Pontederia (Eichhornia) crassipes (water hyacinth) in Hartbeespoort Dam (South Africa)

BACKGROUND

Despite efforts to control *Pontederia (=Eichhornia) crassipes*, more commonly known as water hyacinth, it remains South Africa's most problematic aquatic macrophyte. Water hyacinth is a free-floating highly invasive plant species which given favorable conditions is able to double its biomass every two weeks. It originates from the Amazon Basin in South America and has been introduced into South Africa as an ornamental aquatic plant in the early 1900s. Water hyacinth has been spread mainly due to the activities of gardeners, aquarium owners and boaters. Hartbeespoort Dam has become an example of this plant's invasive capabilities and resilience.

Hartbeespoort Dam is an arch type dam situated in the North-West Province of South Africa located about 35 km north west of Johannesburg and 20 km west of Pretoria. It provides many benefits to livelihoods such as water supply to household use, irrigation for agriculture, mining and recreation, with a number of up-market housing estates having been developed around the dam. The dam has also contributed to tourism becoming a very popular holiday destination in the country, consequently increasing the property prices in residential areas in the region. However, the benefits of the dam have been put at risk due to severe eutrophication (enrichment of water by nutrients) due to wastewater effluent, sewage spills and fertilizer runoff and its consequences, such as the excessive growth of water hyacinth and algae which these nutrients support. In 2006, among many initiatives, the South African Department of Water and Sanitation launched an Integrated Biological Remediation Programme (Harties Metsi a Me), with the management and removal of water hyacinth a priority of the project. Although millions of Euros were spent on the project, it was terminated in 2017 due to a withdrawal of funding.

Left: Water hyacinth *Pontederia (=Eichhornia) crassipes* flowering (Photo: Antonella Petruzzella). Top right: Aerial photo of the Hartbeespoort Dam. Water hyacinth is seen covering part of the dam. Bottom right: Water hyacinth affecting human recreation (Photo: Baoberry SA Twitter)

Water hyacinth has been present at the Hartbeespoort dam since the 1970s reaching 70% coverage of the dam's 2 000 ha surface area. At that time, the Department of Water and Sanitation took action, spraying the plants with herbicides sinking 400 000 tonnes of plant matter to the bottom of the dam. However, over time, this posed a new problem: the plants began to decompose, releasing biomass nutrients into the water. The result was an explosion of algae (cyanobacteria). Again, during summer of 2016 (July), plant growth reached epidemic proportions but herbicide control was halted by that time. Since April 2017 in excess of 500 000 tons of wet weight of this plant have been mechanically removed from the dam by various harvesting teams. (Source: Harties Foundation). Although the manual (mechanical) removal (most widely used invasive plant control method in Europe) of these plants is a better alternative to chemical herbicides it is still very expensive and labor intensive. Therefore, as an alternative, a long-term biological control programme led by us, the Centre for Biological Control (CBC) – Rhodes University was implemented in 2018.

Biological control is the use of natural enemies such as insects, mites and/or fungi to control target invasive plants. The aim is to reunite invasive species with their natural enemies (biocontrol agents) which will only feed on the target plant. Biocontrol agents target specific plant organs, such as the vegetative parts of the plant (its leaves, stems or roots) or the reproductive parts (flowers, fruits or seeds). Biological control has been a successful, sustainable and cost-effective method of managing weeds on land and in the water in South Africa for over 100 years. Biocontrol agents have been instituted on the Hartbeespoort Dam since the 1980's but due to periodic herbicide application, their populations have been inhibited. Since 2018, the CBC has intensified insect releases by sending regular shipments of biocontrol insects from our facility in the Eastern Cape and together with willing partners, including the Harties Foundation, we are mass-rearing the insects nearer to the dam where they can be released strategically and regularly.

Left: Satellite image of Hartbeespoort dam taken on 9 September 2017 with hyacinth coverage peaking above 30% of the surface of the dam (Photo: Part of David Kinsler's masters research). Right: Satellite image of Hartbeespoort Dam taken on 20 July 2020 with hyacinth covering 2.5% of the surface of the dam, which is the lowest total water hyacinth cover ever recorded without the use of herbicides (Photo: Part of David Kinsler's masters research).

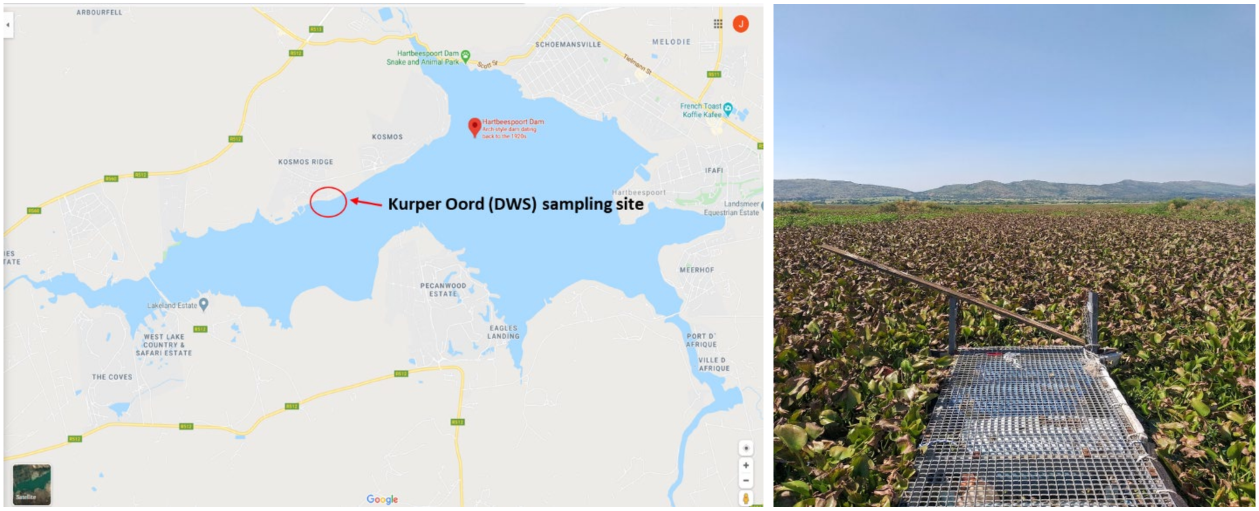
We have seen results so far. An unprecedented reduction in the water hyacinth was recorded between January and March of 2020 which was during our MadMacs project sampling. This was caused by the cumulative feeding from several biological control agents. Currently, six different kinds of insects can be found on the hyacinth at the dam but most of the success can be attributed to the planthopper *Megamelus scutellaris* and the water hyacinth weevils (*Neochetina eichhorniae* and *N.*

bruchi) all native to South America. Due to the effect of the biological control, the cover of water hyacinth fell to as low as 2.5% over the winter of 2020. However, the cumulative effects of the cold winter and the sparse populations of plants that the insects rely on for food meant that the number of biocontrol agents was greatly reduced over winter. Due to the high nutrient status of the water which feeds the water hyacinth growth, rapid increases of the plants are expected from time to time while the insect populations work to catch up. Although the water hyacinth can be managed using biological control, the total eradication of this plant on the Hartbeespoort Dam is unlikely. This is due to the large size of the dam, the rapid growth rate of this species, the extensive seed bank in the sediment and the ongoing water quality crisis.

Top left: Extensive damage on the water hyacinth mat (brown plants) (Photo: Julie Coetzee). Top right: Photo taken on 16 January 2020 showing the plants heavily damaged by the biocontrol agents at the Leeuwspruit, upstream of the Hartbeespoort Dam (Photo: Antonella Petruzzella). Bottom left: *Megamelus scutellaris* adults and nymphs on the stem of a Water Hyacinth plant (Photo: Julie Coetzee). Bottom Middle bottom: *Megamelus scutellaris* adults and nymphs on the leaf of a Water Hyacinth plant. The marks on the leaf are scars produced by the planthoppers (Photo: Julie Coetzee). Bottom right: *Neochetina* weevils in the wrapper Water Hyacinth leaves (Photo: Julie Coetzee).

STUDY SITE AND EXPERIMENTAL DESIGN

The MadMacs project sampling in South Africa was conducted at Kurper Oord, a site that belongs to the Department of Water and Sanitation and is heavily invaded by water hyacinth, during early January 2020.



Left: Map of Hartbeespoort Dam, indicating Kurper Oord, the MadMacs project sampling site (Source: Google maps). Right: Kurper Oord site (Photo: Julie Coetzee).

The sampling approach followed a 'BACI' design – 'Before-After, Control-Impact' whereby 2 sites were selected and allocated either 'control' or 'impact'. The core of sampling in the BACI design is 1 week before and 1 week after plant removal in order to make sure that the case studies are comparable.

Top left and right: Aerial photographs of the 'Before' and 'After' water hyacinth removal at the site. Bottom left and right: Photos of the site before and after the water hyacinth removal (Photos: Warren Aken and Golder Consulting).

At the Hartbeespoort Dam site, Water Hyacinth was manually removed through collaboration with the Harties Foundation, a NPC operating around the Dam.

Photos of the removal of water hyacinth at the sampling site in Kuper Oord at the Hartbeespoort Dam (Photos: Julie Coetzee).

SAMPLING

In order to test the effect of the presence/removal of water hyacinth on the diversity of aquatic organisms, water quality, carbon cycle and a range of ecosystem services (benefits that humans obtain from ecosystems), a number of biodiversity measures were made at both the control and impact site, before removal of water hyacinth, and one week after removal. These included algae, macroinvertebrates, fish and aquatic plant diversity assessments. In addition, water chemistry measures, fluxes of CO_2, CH_4 and N_2O, sedimentation rates, were assessed. Find below some pictures from our experience here in South Africa.

From left to right: PhD student Nonpumelelo Baso and Dr Christophe Piscart sampling zooplankton; PhD student Benjamin Misteli sampling macroinvertebrates; Warren Aken and Dr Samuel Motitsoe collecting fish after electrofishing; Aquatic plant sampling team entering the dense mat of water hyacinths (Photos: Photos taken by several members of the team during the MadMacs sampling January 2020)

From left to right: PhD student Keneilwe Sebola measuring greenhouse gas emissions; A closed chamber is used to measure greenhouse gas emissions in the Impact site after removal of water hyacinth. The green on the water is due to algae bloom (cyanobacteria) after plant removal; Improvised laboratory; PhD student Kirstine Thiemer doing ecosystems services questionnaires in a shopping mall in Hartbeespoort (Photos: Photos taken by several members of the team during the MadMacs sampling January 2020).

PRELIMINARY RESULTS

The effect of water hyacinth presence/removal on the aquatic organism biodiversity

Biodiversity beneath the water hyacinth mat was lower than in the open water, and this has consequences for ecosystem structure and functioning. Details of these community structures are not yet available though as samples still need to be processed.

Fish

The sites covered with dense water hyacinth (before removal), appeared to have less diverse and abundant marginal / littoral zone dependent fish species. This may have been exaggerated by the limited access within the dense coverage, as well as the dam's depth. However, it is also likely that the dense coverage of water hyacinth provides a homogenous (and plentiful) habitat with little open water and light for many species, with only species such as Carp (*Cyprinus carpio*) and Sharptooth Catfish (*Clarias gariepinus*) inhabiting the benthos and Mosquitofish (*Gambusia affinis*), inhabiting the roots.

The exotic *Gambusia affinis* dominated the catch (Photo: Wikipedia)

Accessibility was improved once the macrophytes were removed, and more fish species were sampled. It should be noted that some of the species sampled, following the removal, were utilizing the open water areas between the water hyacinth and the marginal reeds. This observation was supported by the sampling of the control site, whereby fish were observed to be moving in open water between different cover habitats.

Although a snapshot in time, these results indicate that the fish species reliant on the marginal/littoral zones require a combination of open water habitat and sufficient cover for protection. Fish were observed moving out in the open water, and only once threatened, did they take refuge in the vegetation cover (both marginal and floating water hyacinth).

The effect of water hyacinth presence/removal on the water quality (nutrient concentration and water chemistry)

Water quality in terms of phosphates is poor – ranged between 2.5 and 4 mg P/l. The international standard is 0.1 mg P/l, and the SA standard is 0.2 mg P/l. These values were found in both the cleared and control sites.

Oxygen levels increased after water hyacinth removal, in both the control and impact sites, with no significant differences between the two sites. Oxygen levels were overall higher in the open water than in the control and impact sites. Similarly, results for pH, conductivity and temperature did not show clear differences between sites.

Ecosystem services questionnaires

The perceptions of residents and tourists around the presence of water hyacinth are mixed, although most agreed it was a nuisance, affecting property values, tourism, and health. Some respondents perceived its presence to be more beneficial than the presence of blue-green algae. The questionnaire still needs in depth analysis.


Less than a week after removal, the cyanobacteria bloomed (most likely *Microcystis aeruginosa*, but this needs to be confirmed). It was present in the water hyacinth impact site before the removal, but was not able to bloom due to lack of sunlight, a requirement for photosynthesis. Water hyacinth prevents the build-up of blue-green algae through its shading effect, and not through its uptake of nutrients.

SOUTH AFRICAN TEAM

From left to right: PhD student Keneilwe Sebola (standing) and Prof. Julie Coetzee (South African coordinator), Dr Samuel Motitsoe, Dr Antonella Petruzzella, Dr Rosali Smith and PhD student Nonpumelelo Baso https://www.ru.ac.za/centreforbiologicalcontrol/

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