BioInvasions Records (2016) Volume 5, Issue 1: 1–6
DOI: http://dx.doi.org/10.3391/bir.2016.5.1.01

Open Access

Rapid Communication

Hydrocleys nymphoides (Humb. & Bonpl. ex Willd.) Buchenau: first record of naturalisation in South Africa

Menzi M. Nxumalo[1]*, Reshnee Lalla[1], Jorge L. Renteria[1,2] and Grant Martin[3]

[1]*Invasive Species Programme, South African National Biodiversity Institute, KwaZulu-Natal Herbarium, Berea Road, Durban, P.O. Box.52099, Durban 4007, South Africa*
[2]*Land Use Planning & Management, School of Agricultural, Earth & Environmental Sciences, University of KwaZulu-Natal, South Africa*
[3]*Dept. of Zoology and Entomology, Rhodes University, Grahamstown 6140, South Africa*

**Corresponding author*
E-mail: m.nxumalo@sanbi.org.za

Received: 21 July 2015 / Accepted: 16 October 2015 / Published online: 25 November 2015

Handling editor: Vadim Panov

Abstract

Hydrocleys nymphoides (water poppy), an aquatic plant native to South America, has been recorded as invasive on several continents (Europe, Australia and Asia). Here we report on the first known naturalized population in South Africa, in a dam in the KwaZulu-Natal (KZN) Midlands region, near the town of Howick. This population, first detected and identified in 2009, had by the end of the 2013 summer season occupied 1.8ha (30% of the dam). Surveys of 34 surrounding water bodies during the period between 2012 and 2013 did not result in detection of any new populations. The only other population (0.1 ha) was recorded growing in cultivation at the Durban Botanic Gardens. This note reports on the history of *H. nymphoides* in South Africa, details its current and potential distribution, looks at the risk it poses, and outlines plans for nation-wide eradication.

Key words: water poppy, invasive alien aquatic plant, South Africa

Introduction

The negative impacts of invasive alien plants to natural resources are well documented (Richardson and van Wilgen 2004). Aquatic invaders are of particular concern in water-scarce countries such as South Africa and should be prioritized for management (van Wilgen and De Lange 2011).

Hydrocleys nymphoides (Humb. & Bonpl. ex Willd.) Buchenau (Limnocharitaceae), is a rooted aquatic plant native to South America (Brazil and Venezuela) that is regarded as a problematic invasive in parts of Australia and Europe (Williams 2008).

It is characterized by floating round to heart-shaped fleshy leaves that are supported by long petioles and cup-shaped flowers with three to six yellow petals and a reddish-brown centre (Figure 1A, B). (Aston and Jacobs 1980). In its introduced ranges, the plant reproduces solely vegetatively (Williams 2008). During vegetative reproduction, stolon fragments break away, at the end of the growing season rise to the surface, and are carried by water movements; these then root and form new plants (Emert and Clapp 1998). *Hydrocleys nymphoides* grows best in shallow waters (less than 2m), and nutrient-rich environments with sufficient light penetration (Sullivan and Hutchison 2010).

Due to its reproductive and growth characteristics, *H. nymphoides* poses an ecological threat to invaded water systems (Smith 1979). Broken plant fragments enable it to regenerate and out-compete indigenous vegetation. Long trailing petioles can cause physical obstruction which interferes with the behaviour of aquatic fauna, and also affect recreational activities such as fishing, swimming, and boating (Sullivan and Hutchison 2010). Dense infestations can trap silt and result in blockages of the water flow. Under favourable conditions, *H. nymphoides* can carpet the entire water surface preventing the penetration of light for photosynthetic process

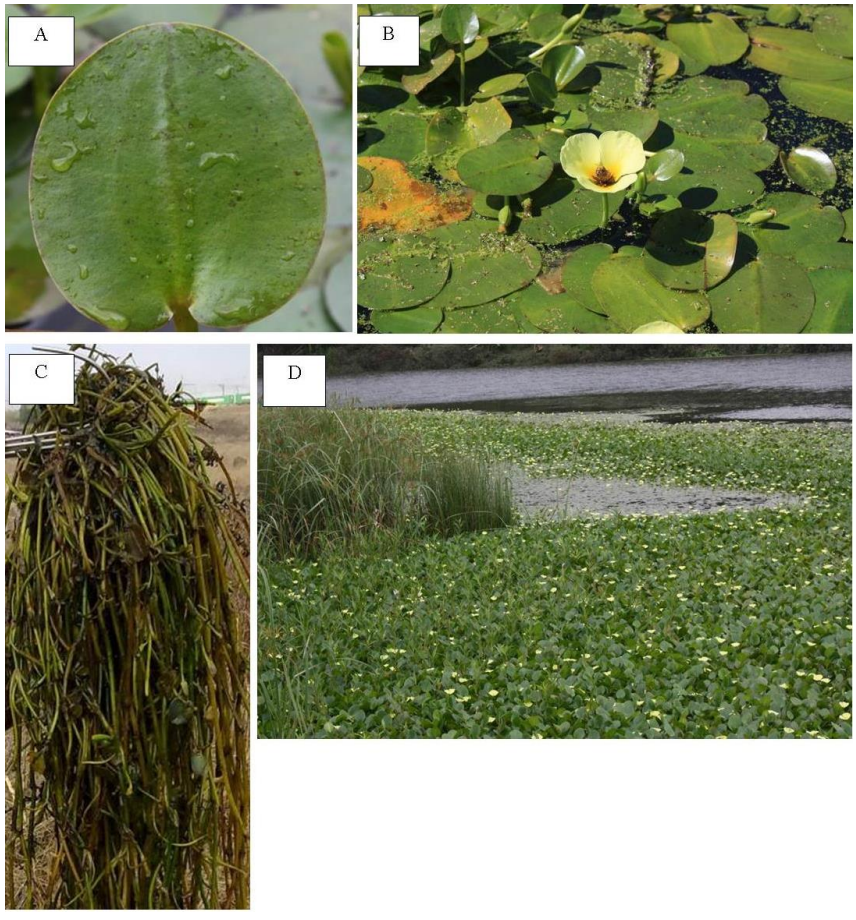

Figure 1. *Hydrocleys nymphoides*: (A) leaf shape, (B) cup shaped yellow flower, (C) dense petiole fragments and (D) infestation at St. Joseph's Dam. Photographs: M. M. Nxumalo.

and depleting oxygen, which changes the state of the water ecosystem, impacting negatively on indigenous flora and fauna (Gorham 2008).

In Australia, *H. nymphoides* was used as an ornamental as early as 1896 (Aston and Jacobs 1980), with the first naturalized populations reported in 1979 from Valencia Creek, Central Gippsland, Victoria. The species has now naturalised in slow-moving and high-nutrient waters of Queensland (Stephens and Dowling 2002), and is listed as a moderate high risk weed in the advisory list of environmental weeds of aquatic habitats of Victoria (Adair et al. 2008). Although adapted to tropical and subtropical habitats, literature suggests that *H. nymphoides* can also thrive in warm and cool temperate regions outside of the tropics (Williams 2008). It has also naturalised in New Zealand (Hosking et al. 2005) and became invasive in the warmer regions of England, USA, Japan, and in Fiji following the dumping of aquaria waste into water courses (Williams 2008).

The species is also recorded in two African countries: Zimbabwe (included in the GBIF records) and Kenya, where it is used as an ornamental plant in tropical water gardens and in constructed wetlands for waste water treatment (Howard and Chege 2007). However there is no evidence for naturalization or invasiveness in any of these cases.

The first naturalized population of this species in South Africa was discovered in 2009, when the South African National Biodiversity Institute's Invasive Species Programme (SANBI ISP) was alerted to an aquatic plant naturalized at a dam in the Midlands area of the KwaZulu-Natal province. The SANBI ISP is mandated to target localized alien species of limited distribution which stand a chance of eradication (Wilson et al. 2013). A herbarium specimen (M Cheek, NH 0135792) was lodged at KwaZulu-Natal herbarium. The St. Joseph's Dam (29.05194 S, 30.03222 E), located in Howick, is approximately 6 ha and occurs on private agricultural land belonging to

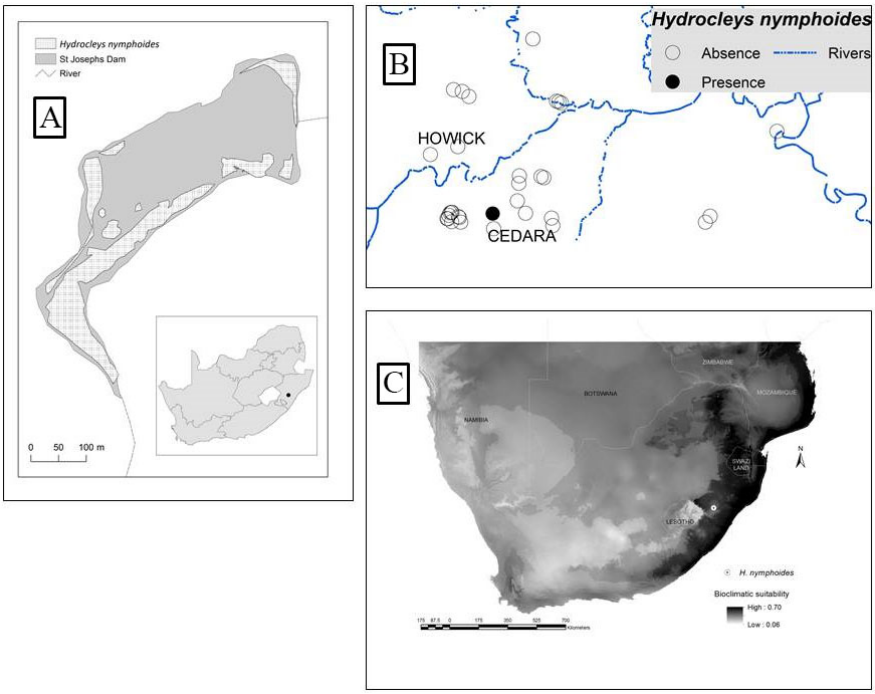

Figure 2. Extent of invasion *of Hydrocleys nymphoides* at St. Joseph's Dam (A), relative position of the surrounding water bodies surveyed, indicating presence and absence data (B), and potential distribution *of H. nymphoides* generated by the bioclimatic models. Values represent the mean probability of the two fitted models (C).

a Theological Institute. The dam is used for irrigation, recreation and to provide drinking water.

This note reports on the current distribution of *H. nymphoides* in South Africa, and speculates as to its potential distribution. Results from an initial assessment on the potential risk of this species to South Africa, and planned initiatives to control the only known population of this aquatic alien plant in South Africa are highlighted.

Methods

Determining the current distribution of H. nymphoides

To determine if there are other populations in South Africa, the Southern African Plant Invaders Atlas (SAPIA) and three national South African herbaria were consulted; scientific literature searches conducted; and data from annual surveys of alien aquatic plants in approximately 200 South African freshwater systems (conducted by Rhodes University since 2008) were analysed. Pamphlets were also developed (Supplementary Figure S2) and distributed at several environmental fora and workshops to encourage people to report sightings, and two posters were presented at scientific conferences in KZN.

In order to see if *H. nymphoides* is locally more widespread than the infestation recorded in St. Joseph's Dam, upstream and downstream surveys were conducted and 34 water bodies (Figure 2B and Table S3) occurring within a 20km radius of the dam were surveyed.

Assessing the potential invasive risk

The Australian Weeds Risk Assessment model (Phelong et al. 1999) was used as a measure of the potential risk of this species in South Africa. Two different bioclimatic models (Bioclim and Domain), using presence-only data, were fitted to predict the potential future expansion in South Africa. Presence records of *H. nymphoides* and 19 climatic variables were gathered from internet sources (GBIF 2014; Hijmans et al. 2005). The climatic variables were merged in a principal component analysis (PCA) and keeping the first five orthogonal axes (cumulated explained variance 93%). The potential area was calculated as the averaged area predicted by two models.

Ecology of H. nymphoides at St. Joseph's dam

The infestation was assessed to detect changes over time and to determine feasible control methods. Surface mapping was done, and the

Table 1. *Hydrocleys nymphoides* fresh weight biomass data from St Joseph's Dam.

Site number and GPS co-ordinates	Fresh Biomass kg/m²			
	Quadrat 1	Quadrat 2	Quadrat 3	Average per site
Site 1 (-29.5197, 30.2635)	73.6	59.6	13.96	49.05333
Site 2 (-29.5186, 30.2631)	27.92	48.24	53.12	43.09333
Site 3 (-29.5199, 30.2631)	43.56	44.92	33.56	40.68
Site 4 (-29.5206, 30.2623)	32.4	18.44	20.68	23.84
Site 5 (-29.5211, 30.2618)	17.12	23.88	17.64	19.54667
Site 6 (-29.5225, 30.2609)	31.32	106.8	52.8	63.64
Site 7 (-29.5209, 30.2609)	71.72	44.8	32.64	49.72
Site 8 (-29.5204, 30.2609)	35.76	33.76	20.32	29.94667

infestation was found to occur mostly along the edges of the system running from the wall to the catchment. The dam was then divided into four sections (40m apart). Within each section, eight sampling sites were randomly selected, and three $1m^2$ quadrants were placed in each of these sampling sites for data collection, such as submerged aquatic macrophyte composition and density (fresh weight biomass). These were collected using a sampling rake (a metal leaf rake with eight 18 cm long teeth bending upward around the rake), which was thrown down into the water, lowered to the substrate, and twisted 180° as it was lifted vertically from the water to ensure that no plants were left behind. Plant samples were bagged, left to air dry for 5 to 7 minutes and weighed using a spring balance (kg). GPS coordinates and depth readings were recorded for every sampling site. Samples were transported to the laboratory for drying in order to get the dry weight biomass. Samples were air-dried for two weeks to remove as much moisture as possible from the plants and were then further dried using a 700 watt microwave oven (which was set to maximum heat) three times for 15 to 20 minutes. The dry mass was then recorded.

Results

Distribution and ecology

The only other herbarium record of the species in South Africa was from a cultivated specimen collected in 1951 from the Durban Botanic Gardens in South Africa (ER Thorp, NH 40848). As a result of this study, the Durban Botanic Gardens management was alerted to the plant, and the population was manually removed in 2013. Since then, no plants were recorded in the pond.

The history behind its current occurrence in St. Joseph's dam (~65km away from the Durban Botanic Gardens) is not clear. Management staff at the St Joseph's Theological Institute and neighboring agricultural college (CEDARA) were approached, but they could not provide details of how the population originated.

Surveys conducted by Rhodes University in water bodies in South Africa revealed no other infestations (Supplementary Figure S1 and Table S1). Surveys of water bodies surrounding St. Joseph's dam also showed no signs of spread or establishment of *H. nymphoides*. Hence, the population detected at St. Joseph's dam is the only known naturalized population in South Africa (Figure 2B).

Plants at the dam were observed forming dense mats mostly along the edges of the dam, occupying about 30% surface area where the depth was between 0.8 to 2.3 meters. The average of fresh weight biomass from the eight sampled sites was 39.92 kg/m^2. Flowers were observed, but seeds were never found. The most prominent co-occurring species was the non-indigenous invasive aquatic weed, *Egeria densa* Planch (Hydrocharitaceae).

Invasive potential and risk

Hydrocleys nymphoides obtained a score of 22 for South Africa, based on the Australian Weeds Risk Assessment Protocol (Table S2). However, in New Zealand where it has also naturalized, *H. nymphoides* obtained an even higher score of 45 (Champion et al. 2014). Other studies have also suggested that *H. nymphoides* requires attention as a potential invader of wetlands when conditions are favourable (Williams 2008; Aston and Jacobs 1979; Smith 1979). In the US, despite being been present for over a century and currently a minor invader of water systems, Gordon et al. (2012)

iterated the importance in implementing management efforts at this stage, to avoid probable future impacts. In addition, the bioclimatic modelling map has shown the eastern region of South Africa to be climatically suitable for *H. nymphoides*. This includes the Eastern Cape, KZN, Mpumalanga and Limpopo provinces (Figure 2C).

Discussion

Since the discovery of *H. nymphoides* in South Africa, the SANBI ISP has taken steps to assess the distribution and threat of this species. Results indicate that *H. nymphoides* is limited to only one locality at the St. Joseph's Dam in KZN.

According to Aston and Jacobs (1980), *H. nymphoides* grows best in warm nutrient rich environments, but dies back in winter. The Midlands region of KZN in which the St. Joseph's Dam is located experiences very low temperatures and endures frost in winter. This, together with the inability of *H. nymphoides* to produce seeds, may also be a limiting factor towards establishment and spread to nearby water bodies or downstream.

Hydrocleys nymphoides grows in an artificial dam that is connected to the stream that runs down into another dam (Albert Falls Dam). From our in-field observations, should the system experience floods or any disturbance that leads to the movement of plants, there is a high probability that plants and fragments could escape downstream and start invading lower parts of the stream.

Freshwater aquatic plant species have demonstrated a high rate of becoming invasive and pose higher risks of invasion when grown or released in new habitats (Gordon and Gantz 2011). Due to its demonstrated invasiveness in other countries with a similar climate and taking into account the assessment of the results from both the AWRA and the bioclimatic model, it is concluded that *H. nymphoides* poses a risk of invasion to waterbodies in South Africa, particularly in the eastern parts of the country.

At this early stage of invasion in South Africa *H. nymphoides* stands a good chance of eradication and management efforts should aim to remove the current infestation and prevent spread to other water bodies. As such we support the categorisation of *H. nymphoides* as an eradication target under South African regulations (*i.e.* Category 1a species on the NEM: BA regulations (DEA 2014).

The ISP has already started controlling the population at St Joseph's Dam, and we also suggest targeting surrounding water bodies that are *directly* linked to St. Joseph's Dam for future surveys, due to this species' preference for vegetative propagation. Awareness-raising initiatives should also extend to other climatically suitable areas of the country, as indicated from results of the bioclimatic model (e.g. in the northern provinces).

Acknowledgements

This work was supported by the South African National Department of Environment Affairs through its funding of the South African National Biodiversity Institute Invasive Species Programme. We would like to thank Michael Braack for bringing the species to our attention, Max Mwakasheya and Tim Turner of St. Joseph's Theological College for access to their property and on-going support with the control. Various ISP staff members are thanked for their assistance in this project. We also wish to extend our gratitude to the BIR reviewers, Dr. Vadim E. Panov, Dr. Mihai Serban Proches and the anonymous reviewer who made valuable suggestions for improvement of this manuscript.

References

Adair R, Cheal D, White M (2008) Advisory list of environmental weeds in aquatic habitats of Victoria. Available at http://pandora.nla.gov.au/pan/138724/20130212-1309/Advisory%20list%20environmental%20weeds%20aquatic%20habitats.pdf

Aston HI (1973) Aquatic Plants of Australia. Melbourne University Press, Victoria, 368 pp

Aston HI, Jacobs SWL (1980) *Hydrocleys nymphoides* (Butomaceae) in Australia. *Muelleria* 4 (3): 285–293

Champion PD, de Winton, MD, Clayton JS (2014) A risk assessment based proactive management strategy for aquatic weeds in New Zealand. *Management of Biological Invasions* 5: 233–240, http://dx.doi.org/10.3391/mbi.2014.5.3.06

Emert S, Clapp L (1998) Gardener's Companion to Weeds. Lansdowne publishing. Australia, 240 pp

GBIF (2014) Recommended practices for citation of the data published through the GBIF Network. Version 1.0 (Authored by Vishwas Chavan), Copenhagen: Global Biodiversity Information Facility, pp 12, ISBN: 87-92020-36-4, http://links.gbif.org/gbif_best_practice_data_citation_en_v1

Gorham P (2008) Aquatic weed management in waterways and dams.prime fact 30. Noxious Plants, NSW DPI. Richmond

Gordon DR, Gantz CA (2011) Risk assessment for invasiveness differs for aquatic and terrestrial plant species. *Biological Invasions* 13: 1829–1842, http://dx.doi.org/10.1007/s10530-011-0002-2

Gordon DR, Gantz CA, Jerde CL, Chadderton WL, Keller RP, Champion PD (2012) Weed Risk Assessment for Aquatic Plants: Modification of a New Zealand System for the United States. *PLoS ONE* 7(7): e40031, http://dx.doi.org/10.1371/journal.pone.0040031

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) The WorldClim interpolated global terrestrial climate surfaces, version 1.3. Available at http://biogeo.berkeley.edu/

Hosking JR, Conn BJ, Lepschi BJ, Barker CH (2005) Plant species first recognized as naturalised or naturalising for New South Wales in 2004–05. Cunninghamia 12. Australia. Collingwood, 89–90 pp

Howard GW, Chege FW (2007) Invasions by plants in the inland waters and wetlands of Africa. Springer Netherlands, pp 193–208, http://dx.doi.org/10.1007/978-1-4020-6029-8

Pheloung PC, Williams PA, Halloy SR (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57: 239–251, http://dx.doi.org/10.1006/jema.1999.0297

Richardson DM, van Wilgen BW (2004) Invasive alien plants in South Africa. How well do we understand the ecological impacts? *South African Journal of Science* 100: 45–52

Smith AC (1979) Flora Vitiensis Nova. A New Flora of Fiji. Vol. 1. Pacific Tropical Botanical Garden: Hawaii, http://dx.doi.org/10.5962/bhl.title.44033

South African Department of Environmental Affairs (2014) National Environmental Management: Biodiversity Act 2004 (Act No. 10 of 2004) Alien and Invasive Species Lists, 2014. Government Gazette of South Africa, Pretoria. Vol. 599 Issue 37886, pp 3–80

Stephens KM, Dowling RM (2002) Wetland Plants of Queensland, A Field Guide. CSIRO, 46 pages

Sullivan JJ, Hutchison M (2010) Pest impact assessment and cost-benefit analysis for the proposed Bay of Plenty Regional Pest Management Strategy. Lincoln University. New Zealand, pp 174–175

Van Wilgen BW, de Lange WJ (2011) The costs and benefits of biological control of invasive alien plants in South Africa. Centre for Invasion Biology, CSIR Natural Resources and the Environment, P.O. Box 320, Stellenbosch, 7599 South Africa, pp 47–50

Williams PA (2008) Biological success and weediness of existing terrestrial pest plants and aquatic weeds in Northland. Land Care Research. New Zealand ltd 2008, pp 51–52

Wilson JRU, Ivey P, Manyama P, Nänni I (2013) A new national unit for invasive species detection, assessment and eradication planning. *South African Journal of Science* 109 (5/6): Art. #0111, http://dx.doi.org/10.1590/sajs.2013/20120111

Supplementary material

The following supplementary material is available for this article:

Table S1. Details of surveys conducted by Rhodes University in water bodies in South Africa.

Table S2. Australian Weed Risk Assessment used for *H. nymphoides* in South Africa.

Table S3. Details of water bodies surveyed surrounding St Joseph's dam within a radius of 20 kms.

Figure S1. Sites surveyed at a national scale annually by Rhodes University in South Africa to assess water weeds invasion.

Figure S2. Awareness raising pamphlet on *H. nymphoides*.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2016/Supplements/BIR_2016_Nxumalo_etal_Supplement.xls