs.

It is important that the stakeholders agree on the methods of control to be used and that regular meetings are held to track progress. It is advisable for each stakeholder to play some part in the control process, whether it is providing herbicide, monitoring biocontrol agents, assisting with a boat when necessary, or promoting public awareness of Water Hyacinth. This participation by stakeholders reduces the overall cost of control for the partners involved.

AQUATIC WEEDS WORKSHOP

The Aquatic Weeds Workshop is another collaborative platform. It is a forum that is championed by DUCT, and comprises government bodies such as WFW (national), Umgeni Water (provincial parastatal) and the eThekweni Municipality. The forum organises the control of aquatic weeds along the uMngeni River within the uMgungundlovu and eThekweni Municipalities and co-ordinates resources, expertise and the release of biocontrol agents.

Contact: www.duct.org.za

KZN INVASIVE ALIEN SPECIES FORUM

The KZN Invasive Alien Species Forum is a platform that was established aiming to improve invasive alien plant control through active collaboration between municipal departments, provincial and national government, parastatals, private land owners, NGOs, conservancies etc. This enhances co-ordination, reduces duplication and increases the areas under efficient management. The forum meets quarterly and there is no restriction on who attends. For more details, or if you are interested in attending this forum, contact the Working for Water office situated outside Howick.

Contact: Ryan Brudvig – Rbrudvig@environment.gov.za
Reshnee Lalla – r.lalla@sanbi.org.za



Above: The uMsunduzi River before and after Water Hyacinth treatment in 2012

7.2 Planning and Preparations

7.2.1 Surveying and mapping Water Hyacinth infestations

In order to properly plan a Water Hyacinth clearing/control programme, a survey of the extent of Water Hyacinth infestation needs to be conducted. This can be a very basic mapping exercise, e.g. a hand-drawn map, or a GIS-based mapping exercise for larger areas. It is important to start the mapping exercise at the uppermost limit of the infestation as the natural movement of the weeds will be downstream. It is important that the full extent of the Water Hyacinth infestation is mapped, which allows for a quantification of the total area infested and an accurate calculation of the costs of control. It is critical to ensure that an accepted methodology is used and

that the outcomes of any baseline studies are accurately recorded. This will allow the infestation to be monitored over time and will help in demonstrating the impacts of clearing interventions.

"It is important that the full extent of the Water Hyacinth infestation is mapped."

Mapping of aquatic IAPs is a difficult task as the plants move and thus the map will constantly change. This obstacle can be overcome to a large extent by spanning cables over the river. This not only assists by containing the Water Hyacinth in an area, but helps to ensure a build-up of Water Hyacinth behind each cable, which makes the task of spraying herbicide easier.

This technique however, is not appropriate for some areas for the following reasons:

- securing cables on river banks is often not easy, especially if there are no solid structures nearby;
- rivers can often be either too wide or the river banks too steep;
- theft of cable is a problem;
- spanning cables on rivers where boats or canoeists are present is problematic.

Each case needs careful assessment, and the techniques used should always be fully assessed and explored.



Above: Example of light infestation of Water Hyacinth



The following steps should be followed for surveying of the infestation:

- 1** Divide the river into management units and give each unit its own name/number. These management units may be separated using existing structures within the system such as bridges or gauging weirs. Cables and booms can also be used.
- 2** Map the IAP densities indicating the percentage infestation in each management unit.
- 3** Check if there is any other aquatic IAP present. Ensure that these are also mapped.
- 4** Confirm if there are any biocontrol agents present on the Water Hyacinth and whether there is any observable damage to the plants.
- 5** Indicate any other feature of importance, e.g. water treatment works, area used by canoeists etc.



Above and top right: Examples of heavy infestation of Water Hyacinth



Above: Water Hyacinth displayed

7.2.2 Preparing a Control Plan

In order to effectively plan a Water Hyacinth control programme it is necessary to understand the types of control available as well as the level of infestation. It is also important to know whether there was previously a control plan and if so what the successes and failures were. Building on previous successes and correcting previous mistakes is essential for a successful control operation. See Appendix 3 for an example of a Control Plan.

Many efforts have been made in the past to deal with IAPs but most of these efforts have been carried out on a reasonably *ad hoc* basis. While such efforts are well-meaning and sometimes even successful, they can be wasteful. This is because IAPs usually re-infest areas if ongoing and thorough follow-up control is not implemented. The control plan therefore needs to deal both with the initial clearing and ongoing follow-ups.

The Control Plan needs to include:

1	The Water Hyacinth survey map, showing management units.
2	A description (and location) of major nutrient inflow/pollution sources and the agencies that need to be involved in addressing these.
3	Methods of control to be implemented in each management unit, including programme for follow-up treatments and responsibilities for implementation.
4	Management resources, labour, equipment & safety gear requirements – per management unit where relevant.
5	Training requirements.
6	Other stakeholders in the catchment that may be partners in the programme or affected by clearing activities.
7	Budget and funding sources.

Important factors to consider for a Control Plan:

- Understand that requirements for successful control of Water Hyacinth could differ from catchment to catchment. There is no specific method that can fit all waterbodies equally. Each river/stream/management unit needs to be individually considered and the most appropriate control method selected.
- Sufficient budget is required to cover the control option selected and must be sufficient for several years of control. Prioritisation is needed if the available budget is insufficient.
- It is a waste of funds to clear an area if the causes of high nutrient levels have not been addressed. Also, if clearing is not carried out from upstream to downstream it is a waste of funds as the plants will simply recolonise the lower river from seeds and buds washed down from upstream areas.
- Set annual achievable goals. However, be adaptable. If it becomes clear that a control method is not achieving the desired results, consult with the experts, and change the type of control used.
- Set funding aside for new infestations of Water Hyacinth. If spotted, these areas should be treated as soon as is possible.

What are acceptable levels of Water Hyacinth control?

Complete eradication of Water Hyacinth in a waterbody is not always achievable; and control is always a long-term commitment. This is partly due to the fact that seeds can remain viable in sediments for 15 – 20 years, but also because it is almost impossible to clear every single plant. The general acceptable level of control is:

- **5% coverage of the waterbody if biocontrol agents are present.**
- **If manual, mechanical or herbicide control is used up to 20% coverage is an acceptable level of control.**

As soon as coverage on a waterbody exceeds these thresholds, then active control should again be initiated. How often a waterbody will reach 20% after being cleared depends on the season, nutrient levels in the water, and the flow of the river. If a waterbody is newly infested, and control is implemented immediately to avoid high infestation rates, these percentages should not apply.

Easy-to-use flowcharts outlining the preferred approaches to clearing low (Figure 1) and high (Figure 2) infestation levels are provided in Appendix 1.



Above: Water Hyacinth morphology

7.2.3 Preparations before Starting

If the area where Water Hyacinth clearing will take place is not municipal-owned, the land-owner needs to be notified of the clearing activities that will be taking place. If there are neighbours that may be negatively affected by herbicide spraying associated with the clearing activities, they should also be notified prior to the work starting.

"All necessary staff and worker training must be completed prior to the clearing activities being started."

Herbicides, equipment and PPE should be procured and be on site before the work starts. A safe storage area for the herbicides must be established that is bunded to contain any leaks.

(i.e. herbicide should not be able to leak into the soil, any watercourse or wetland, stormwater drain, an area of natural vegetation or a human settlement area). Herbicide storage areas must be secured to ensure that children and animals cannot access the chemicals, and that the chances of theft are minimised.

A site camp may be set up to accommodate vehicles bringing workers onto the site, herbicide and equipment storage, ablutions and changing areas for workers. The site camp must be located outside of sensitive natural areas, must not restrict access routes or points for local residents and businesses, and must not damage private property or community gardens. If the site camp is on private property, the land-owner must give permission for use of this area.

All necessary staff and worker training must be completed prior to the clearing activities being started.

7.3 Water Hyacinth Control Methods

Four methods, or a combination of these methods, are generally used to control Water Hyacinth. It is important to identify the most appropriate methods of control for each Water Hyacinth control / eradication programme.

7.3.1 Manual Control

Manual removal is conducted through hand pulling of the Water Hyacinth from the water surface using a pitch fork. This method is very labour intensive and is only effective for limited areas of infestation. In countries such as South Africa, this method is mainly used as an employment creation exercise. The frequency of follow-up treatments required depends on the initial infestation levels, the season (Water Hyacinth grows faster in summer

months) and on the levels of nutrient enrichment of the waterbody. If the area was initially densely infested and the initial clearing work has cleared most of it, allow for 20% of the water surface to become covered with Water Hyacinth again before applying follow-up treatment. Unfortunately, manual control in deep water (e.g. canals) requires additional equipment such as rafts or boats, as well as a number of added safety precautions.



Top left and above: Manual removal through hand pulling of Water Hyacinth using a pitch fork



Above: Manual removal of Water Hyacinth

Table 1 The advantages and disadvantages of manual control

Advantages	Disadvantages
Effective method in small areas with limited infestations of Water Hyacinth.	Not an effective method for large areas or very dense infestations, as the cost of clearing is extremely high.
High job creation and poverty alleviation potential.	Not always suitable in deep water areas, due to the risk of workers drowning.
No contamination of water with herbicides.	Seeds and pieces of plant left behind are able to rapidly reform new plants.
Plants are removed, avoiding creating large volumes of decaying plant matter in the waterbody that can lead to eutrophication and fish kills. Removed plant material can be used productively as biomass / for natural materials.	

Table 2 Protective clothing and equipment required for manual control

Protective Clothing	Equipment
• Rubber gloves (elbow length)	• Pitch fork (longer wooden handles may be required)
• Waders (used for fishing)	• Boat (may be required for deep water)
• Sun hat	



Unsuccessful case study Lake Chivero, Zimbabwe

A team in Zimbabwe initiated a manual removal programme on Lake Chivero in the early 1980s. The team consisted of 500 people working eight hours a day for six months. The team removed 500 tonnes of Water Hyacinth, but the rapid regeneration of the weed made the effort slow and expensive with no obvious impact.

7.3.2 Mechanical Control

Mechanical control is conducted through the use of various methods, including using boats fitted with mesh rakes, bulldozers, conveyors and mechanical harvesters (mulchers). It is advisable to partner with organisations that have access to mechanical equipment if this is the preferred control method for an area. The eThekweni Coastal Stormwater and Catchment Management (CSCM) Unit or DUCT can be contacted for more information.

Mechanical control is often very expensive, but in areas where Water Hyacinth has caused the river to become impenetrable, mechanical control has proved successful. In some cases mechanical control is needed in order to clear a way to allow boat access for herbicide application.

Another control tactic where, for example, Water Hyacinth is close to a water abstraction pump, is to use cables or booms to prevent the weed from entering the pumps. This may also act as an area for the weed to build up density for later herbicide control.

"In areas where Water Hyacinth has caused the river to become impenetrable, mechanical control has proved successful."



Above: Cables being used to contain infestation of Water Hyacinth

Table 3 Advantages and disadvantages of mechanical control

Advantages	Disadvantages
Useful if dense mats have formed and made the river inaccessible.	Expensive as it requires the use of specialised equipment.
Once access has been achieved through manual control methods, then cheaper forms of clearing can be started such as herbicide control or biocontrol.	Seeds and pieces of plant left behind are able to rapidly reform new plants.
Plants are removed, avoiding creating large volumes of decaying plant matter in the waterbody that can lead to eutrophication and fish kills. Removed plant material can be used productively as biomass/for natural materials.	Specialised nature of the equipment and work makes it less labour intensive than manual control, with less potential for job creation.



Successful case study

Mechanical control in Mexico

There has been success using mechanical control in Mexico at Trigomil Dam, when it was used in combination with herbicide application of 2,4 – dichlorophenoxyacetic acid (or more commonly known as 2,4-D). The herbicide was used together with a mechanical harvester and the combined efforts helped to reduce the amount of Water Hyacinth in the dam.



Unsuccessful case study

Mechanical control in Zimbabwe

In Zimbabwe, mechanical control was initiated around Port Bell and Owen Falls Dam on Lake Victoria, as well as at Lake Chivero. All with very limited success due to the rapid regeneration of the weed. Mechanical control was also tried on the Liwonde Barrage (pictured left) in Malawi with little success.

7.3.3 Herbicide Control

Herbicide application is the most commonly used Water Hyacinth control method in South Africa. Although fast acting, effective control requires a long-term commitment with periodic follow-up applications for 20 years or more. Water Hyacinth is very susceptible to herbicides such as 2,4-D, diquat, paraquat, and glyphosate, which have resulted in successful control in small, single-purpose water systems, such as irrigation canals and dams of approximately one hectare in size. Only herbicides officially registered for use on Water Hyacinth should be used (see Table 5 on page 38).

Any products that contain Tallow Amine SHOULD NOT be used, as these are known to kill amphibians.

Herbicide application is a relatively expensive operation. It requires a fair amount of expertise to ensure the correct plants are targeted and to avoid negative impacts on indigenous plant and animal life. It is essential that staff members who use herbicides attend a herbicide application course.

Table 4 Advantages and disadvantages of herbicide control

Advantages	Disadvantages
Immediate impact on high and low density Water Hyacinth infestations in large or small areas, achieving results within 6 weeks of application.	Herbicides are expensive, but this may be balanced by reduced labour requirements as compared with manual removal methods.
Plants are completely killed off by the herbicide, reducing the chances of small pieces of plant material left behind reforming into full-grown plants as occurs with manual and mechanical control methods. However, seeds remain, requiring regular follow-up treatments.	Water quality problems (decay of large masses of dead Water Hyacinth plants often resulting in severe fish kills due to anaerobic conditions), as well as spray drift and the impacts of herbicides on non-target organisms.
	The use of herbicides may contaminate sites used for drinking water, for washing and for fishing, and can therefore threaten human health.
	Use of herbicides requires specialised training and safety measures.



Unsuccessful case study

uMdloti Estuary (eThekweni Municipality)

In the uMdloti estuary, herbicide was applied to a large mat of Water Hyacinth. The subsequent decay of plant biomass caused a sharp decline in the dissolved oxygen concentrations in the estuary, resulting in a fish kill incident. This is not necessarily the incorrect method, but spraying should be staggered to avoid mass vegetation die-off, as this will ensure that oxygen levels do not drop below critical levels required to support life in the waterbody.

The following two herbicide application methods are used:



1. Aerial Application is conducted by flying a light aircraft over a body of water and spraying herbicide from the aircraft. This is expensive and should only be used when there is no risk of indigenous vegetation or nearby crops being accidentally sprayed. Aerial application is mostly used for treatment of Water Hyacinth on large dams or rivers, and/or at sites of excessively dense infestations where boat access or walking next to the waterbody is not possible.



2. Foliar Application is applied by walking next to the waterbody with a knapsack sprayer and spraying the herbicide manually onto the leaves of plants. It can also be applied by boat using a pressure pump sprayer with an adapted nozzle. This method of control is used for both sparse to densely invaded water bodies. Care needs to be taken to train all persons involved in the operations and to ensure that all safety precautions have been considered, e.g. life jackets.



Above: Light aircraft spraying herbicide



Above: Foliar application of herbicide from a boat using a pressure pump sprayer with adapted nozzle



Herbicide licenses & permits

If clearing teams are to work with herbicides the contractor needs to have a valid **Scheduled Trade and Occupations Bylaws permit** from the eThekweni Municipality, which registers them for the storage and commercial use of herbicides.

For information on how to obtain this permit, contact the Environmental Health Services Department of the eThekweni Municipality on +27 31 311 3555

The contractor also needs to have a valid **Pest Control Operators Licence** (limited weeds controller) according to the "Fertilizers Farm Feeds, Agricultural Remedies and Stock Remedies Act", (Act No. 36 of 1947) which is regulated by the Department of Agriculture, Forestry and Fisheries.

The act is available online at: <http://www.gov.za>

"The foliar method of herbicide control is used for sparse to densely invaded waterbodies."



Above: Safety gear should be used during foliar application of herbicide



Above: Example of aerial application of herbicide to Water Hyacinth

Table 5 Herbicides registered for foliar and aerial spraying of Water Hyacinth

Foliar Application (spray from boat or shoreline)

Herbicide	Trade name	Dosage (ml/g)	Est product (L/ha or kg/ha)
Glyphosate (as sodium salt) 700g/kg WG	Kilo Max	220	6.6
Glyphosate (as isopropylamine) 480g/L SL	Seismic	220	6.6
Glyphosate (as sodium salt) 500g/kg WG	Kilo	220	6.6
Glyphosate (as potassium salt) 500 SL	Touchdown forte hitech	450	13.5
Glyphosate (as phosphonic acid) 480g/L SL	Mamba DMA	225	6.75

Aerial Application

Diquat dibromide (as dibromide salt) 200g/L SL	Aquaquat	500	2.5
Glyphosate (as potassium salt) 500 SL	Touchdown forte hitech	450	4.5

Note: Agricultural co-ops and supply chains sell herbicide, but there are also a number of product representatives (or sales reps) who will supply the herbicide directly.

IMPORTANT NOTE: Tallow amine is a surfactant that kills amphibians. These recommended products do not contain tallow amine. When undertaking work near a waterbody, **always ensure that the herbicides being used do not contain any tallow amine.**



Herbicides can be toxic and safety should always be a top priority. Table 6 below provides a list of protective clothing and equipment required for foliar herbicide application.

Table 6 Protective clothing and equipment required for foliar spraying with a knapsack sprayer or by boat

Protective Clothing	Equipment
• Overall two piece overalls	• 16 litre sprayer standard sprayer with cone nozzle Ensure the spare parts can be easily bought
• Gumboots standard gumboots	• Mixing jug jug to measure out at least 1000 ml
• Face mask mask specific for spraying to prevent inhalation of herbicides	• Funnel wide funnel to fit into 25 litre containers
• Goggles it is important that goggles close around the eyes to prevent herbicide entering	• Tarpaulin/Basin for mixing big enough to prevent spills
• Sun hat	• 25 litre containers to use for carrying clean water for mixing of herbicides
• Rubber gloves wrist-length to prevent herbicide from getting onto hands	• Soap & water for washing hands when in contact with herbicides
• Life jackets these are essential for teams working in deep water	

Note: Several firms in Durban supply such Personal Protective Equipment (PPE). Some of these may specialise in overalls and hats, whilst others might specialise in boots and goggles. The 'yellow pages' is a great starting place to search for suppliers.



Top: Example of foliar application of herbicide from a boat; Above: Preparation of a boat prior to herbicide application



DOWNLOADABLE RESOURCES

See the eThekweni Municipality Guideline for Control of Invasive Alien Plants for more information on herbicide safety and storage. <http://www.invasives.org.za>

Required permits and staff training for herbicide application includes:

- Pest Control Operators Licence:**
 In order to comply legally, the person issuing the herbicide needs to have a Pest Control Operator's (PCO) Licence. This is normally the contractor and/or manager. A certified PCO Course can be attended after which practical training under a licenced PCO will have to be gained. Thereafter application may be made for a PCO licence.
- Herbicide Application Course:**
 For all workers who will be applying herbicide, this is a certified training course on maintaining the knapsack sprayer, herbicide safety, correct mixing and spraying of herbicides.
- Invasive Alien Plant Identification Course:**
 It is advisable that workers are able to correctly identify the IAPs they will be treating. Even if only spraying Water Hyacinth, workers must be able to differentiate between target and non-target plants. This could be an in-house course.
- Safety by the water and swimming classes:**
 As workers will be spraying next to the water, it is important to either use persons who can swim, or train them to swim in case of an emergency.



7.3.4 Biological Control

Invasive alien plants such as Water Hyacinth thrive and spread in an exponential manner, partly due to the lack of natural enemies (e.g. browsers or pathogens) that might occur in their land of origin. Biological control, or biocontrol, is the introduction of these natural enemies to remove the plant's competitive advantage and reduce vigour to a level comparable to that of the natural vegetation.

The most frequently used biocontrol agents are insects, mites or other pathogens (e.g. disease-causing organisms such as fungi or bacteria). Biocontrol agents often attack specific organs of the target plants (its leaves, stems or roots) or the reproductive parts (flowers, fruits or seeds).



Top and above: Examples of how biocontrol agents can be used to remove the competitive advantage of alien plants.

"Biocontrol agents often attack specific organs of the target plants or the reproductive parts."



The biological control of Water Hyacinth in South Africa (see Appendix 4 on page 54) currently relies on:



Two weevil species: *Neochetina bruchi* (left) and *N. eichhorniae* (right)



A pyralid moth: *Niphograpta alboguttalis*



The Water Hyacinth bug: *Eccritotarsus catarinensis*



A galumnid mite: *Orthogalumna terebrantis*



A leaf sap sucker that has been cleared from quarantine for release: *Megamelus scutellaris*

The Biocontrol Manager of the KwaZulu-Natal Department of Water Affairs Working for Water Programme is responsible for the releasing and monitoring of biocontrol agents in the province. The South African Sugar Research Institute (SASRI) has a mass rearing programme for weed biological control agents and is based in Mount Edgecombe. All the biocontrol agents from SASRI will be free of charge and can either be posted or collected from SASRI.

Table 7 Advantages and disadvantages of biological control

Advantages

Most environmentally friendly and most sustainable of all available Water Hyacinth control methods.

Usually does not require high or long term maintenance.

Relatively low cost requirements over the long term.

Disadvantages

Generally slow to achieve its aim, especially initially.

Low levels of infestation, with occasional outbreaks, will remain a feature of systems under biological control.



Successful case study Clairwood Quarry (eThekweni Municipality)

At the Clairwood Quarry (pictured above during biocontrol application), biocontrol alone is effective due to the quarry being a closed aquatic system. At times Water Hyacinth densities have increased, only to be followed by an increase in the numbers of the biocontrol agent. As biocontrol numbers increase, so the levels of plant infestation decrease until a balanced state with acceptable infestation levels is again achieved. It is important to note that at certain times of year, or in areas where there are high nutrient levels, biocontrol alone is ineffective.

Biological control of Water Hyacinth has been highly successful in tropical freshwater systems throughout the world, but less successful where the plant grows in temperate climates and rivers and lakes that suffer excess nutrient pollution. Biocontrol agents are also best released in slow flowing watercourses.



7.3.5 Integrated Control

Integrated control is achieved through implementing a combination of methods to control IAP infestations. Most commonly, biocontrol and herbicide application are used in a complementary manner. In some cases, such as where Water Hyacinth has formed a dense mat and has become impossible to move through by boat, mechanical control (e.g. mechanical harvester) may be used. This ensures that pathways are opened, which allow for a boat to be able to enter and thereafter herbicide can be applied. Different sections of a waterbody might require different control methods. For example, in a large dam that is densely invaded, spraying of herbicide using a boat or aeroplane might be the best

option. However, in a sparsely invaded area close to sensitive vegetation, biocontrol may be a more responsible option.

At a catchment-wide scale where Water Hyacinth infestation levels vary, where there are different ecological and economic considerations and many stakeholders, integrated control is the most effective control option. However, the decision about which approach to select needs to be based on an understanding of:

1. the relative cost-effectiveness of different control methods; and
2. the economic, social and environmental benefits and risks associated with each control method.

"Where dense Water Hyacinth has made it impossible for a boat to manoeuvre, a mechanical harvester may be used."



Above: A mechanical harvester clearing Water Hyacinth

7.4 Monitoring

Part of effective implementation is to ensure efficient record keeping of all costs, person-days and methods used.

Records should then be used to ascertain future control costs for a particular waterbody, and as a reference when costing out further control plans. Care should be taken to ensure that the best operating practices and equipment are used for all control work undertaken, e.g. use the correct protective clothing when conducting foliar spray, ensure boat safety, etc.

Monitoring is critical to ensure that the control plan is being implemented effectively. If the control method is not working then an alternative plan needs to be considered. The eThekwin Municipality's Invasive Alien Species Framework Strategy and Action Plan notes that 'adaptive management' should always be embraced. As such, all actions should be monitored and evaluated so that management actions can be adapted based on what is observed.

To undertake a cost/benefit analysis for Water Hyacinth control, the following data will need to be recorded:

- The method of control used
- The level of success achieved
- The cost per unit area

"Monitoring is critical to ensure that the control plan is being implemented effectively."



Above: The distribution of a biocontrol agent

Monitoring of the effectiveness of biocontrol agents is the responsibility of the Department of Water Affairs (DWA), which implements biocontrol measures nationally. It is, however, recommended that the municipality's lead agent or champion be involved to keep an eye on progress.

If the river system is not entirely infested, then it is important to keep monitoring the uninfested areas. Any encroachment of IAPs into those areas can then be quickly dealt with. If Water Hyacinth is found in these 'clean' areas, it should be removed as soon as possible unless that section has a demonstrated resilience to high density infestations (e.g. due to rapid water flows and water with low or normal nutrient levels). A budget should always be set aside for dealing with invasion emergencies.



Left: Water Hyacinth; Right: Cables being used to contain infestation of Water Hyacinth

7.5 Public Awareness

There may be instances where the area in which Water Hyacinth control is being undertaken is used by the public.

For example, if the river or dam is being used by boat anglers, canoeists, or if there are picnic areas or any other form of activity on the banks of the waterbody, then it is important to create public awareness. This can be done by either:

- Erecting signs along the edge of the waterbody or at the resort entrance, at boat access points and picnic areas.
- Having signage at boat launching points encouraging boat users to ensure that boat propellers are free of any Water Hyacinth before leaving the area.

8 REFERENCE MATERIALS AND FURTHER READING

Acts

- Conservation of Agricultural Resources Act (Act No. 43 of 1983)
- Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act No. 36 of 1947)
- National Environmental Management: Biodiversity Act (Act No. 10 of 2004)
- Occupational Health and Safety Act (Act No. 85 of 1993)

Reference Books and Guides

- Byrne, M., Hill, M., King, A., Jadhav, A., Katembo, N., Wilson, J., Brudvig, R., et al. (2010). Integrated management of Water Hyacinth in South Africa: management plan for Water Hyacinth control, combining biological control, herbicidal control and nutrient control, tailored to the climatic regions of South Africa. Research Report, South African Water Research Commission.
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- Hill, M. P., & Olckers, T. (2001). Biological Control Initiatives against Water Hyacinth in South Africa: Constraining Factors, Success and New Courses of Action. In M. H. Julien, M. P. Hill, T. D. Center, & D. Jianqing (Eds.), ACIAR Proceedings (Vol. 102, pp. 33–38).
<http://www.bio-nica.info/biblioteca/Hill2001Eischhornia.pdf> (accessed on 20 August 2013)
- eThekweni Environmental Planning and Climate Protection Department (2013). Invasive Alien Plant Control Guideline Document. eThekweni Municipality, Durban.
http://www.durban.gov.za/City_Services/development_planning_management/environmental_planning_climate_protection

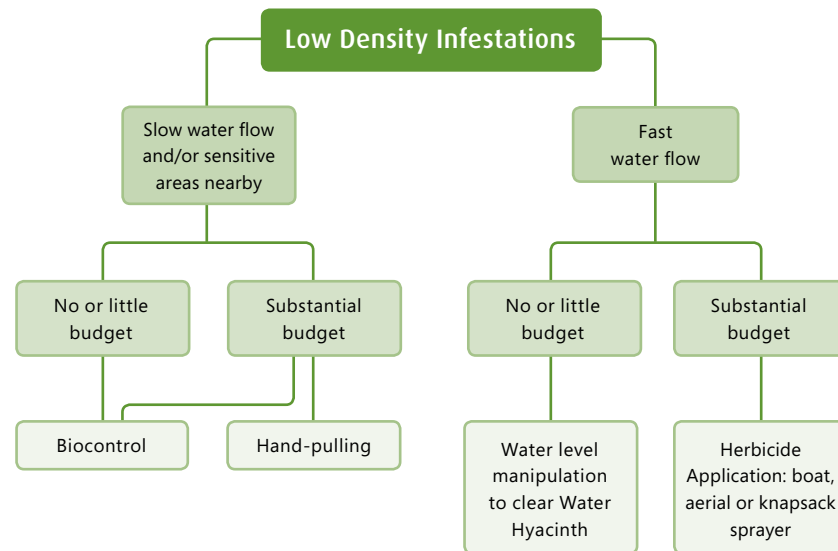
Websites

- Invasive Species South Africa: <http://www.invasives.org.za/>
- Relevant legislation and regulations for South Africa: <http://www.gov.za/>
- Durban's Early Detection and Rapid Response website: <http://www.durbaninvasives.org.za>
- Plant Protection Research Institute website: <http://www.arc.agric.za>

APPENDIX 1

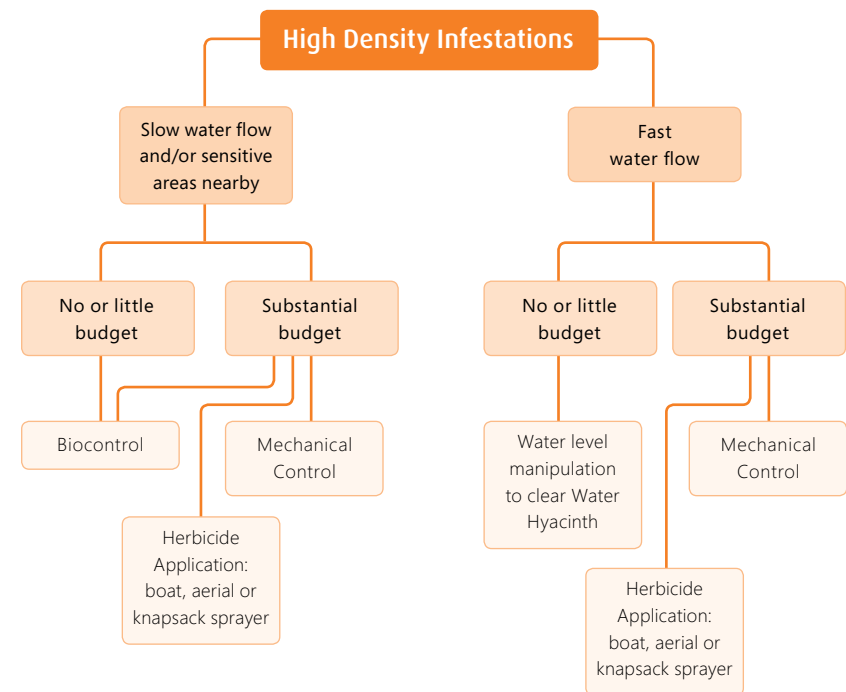
Decision-support Flowchart for Selecting Control Methods

Figure 1: Control options for areas with low density infestations of Water Hyacinth



(Areas with slow flow are more susceptible to the decay of plant matter and associated impact of low dissolved oxygen concentrations. Under this scenario it is suggested that there be limited or selective spraying, with a greater emphasis on biocontrol)

Figure 2: Control options for areas with high density infestations of Water Hyacinth



APPENDIX 2

Costs associated with different Control Methods

The costs listed below are estimates obtained from agencies that have conducted successful Water Hyacinth control work in KwaZulu-Natal. All the costs are based on heavily infested areas, estimated at 100% density per hectare.

Control Method	Cost per day/hectare (100% dense ha)	Comments
 Biocontrol	No cost	No cost to eThekweni Municipality for implementation, except the management costs if assisting to release and monitor when necessary.
 Hand pulling	125 person-days/ha	This figure is from hand pulling at iSiphingo and Working for Water standards. Factors such as accessibility to the site, river width and terrain all contribute to the amount of person-days necessary.
 Mechanical Harvester	R10 000 p/day – 2 people Amount of hectares to be cleared per day depends on densities	
 Aerial Spraying	Microlight: R400/ha with carrying capacity of 100 litres Helicopter: R8500/hr = between R1200 – R4800 p/ha	If aerial spraying is not done by a pilot with experience in spraying, then it could be a waste of money.
 Foliar Spraying with Knapsack walking along river. Based on a team of 10 people all spraying.	60 – 80 person-days/ha Cost pp/day: R300 – R400 Cost p/ha: R550 – R830/ha (more people are required which is similar to boat fuel, maintenance, herbicide costs)	This is dependent on the terrain and can be more or less.
 Foliar Spraying by boat based on a tug20 boat. Team size of six, using handheld pressurised spray rig with handle nozzle and 15 hp outboard motor.	26 – 35 person-days/ha: Cost pp/day: R257 – R450 (incl. wages, PPE, equipment, training) Boat costs: R550 – R830/ha (incl. fuel, maintenance, herbicide costs)	This is dependent on the accessibility to the area.

APPENDIX 3

Control Plan Example

Management unit	Size (ha)	Density	Control Option
1	9	60%	Herbicide first, then release Biocontrol. If infestation density then increases beyond 10%, use herbicide again.
2	18	100%	Mechanical control using mulcher to get access, thereafter herbicide application.
3	10	90%	Mechanical control using mulcher to get access, thereafter herbicide application.
4	36	60%	Biocontrol

Year	Notes	Responsibility	Cost per annum*
2011	Boat access not possible, but can be sprayed by walking next to the stream. Slow flowing area.	Conservancy	e.g. (shift/ha at 60% density x)
2011	Used by canoeists.	eThekwini Municipality	
2012		eThekwini Municipality	
2011	Biocontrol is the best option. Need to minimise disturbance to the bird sanctuary. This is the lowest point in the river and the weeds spread further downstream.	DUCT	

APPENDIX 4

Biocontrol agents

Name	Organism Type	Mode of Attack & Feeding Damage	Identification	Damage to weed
<i>Neochetina eichhorniae</i> (Mottled Water Hyacinth weevil)	Weevil	Stem borer: - Larvae tunnel into the petioles and the crown of the plant causing waterlogging and eventual plant death. - Dense mats of the weed start to break up as the new growth is damaged. - The adults feed on the leaf's epidermis forming characteristic square feeding scars. - Long-term damage results in reduction of production of flowers, leaves and daughter plants and a stunting of plant growth. <i>N. eichhorniae</i> is the most widespread and abundant of the introduced natural enemies but floods, physical removal and herbicide sprays have reduced its effectiveness.	- Adults are about 4-5 mm long. <i>Neochetina eichhorniae</i> is mottled brown/grey <i>N. bruchi</i> is brown/tan. - Nocturnal & shelter during day in the leaf sheath near the crown of the plant or in rolled leaves. - Adults are long lived ($\pm$ 280 days). - Females of both species produce approximately 350 to 400 eggs in their life time. Eggs are white and take $\pm$ 9 – 16 days to hatch. <i>N. eichhorniae</i> females insert eggs into the leaf tissue of the younger leaves while <i>N. bruchi</i> females prefer to lay eggs on the upper part of the older petiole (leaf stem).	Substantial
<i>Neochetina bruchi</i> (Chevroned Water Hyacinth weevil)	Weevil	<i>N. bruchi</i> supplements damage caused by <i>N. eichhorniae</i> and is an important agent in eutrophic water and on the cold Highveld.	There are 3 immature stages in both species.	Substantial
<i>Orthogalumna terebrantis</i>	Mite	Leaf miner: - The mite larvae and nymphs produce feeding tunnels (affecting up to 90% of the leaf surface), which reduce their photosynthetic capability, thus reducing the vigour of the plant. The damage is most visible in late summer (February). - Pin holes in leaves indicate adult emergence from the tunnels. The holes can be seen by holding the leaf up against the light. - Under correct environmental conditions, this agent, in combination with the other biological control agents that have been released on Water Hyacinth can bring the weed under complete control.	- Adults are shiny, dark brown/black, less than 1mm & tear-dropped shaped. - Barely visible with the naked eye – appear as a small dot on leaves. - Adults often aggregate in the feeding scars of the two weevil species. - Eggs are $\pm$ 0.1 mm in size. - Life expectancy if the adult is about 85 days. - These mites can survive temperatures ranging from 0°C – 40°C.	Considerable

APPENDIX 4

Biocontrol agents continued

Name	Organism Type	Mode of Attack & Feeding Damage	Identification	Damage to weed
<i>Niphograptia albiguttalis</i>	Moth	Petiole borer: - Damage causes waterlogging of the petiole which leads to the plant sinking. - Older larvae destroy the growth tips. - Prefers young, growing, healthy plants. - Damage to the plants can be severe, but the impacts are often patchy, seasonal and temporary. - Under correct environmental conditions, this agent, in combination with other biocontrol agents that have been released on Water Hyacinth, can bring the weed under complete control.	- Adult moths are 6-10 mm in length with a wingspan of 17-25 mm. - The colour of the moth varies between golden yellow and charcoal grey with brown, black and white markings. - The larvae feed inside the petioles (leaf stems). - The adults are nocturnal and live only 4 – 9 days, in which they do not feed. - Females lay ± 370 eggs during their life. - The eggs hatch after 5-10 days. - The 5 larval stages take 16-21 days to complete.	Considerable
<i>Eccritotarsus catarinensis</i>	Mirid	Sap sucker: - Feeding causes yellow/browning of the leaf due to the extraction of chlorophyll. - Feeding reduces the vigour of the plants. Prefers mature stands where the canopy leaves offer protection from heat and cold. - Small black frass (waste) marks on leaf surface associated with mirid presence.	- The adult mirids are about 3 mm long. - Black with pale legs and reddish eyes. - Often found aggregating on the under surface of leaves. - Creamy white eggs are laid in the Water Hyacinth leaf tissue, mainly on the under surface of the leaves. - Nymphal development is about 15 days. - The adult's lifespan is about 50 days.	Considerable
<i>Cercospora piaropi</i>	Pathogen	Causes leaf spots: - Feeding causes yellow/browning of the leaf due to the extraction of chlorophyll. - Feeding reduces the vigour of the plants.		Considerable
<i>Cercospora rodmannii</i>	Pathogen	Causes leaf spots: - Feeding causes yellow/browning of the leaf due to the extraction of chlorophyll. - Feeding reduces the vigour of the plants.		Considerable

NOTES

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**ENVIRONMENTAL PLANNING
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