BioInvasions Records (2022) Volume 11, Issue 4: 1011–1018

Rapid Communication

# Into Africa: *Salvinia minima* Baker (Salviniaceae) invades South Africa

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**Citation:** Coetzee JA, Paper MK, Miller BE, Kinsler D, Cilliers CJ, Hill MP (2022) Into Africa: *Salvinia minima* Baker (Salviniaceae) invades South Africa. *BioInvasions Records* 11(4): 1011–1018, https://doi.org/10.3391/bir.2022.11.4.19

**Received:** 1 April 2022
**Accepted:** 2 June 2022
**Published:** 3 October 2022

**Handling editor:** Tatenda Dalu
**Thematic editor:** Karolina Bącela-Spychalska



## Abstract

*Salvinia minima* Baker (Salviniaceae) has been recorded for the first time in Africa. This South American native macrophyte is highly invasive and damaging, costing millions of dollars to control in the USA, and has the potential to invade many of southern Africa's waterbodies. Field surveys have confirmed the presence of *S. minima* from four sites in South Africa, with the largest invasion occurring on the highly polluted Hartbeespoort Dam, north east of the country's capital. *Salvinia minima* has been targeted for biological control in South Africa, using the weevil, *Cyrtobagous salviniae*, which is undergoing host specificity testing under quarantine conditions.

**Key words:** common salvinia, macrophyte, management, biological control, *Cyrtobagous salviniae*

## Introduction

A previously unrecorded alien species of *Salvinia* was discovered in South Africa at the Hartbeespoort Dam, North-West Province. The discovery was made in December 2011 by retired Agricultural Research Council (ARC-PHP) entomologist and biocontrol scientist, Dr Carina Cilliers, while undertaking zooplankton studies of water samples from the dam (Henderson 2012). It was confirmed that the Hartbeespoort Dam plants were neither *Salvinia molesta* D. Mitch (giant salvinia), which has long been invasive in southern Africa, nor *Salvinia hastata* Desv., which is indigenous to east and west Africa (Henderson 2012). The species was subsequently identified as *Salvinia minima* Baker (Salviniaceae) (common salvinia), native to Mexico through Meso-America to northern Argentina, but highly invasive in the southern USA (Tewari and Johnson 2011).

### *Biology of* Salvinia minima

*Salvinia minima* is a small, rootless aquatic fern with round floating leaves ~ .5–2 cm in diameter and a distinctive rib creating a bowl-shaped appearance. The adaxial leaf surface contains trichome hairs with a single stalk that divides

**Figure 1.** *Salvinia minima* Baker (Salviniaceae), common salvinia, showing the trichome hairs with a single stalk that divide into four branches. Photo credit: David Taylor, Centre for Biological Control.

into four branches, a diagnostic feature of the species (Nauman 1993) (Figure 1). Below the water surface, leaves are modified to act as a root system for the plant. The plant reproduces via fragmentation from attachment nodes, with up to 5 lateral buds per node, while spores are sterile (Jacono et al. 2001). Rapid expansion has been recorded, with populations doubling every two weeks in the wild, and under ideal greenhouse conditions, the plant can double every five to six days depending on nutrient load (Al-Hamdani and Sirna 2008). Small ponds have been completely covered with this weed in as little as six weeks after introduction.

*Salvinia minima* thrives in slightly acidic, high nutrient, slow-moving freshwater. It can be found in streams, lakes, ponds, ditches, and even rice fields. It is also resistant to periods of low temperature, water-stress, and elevated pH levels (Olguín et al. 2002).

## *Impact of* Salvinia minima

S*alvinia minima,* much like its better-known congener *S. molesta,* becomes problematic when uncontrolled, affecting both human health, recreational economies and ecosystem function (Chow et al. 1955; Ramachandran 1960; Montz 1989; Lounibos et al. 1990; Tewari and Johnson 2011). Persistent mats of *Salvinia* spp. provide an ideal habitat for vectors of disease, allowing for the spread of West Nile Virus, St. Louis Encephalitis and Venezuelan Equine Encephalitis (Chow et al. 1955; Room et al. 1989; Lounibos et al. 1990; Ramachandran 1960).

In the USA, *S. minima* infestations significantly impact local economies as dense mats clog irrigation systems and water intakes, negatively impact

fisheries, interfere with power production and affect recreational activities and tourism (Jacono 2001; Madeira et al. 2003; Tewari and Johnson 2011). In South Africa, the Hartbeespoort Dam's main revenue-generating sector is tourism and property development (Long and Hoogendoorn 2013), so the impact of *S. minima* on this system is likely to be significant.

The rapid growth of *S. minima* can cover whole waterways, creating monospecific mats which cause similar problems to other invasive floating macrophytes (Coetzee and Hill 2020; Motitsoe et al. 2020). *Salvinia minima* is a highly competitive floating aquatic plant, easily outcompeting other species in regions where it is considered naturalised (Dickinson and Miller 1998; Tipping et al. 2009). *Salvinia minima* was the dominant competitor in experimental sites during Florida's summer months, able to effectively outcompete other floating aquatic species such as *Azolla caroliniana* and *Spirodela punctata* (Dickinson and Miller 1998), while in Louisiana, *S. minima* biomass reached as high as 1.02 $kg.m^{-2}$, reducing native plant abundance (Walley 2007). The competitive ability of invasive *Salvinia* spp. negatively impacts native animals and plants by significantly altering aquatic habitats and, therefore, ecosystem structure and function (Tipping et al. 2009).

Here we document for the first time the establishment and spread of *S. minima* in southern Africa, calling for further surveys throughout the region's freshawater systems in an attempt to mitigate spread of this highly invasive species.

## Materials and methods

### *Recording* Salvinia minima *in South Africa*

Post-release evaluations of biological control programmes on floating aquatic weeds have been ongoing in South Africa since the mid-1990s, where the status of infestations and their control are documented (Martin et al. 2018). New invasive species are recorded as part of these country-wide surveys (Coetzee et al. 2021). We surveyed dams in reasonable proximity to Hartbeespoort Dam from where *S. minima* was already recorded, and documented its presence where found. *Salvinia* spp. were identified as *S. minima* by confirming the presence of diagnostic trichome hairs with a single stalk that divides into four branches, using a hand lens (×10 mag). Locations were plotted on a map of South Africa with QGIS version 3.22.3.

### *Measuring changes in* Salvinia minima *cover at Hartbeespoort Dam*

The significant extent of *S. minima* on Hartbeespoort Dam allowed its cover to be estimated with remote sensing methods. With Google Earth Engine software, the aquatic macrophyte cover from September 2020 to January 2022 was observed with Sentinel-2 MultiSpectral Instrument (MSI) satellite imagery at a 10-metre pixel resolution. The floating mats were classed with a K-means algorithm, with a mean difference of 0.84 and a

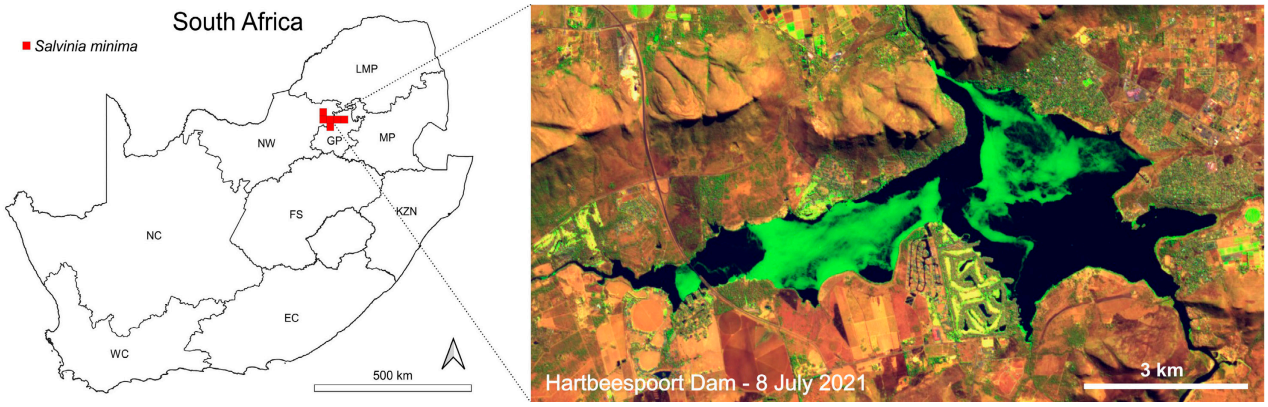


**Figure 2.** Distribution of *Salvinia minima* in South Africa; and Sentinel 2 satellite image of Hartbeespoort Dam, North West Province, South Africa, on 8 July 2021, highlighting the *Salvinia minima* infestation in green. Map created with QGIS version 3.22.3.

standard deviation of 2.84 between the observed and predicted cover percentages. An imaging frequency of < 5 days, combined with the cloud computing resources of Google Earth Engine enabled a detailed time series to be produced. Due to sub-pixel mixing between *S. minima* and *Pontederia* (=*Eichhornia*) *crassipes* Mart. (Pontederiaceae), another invader on this system, during this period, the cover of *S. minima* could not be measured absolutely.

## Results and discussion

### *Distribution of* Salvinia minima

*Salvinia minima* is native to Central and South America (Mickel and Beitel 1988; Stolze 1983) but has been introduced to the southern USA (Jacono 2001), Bermuda (Weatherby 1937), Puerto Rico and Cuba (Liogier and Martorell 2000), Spain (Lawalrée 1964), and now South Africa. South African freshwater systems have experienced invasion by invasive aquatic weed species since the early 1900s (Hill et al. 2020), and most of the floating species are now under effective biological control (Coetzee et al. 2021).

While the first record of *S. minima* in South Africa was made in 2011, from Hartbeespoort Dam, the actual date of its introduction into South Africa, and Hartbeespoort Dam, is unknown. Given its mode of introduction elsewhere, it likely arrived through the aquarium trade (Martin and Coetzee 2011). Records of *S. minima* were limited to Hartbeespoort Dam and ponds on housing estates around the dam, until 2021, when surveys in the region confirmed its presence downstream of the impoundment on the Crocodile River in Roodekoppies Dam, and on two unconnected systems, the Bon Accord and Roodeplaat dams (Figure 2). The spread to these two unconnected systems is likely through the movement of pleasure craft and equipment used by recreational anglers and boaters, a common mode of spread of aquatic invasives (Coetzee et al. 2009).

Hartbeespoort Dam is also invaded by water hyacinth, *Pontederia crassipes*, but is currently under biological control following its resurgence

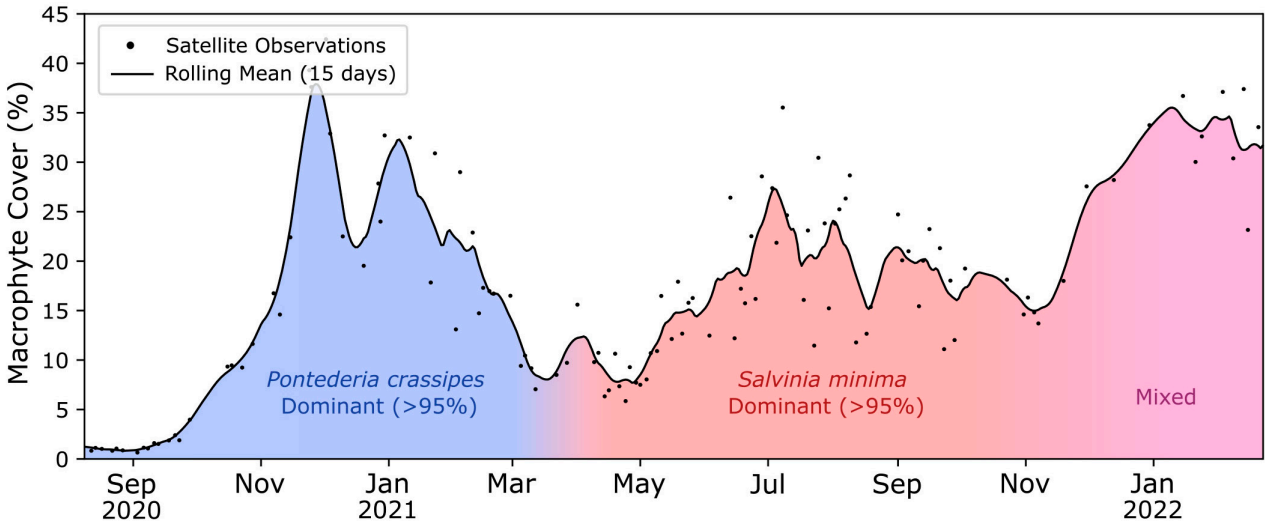


**Figure 3.** Time-series of macrophyte (*Pontederia crassipes* and *Salvinia minima*) cover on Hartbeespoort Dam, derived from Sentinel-1 and Sentinel-2 satellite data.

each spring from seed germination (Coetzee et al. *in review*). *Salvinia minima* cover rapidly increased following the reduction in *P. crassipes* in late Autumn (May 2021) to a maximum of 38% cover (692 hectares) in midwinter, July 2021 (Figure 3). The major increase in cover prevented recreational users and subsistence fishermen from accessing the dam, with some reports of plant fragments damaging boat engines or preventing the passage of boat traffic (*pers. obs.*). Cover fluctuated over the following spring (September–November 2021), whereafter *P. crassipes* became the dominant invader on the system as a result of seed germination (Figure 3). The competitive interactions and dynamics between these two species are unknown but are the current subject of investigation.

### *Legislation*

To address alien plant invasions, South Africa developed legislation related to their management under the National Environmental Management Biodiversity Act (Act 10 of 2004) (hereafter referred to as NEMBA) (Bennett and Van Sittert 2019; NEMBA 2014). The regulations under this legislation list 379 alien plant species that require management in some form, depending on their threat – 367 on mainland South Africa and a further 12 species which are restricted to the sub-Antarctic Island Protectorates (NEMBA 2014). These species are grouped into four categories, depending on whether the species requires compulsory control (Category 1a and 1b), permitting (Category 2) or containment (Category 3) (Cronin et al. 2017). *Salvinia minima* is a listed Category 1b species, requiring it to be controlled.

### *Control of* Salvinia minima

In the USA, control options for *S. minima* include chemical control, mechanical control, and biological control, all of which are potential options for South Africa. However, chemical control is non-selective and expensive

(Tewari and Johnson 2011), while mechanical control is not feasible as fragmentation of plants results in additional vegetative growth, and removal by hand is impossible in most areas. Classical biological control programmes using a weevil, the *S. minima* biotype of *Cyrtobagous salviniae* Calder and Sands (Coleoptera: Curculionidae), has reduced the vigour of *S. minima* at several sites in Louisiana (Parys and Johnson 2013) and Florida (Tipping et al. 2012), showing promise for control if released in South Africa. Adult *C. salviniae* feed on the buds and young leaves of *S. minima*, damaging the meristems, while the larvae tunnel in the rhizomes causing necrosis (Parys and Johnson 2013).

Although *S. minima* is still only known from a few sites in South Africa, it is not an appropriate target for eradication due to the extent of the infestation at these sites, and the small size of the plants. It is also likely that it will spread beyond the four systems from which it is now known. Therefore, it is the target of a biological control programme in South Africa, where the common salvinia biotype of *C. salviniae* has been introduced into quarantine and is undergoing host specificity testing for possible release onto *S. minima*. Given the success and host specificity of the larger Brazilian biotype of *C. salviniae* released against *S. molesta* in South Africa (Martin et al. 2018), we are confident that the *S. minima* biotype will meet the requirements necessary to permit its release in South Africa in the near future. Given the impact that *S. minima* has on waterbodies in its native range, it is crucial to understand its invasion ecology in South Africa, and to implement a biological control programme while its distribution is limited to a few systems on the South African Highveld.

## Acknowledgements

We acknowledge the constructive comments provided by the anonymous reviewers and editor on previous drafts of this submission.

## Funding declaration

The Centre for Biological Control's aquatic weed programme is funded by the Department of Forestry, Fisheries and the Environment: Natural Resource Management Programme (Working for Water Programme). The South African Research Chairs Initiative of the Department of Science and Technology and the National Research Foundation of South Africa provided further funding. Any opinion, finding, conclusion or recommendation expressed in this material is that of the authors, and the National Research Foundation does not accept any liability in this regard. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Authors' contribution

J.C., M.P., B.M. and C.C. collected and identified samples from the field. D.K. analysed satellite imagery and time series of *S. minima* cover. All authors contributed to MS draft preparation and review.

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