Pontederia crassipes [Eichhornia crassipes]. © *Wolfgang Rabitsch*

The management of water hyacinth (*Eichhornia crassipes*)

Measures and associated costs

Scientific name(s)	*Pontederia crassipes* Mart. [*Eichhornia crassipes* (Mart.) Solms]
Common names (in English)	Water hyacinth
Authors	Julie Coetzee and Martin Hill
Reviewers	Giuseppe Brundu
Date of completion	25/06/2019
Citation	Coetzee, J. and Hill, M.2019. Information on measures and related costs in relation to species included on the Union list – *Pontederia crassipes* [*Eichhornia crassipes*]. Technical note prepared by IUCN for the European Commission.

Table of contents

Common names

BG	Воден зюмбюл
HR	Vodeni zumbul
CZ	Tokozelka vodní hyacint
DA	Tykstilket vandhyacint
NL	Waterhyacint
EN	Water hyacinth
ET	Harilik vesihüatsint
FI	Kellusvesihyasintti
FR	Jacinthe d'eau
DE	Wasserhyazinthe
EL	Υάκινθος του νερού
HU	Közönséges vízijácint
IE	–
IT	Giacinto d'acqua
LV	Resnkātu ūdenshiacinte
LT	Paprastoji eichornija
MT	Wardet in-Nil
PL	Eichornia gruboogonkowa
PT	Jacinto-d'água
RO	Zambilă de apă
SK	Eichhornia nafúknutá
SL	Vodna hijacinta
ES	Jacinto de agua
SV	Vattenhyacint

Summary of the measures, emphasizing the most cost-effective options.

Pontederia crassipes Mart. [≡*Eichhornia crassipes* (Mart.) Solms]., hereafter referred to as water hyacinth, remains the most pervasive and damaging aquatic weed worldwide (Coetzee *et al.*, 2017). Water hyacinth is a free-floating aquatic macrophyte, which reproduces both vegetatively through daughter plant (ramet) production and sexually via seeds (Penfound and Earle, 1948), which can remain viable in seedbanks for up to 20 years (Gopal, 1987). It is the only floating species in the genus *Pontederia* and it is the only species within this group to have become invasive.

Water hyacinth is native to tropical South America, its centre of origin is Amazonia, Brazil, with anthropogenic spread to areas such as Argentina, Venezuela and central South America and the Caribbean islands (Barrett and Forno, 1982; Edwards and Musil, 1975; Penfound and Earle, 1948). Water hyacinth has been spread throughout the world and occurs on every continent except Antarctica, in more than 50 countries, as the result of anthropogenic spread. Its distribution is largely restricted by cold winter temperatures to between 40°N and S, while it occurs abundantly in tropical freshwater bodies around the world. The plant thrives in eutrophic waters, which are typical of many European water bodies, and established populations in the EU occur in Portugal, Spain, Italy and France (Q-Bank Invasive Plants, 2017). In the Paúl do Boquilobo Biosphere Reserve in Central Portugal, it forms dense floating mats over extensive areas of wetlands and is considered the most obvious threat to the ecosystem. It is a permanent but controlled invasive aquatic weed in the irrigation canals, rice fields and riverine habitats of the Sado and Soraia River Basins, near Lisbon and the Atlantic Ocean, (Ruiz Téllez *et al.*, 2008). The plant is also recorded as a casual invasive in Asturias, Huelva, Málaga, Cáceres, Taragona, Castellón, Alicante (Ruiz Téllez *et al.*, 2008) and Valencia (Peña Bretón and de la Cruz, 2014) in Spain. In 2005, it was reported to cover 75 km (approximately 200 ha) of the Guadiana River in the South Western Iberian Peninsula (Ruiz Téllez *et al.*, 2008), which has since increased in extent to the Spain–Portugal border (Ruiz Téllez *et al.*, 2016). There are also recent records of its invasion in Italy in Sardinia and Lazio (Brundu *et al.*, 2012), while in other parts of the country (Campania, Tuscany, Sicily, Veneto), it is considered a casual alien (Brundu *et al.*, 2013). In France, the species is only naturalised in Corsica and has not spread (Tison and de Foucault, 2014). In mainland France, the species has been increasingly recorded as escaped in the wild, in the west, the south-west, the Mediterranean region, and more rarely elsewhere (for example Georges and Pax, 2002), but populations cannot tolerate continental winters (Fried, 2017). In addition, it is recorded as a casual in several European countries with temperate climates, for example Belgium (Verloove, 2006), Germany (Buttler and Mitarbeiter, 2017), the Netherlands, the U.K. (Q-Bank Invasive Plants, 2017) and the Czech Republic (Kaplan *et al.*, 2016; Pyšek *et al.*, 2012). The species is also known to occur in thermally abnormal waters in Russia and Germany, for example the River Erft (Hussner and Lösch, 2005), where it would normally be excluded due to cold winter temperatures. Prolonged cold weather may kill plants, but the seeds remain viable (Ueki and Oki, 1979) and allow regeneration when favourable conditions return. For these reasons, water hyacinth's invasive range is restricted to the warmer Mediterranean regions in Europe, in Portugal, Spain, Italy and Corsica (France). However, according to future climate change projections, the greatest potential for future range expansion lies in Europe. Countries at the greatest risk include Albania, Algeria, Bosnia and Herzegovina, Croatia, France (including Corsica), Greece, Israel, Italy (including Sardinia, Sicilia), Jordan, Montenegro, Portugal (including Azores and Madeira), Slovenia, Spain (including Baleares and Canary Islands), Turkey and Tunisia (Kriticos and Brunel, 2016).

PREVENTION

The species only realistic pathway of introduction into the EU is through horticultural trade, which is now banned under Regulation (EU) 1143/2014 on invasive alien species. Import inspections looking for water hyacinth as a contaminant of other traded aquatic plants, and as a contaminant with the movement of boats and other used aquatic leisure equipment into the EU could reduce the risk of the species being unintentionally introduced, however the likelihood of the species being introduced along these pathways is considered to be low.

SECONDARY SPREAD

The species can be accidently spread by human activities, but again due to the conspicuous nature of the plant this is considered a low risk. A public awareness campaign, targeting improving biosecurity practices around the movement of aquatic leisure equipment to prevent the spread of aquatic plants and animals in general is recommended. The use of floating booms can contain the floating water hyacinth plants and prevent them from spreading downstream, however it will not stop the transport of seeds.

SURVEILLANCE

As a large floating conspicuous macrophyte, the species is easy to identify, making it suitable for incorporating into citizen science programmes. This should be combined with active monitoring of high risk sites (for example river systems with known populations upstream in other countries).

RAPID ERADICATION

Manual removal by hand can be used to eradicate small infestations. For larger infestations, eradication can be potentially achieved with the use of mechanical harvesters to remove the bulk of the biomass, but then hand control will still be required for shallow and other inaccessible areas. However, mechanical control is expensive. Herbicides can also be used and could potentially eradicate new infestations. For any eradication attempt it is critical to plan long term monitoring (for up to 20 years) and repeated follow up treatments, as seeds can remain viable for 20 years.

MANAGEMENT

Unfortunately, this plant is well adapted to surviving the many procedures that have been used for aquatic weed management such as the removal or killing of plants, draw down or flushing downstream. Attempts to eradicate the species have largely failed, and control options are limited. Hand control and mechanical harvesters can be used to control the species, mostly with the aim of biomass removal, however due to the very high growth rate of the species, this usually has limited applicability. Chemical control can be effectively used in small contained systems. Biological control has been applied to water hyacinth in 33 countries so far, and is considered to be the most economical and sustainable method of control (up to 80–90% reduction of surface area coverage) in tropical countries, but has not been as effective in temperate countries. However it is the implementation of an integrated control and adaptive management plan that is likely to be the most effective. This involves using a combination of the control strategies mentioned above to put greater pressure on the weed, or to treat the weed according to the conditions in different stages of an infestation.

Much of what is outlined below also applies to other invasive alien aquatic macrophyte species in the European Union and would have been covered in the Technical and Scientific Support Documents to the IUCN on species such as water lettuce (*Pistia stratiotes*) (Hussner, 2017) and giant salvinia (*Salvinia molesta*) (Hill, 2017).

Measures for preventing the species being introduced, intentionally and unintentionally.

This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

A ban on importing (pre-border measure), selling, breeding, growing, and cultivation, as required under Article 7 of the IAS Regulation, targeting intentional introduction of plants and propagules of *E. crassipes*.

MEASURE DESCRIPTION

As the species is listed as an invasive alien species of Union concern, the following measures will automatically apply, in accordance with Article 7 of the EU IAS Regulation 1143/2014:

Invasive alien species of Union concern shall not be intentionally:

(a) brought into the territory of the Union, including transit under customs supervision;
(b) kept, including in contained holding;
(c) bred, including in contained holding;
(d) transported to, from or within the Union, except for the transportation of species to facilities in the context of eradication;
(e) placed on the market;
(f) used or exchanged;
(g) permitted to reproduce, grown or cultivated, including in contained holding; or
(h) released into the environment.

Also note that, in accordance with Article 15(1) – As of 2 January 2016, Member States should have in place fully functioning structures to carry out the official controls necessary to prevent the intentional introduction into the Union of invasive alien species of Union concern. Those official controls shall apply to the categories of goods falling within the Combined Nomenclature codes to which a reference is made in the Union list, pursuant to Article 4(5).

Therefore measures for the prevention of intentional introductions do not need to be discussed further in this technical note.

Border inspections.

MEASURE DESCRIPTION

Water hyacinth is an aquatic macrophyte and thus has very specific environmental requirements in that it has to remain moist. Therefore, the likelihood of introduction of this species as a contaminant of plants for planting is low. In addition, according to Maki and Galatowitsch (2004), water hyacinth has not been found as a contaminant of other traded aquatic plants. They considered that contaminants are usually vegetative parts of aquatic plants, which is very unlikely for water hyacinth since daughter plants are big, and seeds would have to be introduced through sediments. Although the risk of water hyacinth being introduced unintentionally as a contaminant of commodities is low, border surveillance, in particular at large ports, could reduce the risk of the species being unintentionally introduced via this pathway.

SCALE OF APPLICATION

This measure would have to be applied across the entire region (in this case the European Union), as once established, the plant will move between countries through shared waterways.

EFFECTIVENESS OF MEASURE

Unknown.

There are no data on this plant having being introduced as a contaminant of commodities.

EFFORT REQUIRED

Border controls need to be implemented in the long-term and form a standard part of the phytosanitary advocacy of border controls.

RESOURCES REQUIRED

No additional staff are required, other than those already in place at borders to the EU for phytosanitary pest detection.

SIDE EFFECTS

Environmental: Neutral or mixed

Social: Neutral or mixed

Economic: Neutral or mixed

There are no known potential side effects from this measure.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Prevention of unintended introductions and movement of water hyacinth is far more cost-effective than inaction or management once the weed has established (see sections below).

ADDITIONAL COST INFORMATION

Although there are no data available on this, this will require initial and periodic follow up training of border biosecurity staff.

LEVEL OF CONFIDENCE[1]

Inconclusive.

As there are no studies on water hyacinth entering a region as a contaminant of traded commodities, the level of confidence here is low.

1 See Appendix

Biosecurity standards.

MEASURE DESCRIPTION

The introduction of water hyacinth as a contaminant of leisure equipment (hitchhiking on boats and boat trailers and in holds of leisure craft) is considered to be low because of the conspicuous nature of the plant (EPPO PRA EICCR). There is no published evidence that this weed has been spread through seeds on leisure equipment. Therefore the introduction of import standards (the issuing of an import permit once biosecurity procedures are followed) for the cleaning of high risk equipment that may carry the species will help reduce this risk. This measure could be applied at an EU level, such as for the import of equipment from outside the EU into an EU Member State, but also at an individual Member State level where national policies could implement such procedures. As equipment can move freely between Member States once inside the EU, such national policies would greatly benefit from public awareness campaigns, as discussed in the section below.

An example is the Government of Botswana that gazetted the Aquatic Weed (Control) Act in 1971 (implemented 24th October 1986), which regulates “the Inspection, Movement and Importation of boats and aquatic apparatus, and fishing gear, to prevent the importation and spread of aquatic weeds”. The government specifies inspection and disinfection procedures for boats and aquatic apparatus and they are checked and/or treated before entering the country. Import for boats from outside the country should carry import permits. Any person found with a boat without import permit, registration number, herbicide treatment, shall be guilty and upon conviction be “liable to a fine of US$ 100.00 and/or imprisonment for 12 months or to both” (Kurugundla *et al.*, 2016).

SCALE OF APPLICATION

This measure would have to be applied at an EU level, especially land borders with non-EU states, as once established the plant will move between countries through shared waterways (see below). The measure could also be applied at a national Member State level.

EFFECTIVENESS OF MEASURE

Unknown.

Although not a prominent pathway for the unintentional introduction of water hyacinth, the species has not yet established in Botswana, but it is difficult to ascribe its

Pontederia crassipes [Eichhornia crassipes]. © *Wolfgang Rabitsch*

lack of presence with the Aquatic Weed (Control) Act in this country (where it was combined with a public awareness campaign).The effectiveness of the measure to prevent the accidental, or unintentional introduction of water hyacinth to an EU member state where it is not yet present will rely on aspects such as the level of education of the relevant authorities (particularly at the border control) (Champion *et al.*, 2010).

EFFORT REQUIRED

The measure would need to be in place permanently.

RESOURCES REQUIRED

Biosecurity capacity already exists across the EU, but training and resources may be required for those involved in the inspections.

SIDE EFFECTS

Environmental: Positive
Social: Negative
Economic: Negative

This measure would address other aquatic plants and animals that may be introduced via the same pathway. The measure could have negative social and economic impacts if applied at individual EU MS level, where recreational boat users moving boats and equipment across EU MS borders, would be affected.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

As this is seen as an unlikely pathway of introduction for the species, some implementing authorities and importers (especially those in MS where the establishment of water hyacinth is a low risk) may find the costs of implementing the measure unacceptable. However if this measure was implemented to target the pathway as a whole, and not just on water hyacinth, it may be seen as acceptable.

ADDITIONAL COST INFORMATION

No additional information.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

While there is evidence regarding the procedures to reduce the risk of importing aquatic plants as a hitchhiker with boats and equipment, there is little information on the effectiveness of the measure being applied though national legislation in association with imports.

1 See Appendix

Measures to prevent the species spreading once they have been introduced.

Public awareness campaigns.

MEASURE DESCRIPTION

Once introduced into a freshwater ecosystem, water hyacinth can be accidentally dispersed by human activities during maintenance of swimming areas, attached to fishing gear or to the hulls, anchor lines, engines, or other parts of boats. Moreover, existing practices of mechanical waterway maintenance tend to cut off plants and spread the fragments. However, the secondary spread of water hyacinth as a contaminant of leisure equipment (hitchhiking on boats and boat trailers and in holds of leisure craft) is considered low because of the conspicuous nature of the plant (EPPO PRA EICCR). There is no published evidence that this weed has been spread through seeds on leisure equipment.

This measure is similar to that above, in that the biosecurity procedures to be recommended will be similar to those required to address unintentional introductions via the import of boats and equipment. However, this measure focuses on improving public (key stakeholder groups) awareness and practices within Member States to reduce the risk of spreading the species when they move boats or equipment between different bodies of water especially where there are established populations of water hyacinth.

Such public awareness campaigns already exist, for example the “Check, Clean and Dry” and “Be Plant Wise” campaigns in the UK and other regional information portals (EUBARnet, 2013). Similar “Clean, Drain and Dry” campaigns have been employed in the USA (Stop Aquatic Hitchhikers), and Canada (British Columbia) to increase awareness of this potential pathway.

SCALE OF APPLICATION

This measure would have to be applied across the entire region within the EU where the water hyacinth is already established, and ideally in areas adjacent to them and where the species could establish. However, while this measure is being discussed in the context of water hyacinth, it would address other aquatic invasive alien species spread via the same pathway and therefore it is recommended that it be applied at an EU level.

EFFECTIVENESS OF MEASURE

Effective.

Although not a prominent pathway for the secondary spread of water hyacinth, the public awareness campaign targeting contamination of leisure craft and other aquatic vehicles has been highly successful, especially in Botswana (Kurugundla *et al.*, 2016).The Check Clean Dry (CCD) campaign in the UK, led to a 9% increase in the numbers of general public in the Broads following the recommended biosecurity procedures (Burchnall, 2013), and 14% increase in high risk user compliance. In addition, a study on anglers and canoeists in the UK found that those who had heard of the CCD campaign exhibited biosecurity hazard scores that were 40% lower than those who had not (Anderson *et al.*, 2014).

EFFORT REQUIRED

The implementing measures to prevent the unintentional human mediated secondary spread of water hyacinth will rely on the implementation of stakeholder engagement and awareness raising campaigns in the long-term (Hill and Coetzee, 2008).

RESOURCES REQUIRED

The costs of generating a public awareness campaign and implementing the cleaning of water-craft and trailers are relatively low compared to the costs of managing established water hyacinth infestations. Whilst very little data are available on the costs of these programmes, the initial start-up costs of the Stop Aquatic Hitchhikers in 2002 were USD 120,000 (ca. EUR 105,000) but relied heavily on volunteerism, and over the campaigns 13 year lifespan additional USD 130,000 (ca. EUR 114,000) were provided (according to an undated US Department of the Interior summary document). The cost of the Check, Clean, Dry campaign interventions in New Zealand from 2005 to 2008 was NZ$4.5 million (ca. EUR 2.6 million)(according to an undated National Social Marketing Centre case study).

Fortunately much of the information on the negative impacts of water hyacinth is published in open access journals and thus easy to access (for example Villamagna and Murphy, 2010), as well as the EPPO PRA EICCR.

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Neutral or mixed

This is a common pathway of secondary spread for many aquatic invasive species, which this measure would address and not just water hyacinth. There will be some social (recreational) and economic effects of the measure in relation to its implementation but these are not considered significant.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Key stakeholder groups such as water authorities, conservation officers, fishing community and recreational boaters should be receptive to these campaigns, as have been shown in the UK.

ADDITIONAL COST INFORMATION

Campaigns such as the “Check, Clean, Dry” campaign through the Great Britain Non-native Species Secretariat is already in place and thus could be rolled out to the entire EU at very little extra cost.

The prevention of unintended introductions and movement of water hyacinth is far more cost-effective than inaction or management once the weed has established (see below). An Economic Impact Assessment (EIA) of the Check, Clean, Dry campaign in New Zealand in March 2006 projected that as a result of the North Island staying free of the diatom, *Didymosphenia geminate*, the cost-saving to New Zealand was an estimated NZ$11 million (ca. EUR 6.4 million) up to June 2008. Therefore the cost-saving to New Zealand by delaying the spread of this species to the North Island is estimated to be NZ$2.15 (ca. EUR 1.25) for every NZ$1 (ca. EUR 0.58) spent on the campaign (according to an undated National Social Marketing Centre case study).

LEVEL OF CONFIDENCE[1]

Well established.

The public awareness campaigns to prevent the human mediated secondary spread of invasive aquatic plants, including water hyacinth have been implemented in for example New Zealand (Check, Clean, Dry campaign) and the US (Stop Aquatic Hitchhikers) with good success.

1 See Appendix

Containment of non-human mediated secondary spread.

MEASURE DESCRIPTION

Once established water hyacinth has the potential to spread (floating form of the plant) within water bodies via movement downstream, through irrigation schemes and shared waterways; and flooding also has the potential to carry plants to new water bodies or wetland habitats (McFarland *et al.*, 2004). Wildfowl or other wetland animals could also contribute to spread, particularly for juvenile forms of the species as has been shown for other aquatic species (Green, 2016). A single water hyacinth plant can produce up to 3,000 seeds during its life span. These seeds are very small and are transported within the water column. Seeds are therefore a source of new infestation or re-invasions (Albano Pérez *et al.*, 2011).

Booms (or floating barriers, see management section below for description) can be erected with the aim to prevent secondary spread via the downstream movement of plants, and sieves can be affixed to irrigation scheme intakes (Hill and Coetzee, 2008), but there is very little that can be done to prevent seeds flowing downstream or waterfowl moving propagules between catchments, although the latter two pathways are less common (Albano Pérez *et al.*, 2011). Plant material contained by the booms can then be mechanically removed, or where appropriate, sprayed with a herbicide.

SCALE OF APPLICATION

Currently there are only a few sites infested with permanent water hyacinth infestations in the EU, including the Guadiana River in Spain, the Paúl do Boquilobo Biosphere Reserve in Portugal, and in Corsica (see summary above). Thus the implementation of containment structures such as booms and sieves will be focussed on these sites. Booms have been used to contain plants to allow for control interventions against water hyacinth on the Nseleni River in a subtropical part of South Africa. These booms spanned the width of the river up to 70m at its widest.

EFFECTIVENESS OF MEASURE

Ineffective.

Because a water hyacinth infestation can be the result of a single plant transported by a waterfowl, or through seeds in the water column, containment is largely unsuccessful once the weed gets established in an area.

Containment within a catchment, without the use of additional control measures, is impossible as propagules will continually move down the system. Sieves at the intakes of irrigation schemes and inter-basin transfer schemes will keep out whole plants, but not seeds. Further, the movement of propagules between watersheds by waterfowl is also impossible to control.

Thus it is recommended that resources should rather be allocated to early detection and eradication which relies on suitably trained staff within the relevant water and conservation authorities to detect the weed (see sections below).

EFFORT REQUIRED

The type and design of booms required to contain infestations and to prevent further spread within a system will vary depending on the size of the river and hydrological regime of the system. In small systems with low flows, fairly rudimentary booms made out of rope and some flotation device can be effective, while larger systems where the breadth of the system is >20m and flows are moderate to high, more elaborately engineered booms using metal cables of a diameter of 70mm and industrial buoys tethered to concrete blocks are required. The effort required to construct and maintain these booms will thus vary, and regular maintenance of the booms will be required, especially after flooding events.

RESOURCES REQUIRED

System specific costs depending on size of infestation and type of water body.

SIDE EFFECTS

Environmental: Negative
Social: Neutral or mixed
Economic: Neutral or mixed

The build-up of phytomass that occurs behind the booms can have negative environmental impacts, unless the measure is coupled with removal. In fact, the added advantage to this approach is that booms concentrate water hyacinth in one area that makes manual and mechanical control more efficient (Hill and Coetzee, 2008). The disadvantage of using booms to prevent downstream spread is that they will be washed away during high flows, and that the booms themselves (and the resulting phytomass) can impede navigation and transport on the river.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Water hyacinth is a highly damaging aquatic macrophyte both economically and ecologically, thus a containment strategy would be acceptable to stakeholders.

ADDITIONAL COST INFORMATION

The cost of inactivity is high. Although the potential returns on trying to control the distribution of water hyacinth within a shared catchment are low, an early warning and rapid response facility to deal with dispersal between watersheds would likely yield high returns.

LEVEL OF CONFIDENCE[1]

Unresolved.

While booms have been used as an attempt to contain the species in South Africa, there are no studies on the unintentional, non-human mediated secondary spread, and containment of water hyacinth.

1 See Appendix

Measures for early detection of the species and to run an effective surveillance system for an early detection of a new occurrence.

Active monitoring and citizen science.

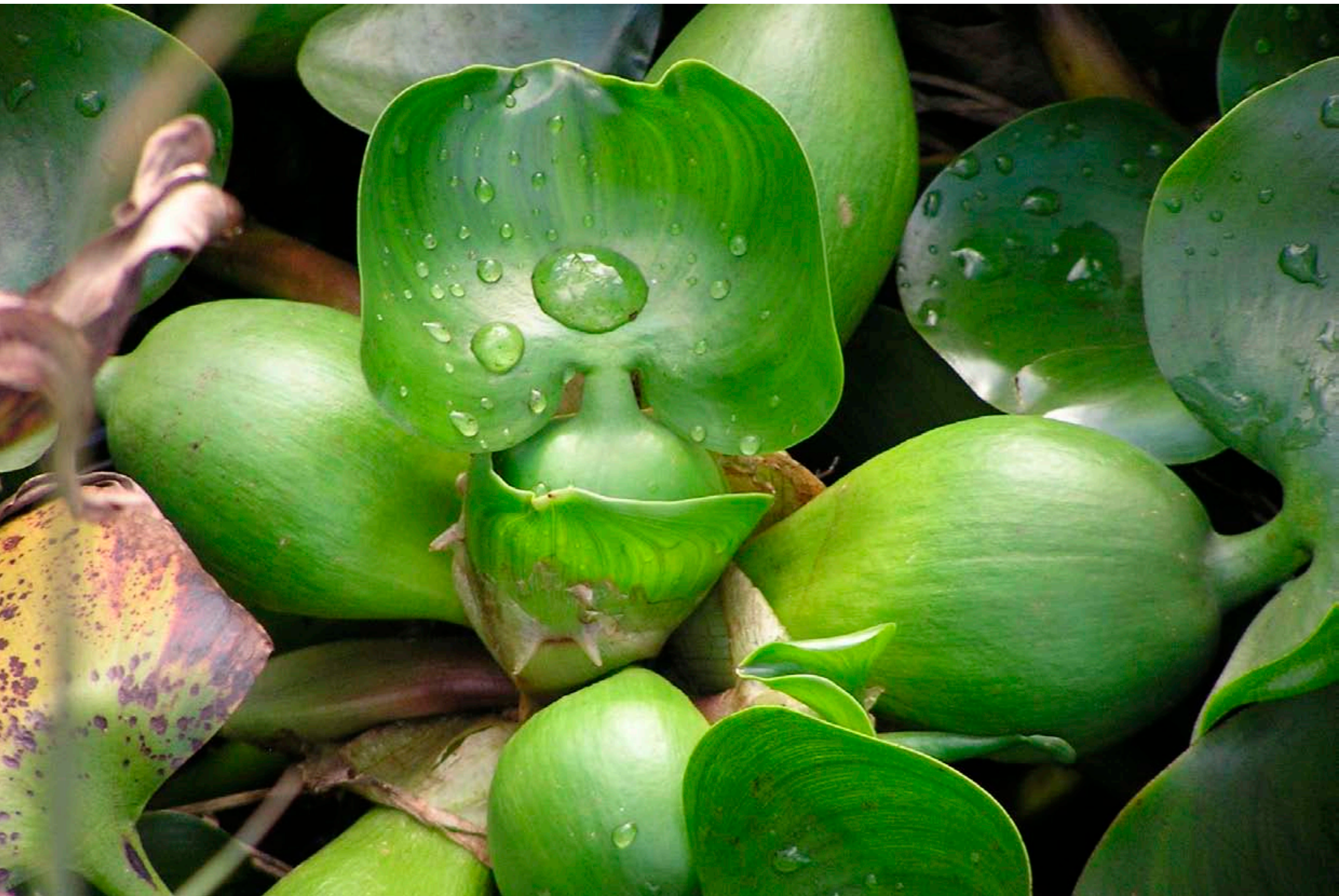
MEASURE DESCRIPTION

The early detection of invasive alien aquatic plant species is a proactive approach and is a key factor in the successful eradication of new infestations. Thus programmes centred on Early Detection and Rapid Response (EDRR) are crucial for effective management and successful eradication (Genovesi *et al.*, 2010; Hussner *et al.*, 2017). The early detection of water hyacinth (and other floating aquatic weed species) is likely to be easier than submerged species as they are more conspicuous and easier to identify.

Successful early detection relies on a well-educated trained workforce of conservationists and water resource managers (and an informed general public through citizen science) who are able to prioritise high risk sites and identify water hyacinth, and a repository to verify and store the information for the rapid response team. This should be supported by citizen science activities, and also potentially through using remote sensing technologies.

High risk sites will include those water bodies capable of support water hyacinth that are hydrologically connected to known infested areas, or close by. These will include ponds or slow-moving water bodies, and areas known to receive high levels of nutrients (such as runoff from agricultural, horticultural or industrial land).

Pontederia crassipes [Eichhornia crassipes]. © *Jean-Marc Dufour-Dror*



Thus an early detection system might include: identification and active monitoring of high risk sites, and vouchering of submitted specimens (by designated botanists), verification of suspected new local or national record of the weed (potentially through citizen science records), archival of new record(s) in designated regional and plant databases, rapid assessment of confirmed new records (by qualified scientists), and rapid response to new records (see below). Fortunately there are several identification keys for water hyacinth (for example Sainty and Jacobs, 2003). The European Alien Species Information Network (EASIN) or GISIN (Global Invasive Species Network) provide platforms for the identification, biology and impact of invasive alien species.

Remote sensing could support a surveillance system, particularly for the active monitoring of high risk sites, or sites difficult to access. New techniques such as hyperspectral remote sensing (Hestir *et al.*, 2008), can be used for the large-scale surveillance of water bodies, but require an element of ground-truthing. Hung and Sukkarieh (2013) showed that unmanned robotic aircraft (drones) fitted with a camera was effective in detecting the floating macrophyte, *S. molesta* infestations in remote areas of Australia, and a similar approach could be applicable to water hyacinth.

This measure will serve as support to early detection within Member States that that do not yet have established populations (but may be connected hydrologically to others that do) for example watersheds connected to existing populations in Spain, Portugal and Italy, but also to identify new populations within Member States. This measure must be linked to rapid eradication process referred to below.

SCALE OF APPLICATION

The scale of surveillance will vary from small impoundments of less than 1ha or section of river, to larger wetlands and entire stretches of river of many kilometres. In South Africa, surveillance of un-infested water bodies is undertaken annually on a national scale (Coetzee *et al.*, 2011).

EFFECTIVENESS OF MEASURE

Effective.

The species is a large, conspicuous, floating macrophyte and therefore relatively easy to detect and to identify making it suitable for effective professional monitoring, supported by citizen science programmes. Such a surveillance system, leading to early detection and followed by a rapid response have been documented as successful methods in the eradication of new infestations of invasive species (Anderson, 2005).

EFFORT REQUIRED

This measure would need to be in place permanently within Member States that have high risk sites. Early detection is only achievable through comprehensive and repeated monitoring. A key time for surveying high risk sites is following flooding and during spring and summer months when growth is optimal.

RESOURCES REQUIRED

Resources would require trained professional staff able to undertake active monitoring, database to store records (though this is likely to be multi-species), and remote sensing technology if being used. By developing identification keys for the public and developing data recording apps for mobiles (again likely to be multi-species and already exist in many EU Member States), the cost of monitoring can be reduced and larger areas can be surveyed via citizen science.

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Neutral or mixed

Awareness building on aquatic plant invasive species amongst the public through engagement in citizen science, is likely to lead to additional invasive species being reported.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Early detection allowing for a rapid response, and thereby eradication of water hyacinth will have the least impact on aquatic biodiversity and the utilization of the water resource. Community engagement through an area-wide awareness campaign will ensure stakeholder buy-in and acceptance of eradication and control efforts.

ADDITIONAL COST INFORMATION

The cost of inaction is considered to be high, as water hyacinth is known to have severe impacts and thus early detection followed by rapid response and possible eradication is the most cost-effective method for the control of this weed. There is no published information available on the overall costs of early detection, but while they are likely to be high, the potential return on investment in this method will be higher.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Information comes from published data in the grey literature and expert opinion.

1 See Appendix

Measures to achieve rapid eradication after an early detection of a new occurrence.

Manual ('hand') control.

MEASURE DESCRIPTION

Manual removal through hand pulling or using pitch forks, scoops, nets, shovel rakes, can be used to eradicate new, small infestations. The Environmental Planning and Climate Protection Department of South Africa have produced a water hyacinth control guidelines document that outlines the methods. This method is very labour intensive, but can be effective for small incipient infestations (Julien *et al.*, 1999). However, because water hyacinth has a long-lived seedbank, eradication may only be feasible in the initial stages of infestation prior to flowering (occurs multiple times throughout the growing season), and this should be a priority.The removal of the biomass taken from the water body and correct disposal at a suitable landfill site is essential to prevent the unsightly and odorous build-up of rotting plant material, as well as re-infestation from removed material.

Eradication measures should be promoted where feasible with a planned strategy and action plan, to include surveillance, containment, treatment and follow-up measures to assess the success of such actions.

Thus, early detection followed by prompt management action would help to eradicate water hyacinth in its initial stages within a water body.

SCALE OF APPLICATION

Manual removal of water hyacinth is limited to small water bodies, likely to be less than 1ha in size (Julien *et al.*, 1999).

EFFECTIVENESS OF MEASURE

Neutral.

Eradication via manual removal is only achievable for small infestations. There are a few cases where water hyacinth has been eradicated from small waterbodies, but generally this method is not effective as regeneration usually occurs from seeds or from plants remaining behind following removal. For example, a programme in the City of Cape Town, South Africa, targeted small infestations in the metropole, and only one of these (<1ha) remains clear (Chandre Rhoda, City of Cape Town, Pers. Comm.).One key factor in this measure effectiveness is the need for long term monitoring, if this is not implemented comprehensively the measure will likely fail as the species can regenerate from the seedbank or from plants that are missed during the removal.

However, in Europe's temperate climates, water hyacinth regeneration will be slower than in sub-tropical and tropical climates, improving the chances of successful eradication. For example, successful eradication of a small infestation of water hyacinth was achieved by hand-weeding and collecting using small hand nets in Eastern Germany (Hussner, 2017).

New Zealand also has a particularly effective eradication campaign against water hyacinth, which has been ongoing since the 1950s. Water hyacinth is one of nine National Interest Pest Response (NIPR) species that the Ministry for Primary Industries (MPI), New Zealand, has identified for either eradication or national control. MPI works closely with the regional councils and Department of Conservation on these programmes. The water hyacinth eradication programme includes containment of known infestations and physical removal to eradicate the plants. Due to the longevity of the seed, sites are monitored for a total of 20 years subsequent to no detections, to ensure elimination of the infestation (see Biosecurity New Zealand).

Given the authors past experiences with this species (and other invasive aquatic plants), eradication, even within a single system, is almost always unattainable. It seems more likely that management approaches will need to be developed that seek to reduce the extent of water hyacinth infestations to acceptable levels.

EFFORT REQUIRED

Once the removal has taken place, long-term intensive monitoring (and repeated actions) of treated sites is essential to deal with reinvasion, from missed plants and regeneration from the seedbank. In New Zealand, treated sites are monitored for 20 years post removal.

RESOURCES REQUIRED

Costs and staff will vary depending on the size and accessibility to the infestation. Waders, nets and boats are required. For all activities from boats, personal floatation devices, and skills in boat handling are mandatory for the safety of the operator. The costs for follow-up treatments can be reduced by using volunteers who are able to identify plant regrowth and eliminate these plants. Costs and machinery (for example vehicles) are also needed for the removal and disposal of plant biomass taken from the water body. Experts, and travel costs, for long term monitoring are also required.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

Environmental: This is a species-specific control measure and should have minimal negative effects on native plants if the management is carried out by skilled operators. However, the potential negative side effect of manual removal is that indigenous plants and invertebrates may be removed, and riparian zones may scoured. Thus this method may not be appropriate in sensitive areas such as protected areas.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

As manual removal has only a minor negative impact on an ecosystem, a high acceptance from stakeholders and the public are highly likely. It is important to dispose of all plant material removed from the water body to avoid unsightly and odorous build-up of rotting plant material. No impacts of manual removal on animal welfare have been reported.

ADDITIONAL COST INFORMATION

Manual removal has a relatively high labour cost per area, but the cost-effectiveness is likely to be high when eradication is achieved. Inaction will lead to the spread of the target species, increasing the management costs and reducing the likelihood of future eradication. Although manual removal does not require highly trained labour, or expensive machinery, it does require training around water safety, and the cost of this control method will thus rely entirely on the remuneration scales in a particular member state.

In Ghana, water hyacinth provided the substrate for the colonization of other species forming what are referred to as 'Sudds', some up to 1 metre in thickness and heavy (450 to >1000 kg per square metre), floating in up to 3 metres depth of water. These were effectively manually cleared at a cost of about UDS 2,000 (ca. EUR 1,756) per hectare in 1990 (de Graft Johnson, 1996).

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Information comes from limited published material (see bibliography) and grey literature, and current practices based on expert experience.

1 See Appendix

Mechanical control.

MEASURE DESCRIPTION

Mechanical control through the use of harvesters, can be used to eradicate water hyacinth with the explicit aim of complete biomass removal. There are a number of different types of mechanical harvesters, including those that destroy water hyacinth and leave it in the system and those whereby the weed is pushed to a conveyor belt and loaded onto trucks and removed from the locality. Mechanical control can remove the bulk of an infestation in accessible areas, but other control methods such as manual removal are then required for plants remaining close to edges, or in shallow or inaccessible areas (Mangas-Ramírez and Elías-Gutiérrez, 2004).

Eradication measures should be promoted where feasible with a planned strategy to include surveillance, containment, treatment and follow-up measures to assess the success of such actions.

SCALE OF APPLICATION

Successful mechanical eradication varies depending on the size of the infestation, and accessibility. For example, some 8 km (560,000 m^2) of the River Mare Foghe (central eastern Sardinia) was covered by a dense mat of water hyacinth (mixed with *Hydrocotyle ranunculoides* L.f. (pennywort)) in 2010 (Brundu *et al.*, 2012). Mechanical control was implemented using crane trucks with grapples and pushing boats. Sites that were difficult to access were cleaned using motor boats and manual extraction means, or boats equipped with cutting devices, however a lack of follow up resulted in re-infestation. Most successful eradication campaigns are limited to small accessible infestations in their early stages of invasion, where the seed bank is limited.

EFFECTIVENESS OF MEASURE

Neutral.

Harvesters have been used for the successful eradication of infestations of water hyacinth in Portugal (Laranjeira and Nadais, 2008). However, follow-up measures are needed if regrowth from seeds or remaining plants occur, even though new regrowth can be removed by manual removal. One key factor in this measures effectiveness is the need for long term monitoring, if this is not implemented comprehensively the measure will likely fail as the species can regenerate from the seedbank or from plants that are missed during the removal.

Given the authors past experiences with this species (and other invasive aquatic plants), eradication, even within a single system, is almost always unattainable. It seems more likely that management approaches will need to be developed that seek to reduce the extent of water hyacinth infestations to acceptable levels.

EFFORT REQUIRED

Following mechanical removal, plant regrowth will most likely occur and thus eradication will require follow-up management measures, until the last plant has been successfully removed (de Winton *et al.*, 2013). If a persistent seed bank in the sediment exists, the follow-up management must last for several years until no regrowth from seeds occur. De Winton *et al.* (2013) recommended monitoring for 3-5 years after the removal of the last fragments before the eradication of the species can be confirmed. In New Zealand, water hyacinth sites are monitored for a further 20 years following eradication (according to the Biosecurity New Zealand water hyacinth page).

The total eradication of water hyacinth by mechanical harvesters is only achieved in combination with manual removal, which is used to collect the remaining small plant patches and single plants.

RESOURCES REQUIRED

A harvester, a transporter to store the harvested plant material and transport it to the shore, a conveyor to elevate the harvested biomass to a truck and a suitable disposal site are required (Gettys *et al.*, 2014). The cost for the management of free floating plants with a harvester depends on the population size, the time for transporting, disposal costs and the accessibility of the water (Gettys *et al.*, 2014; Laranjeira and Nadais, 2008) (see *Management* sections: *Mechanical control* below for costs).

For all activities from boats, personal floatation devices, skills in boat handling are mandatory for the safety of the operator (de Winton *et al.*, 2013).

SIDE EFFECTS

Environmental: Negative
Social: Neutral or mixed
Economic: Neutral or mixed

Mechanical harvesters are not species specific and all plants are removed (Gettys *et al.*, 2014). This might include other invasive aquatic plant species as well as native species. Thus this method might not be suitable in conservation areas.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Depending on the size and accessibility of the water body, mechanical harvesting can clean infested areas (even if temporarily) within a short period of time, which will lead to a high acceptance from stakeholders and the public.

The removal of the biomass from the water body and correct disposal at a suitable landfill site is essential to prevent the unsightly and odorous build-up of rotting plant material.

ADDITIONAL COST INFORMATION

Disposal of removed material can be costly, depending on the amount to be removed. As with all management methods, the cost of inaction is usually high and will result in spread of the target species, reducing the likelihood of future eradication and increasing management costs and time frames.

LEVEL OF CONFIDENCE[1]

Well established.

Mechanical harvesting and hand weeding has been used for the successful control and eradication of infestations of free floating IAAPs, including *P. stratiotes*.

1 See Appendix

Herbicide application.

MEASURE DESCRIPTION

Chemical eradication relies on herbicides registered for use against water hyacinth. Water hyacinth is susceptible to herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D), diquat, paraquat, and glyphosate, which are the most widely used throughout the world. Herbicides are usually applied using hand guns or booms from boats, including airboats and sometimes aircraft (see the University of Florida's Center for Aquatic and Invasive Plants chemical control page). The measure requires follow-up monitoring and treatment to spot-spray any plant material that survived the initial application, and also to treat re-invasion from seed germination. As a good management practice, herbicides should be routinely rotated and/or combined with other control strategies to minimize the potential development of herbicide resistance.

The objective of chemical eradication is to remove small to large water infestations in all types of water bodies. Eradication may only be feasible in the initial stages of infestation, and this should be a priority.

Eradication measures should be promoted where feasible with a planned strategy and action plan to include surveillance, containment, treatment and follow-up measures to assess the success of such actions. As highlighted by EPPO (2014), regional cooperation is essential to promote phytosanitary measures and information exchange in identification and management methods.

It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

SCALE OF APPLICATION

There is little information on successful eradication using herbicidal control. It would depend on the size of the waterbody (< 10ha (Julien, 2008)) and the accessibility, as well as the number of follow up treatments.

EFFECTIVENESS OF MEASURE

Neutral.

There are no situations where a single application of herbicide will eradicate water hyacinth. Initial treatments will always need to be followed up with further treatments. If post-treatment monitoring, which can be expensive, is not conducted over the long-term, the chances of a successful eradication diminish. Surveillance should theoretically continue for 20 years (the longest recorded longevity of seed) after the last flower was observed.

Given the authors' past experiences with this species (and other invasive aquatic plants), eradication, even within a single system, is almost always unattainable. It seems more likely that management approaches will need to be developed that seek to reduce the extent of water hyacinth infestations to acceptable levels.

EFFORT REQUIRED

It takes several weeks for susceptible plants to die off, and may need follow-up where germination of plants occurs throughout the growing season, as well as continuous annual surveys to ensure the invasion has been fully eradicated. It is also unlikely that every plant will be killed, which will require follow-up treatment.

Intensive monitoring of treated sites is essential to deal with reinvasion, from missed plants and from germination of seeds. Monitoring is required for the best timing of treatment, which would be as soon as new plants have germinated, usually in the spring and summer months.

RESOURCES REQUIRED

Herbicide application relies on very well trained staff with access to the correct equipment, including spray rigs, boats and where necessary helicopter and plane hire. In addition it may be necessary to obtain relevant legal authorisations before using PPPs from aerial platforms.

Herbicidal control is often prohibitively expensive, and depends on the size and accessibility of the infestation (Julien, 2008). The method of application also determines the cost of the application – as costs differ significantly between aerial spraying using fixed wing aircraft or helicopters, boats, booms, and/or knapsack sprayers. In addition, the adjuvants added to the herbicide differ in cost, but are essential in order to actively target the frond material. Costs in the USA are estimated at $1,000/ha (ca. EUR 878) for glyphosate, and $2,800-4,000/ha (ca. EUR 2,458–3,512) for 2,4-D for application by airboat. Water hyacinth growth can exceed removal rates which can lead to very high management costs.

SIDE EFFECTS

Environmental: Negative
Social: Neutral or mixed
Economic: Positive

Environmental: most herbicides are not specific and therefore non-target effects on native plants occur. Rapid decay of sinking plant material can reduce dissolved oxygen in the water body, resulting in noxious smells, and non-target animal death.

Social: Many water hyacinth-infested sites are used for potable water, washing, and fishing, and so the use of chemical sprays may contaminate these sites and threaten human health. However, chemical control has positive social effects as the infested water body would be available for water-related activities following eradication of the infestation.

Economic: Positive effects of eradication allow the waterbody to be used again for economic activities ranging from water provisioning through to recreational activities.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

There is considerable resistance to the use of herbicides, in particular in aquatic ecosystems. In the EU the relevant legal requirements as set out in Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides, and the Water Framework Directive (WFD) (Dir. 2000/60/EC) need to be respected. Glyphosate, the most widely used herbicide for water hyacinth control, has a low toxicity and rapid decomposition in water.

ADDITIONAL COST INFORMATION

Often, the costs of eradication programmes exceed the benefits because weed growth can exceed removal rates, or the lack of follow-up management allows recolonization by remaining plants.

As with all management methods, the cost of inaction is usually high and will result in spread of the target species, reducing the likelihood of future eradication and increasing management costs and time frames (Hill and Coetzee, 2008).

LEVEL OF CONFIDENCE[1]

Well established.

High, as the information comes from published material (Hill and Coetzee, 2008; Julien, 2008), and current practices based on expert experience.

1 See Appendix

Pontederia crassipes [Eichhornia crassipes]. © *Julie Coetzee*

Measures for the species' management.

Manual control.

MEASURE DESCRIPTION

Manual removal through hand pulling or using pitch forks, scoops, nets, shovel rakes, bins, bags, waders and wetsuits, is used in a number of regions of the world, most notably, southern Africa, Europe and China. This method is very labour intensive, only effective for small infestations and essentially used as an employment creation exercise where labour is relatively inexpensive, for example the Working for Water Programme in South Africa. The objective of this measure is to remove as much biomass as possible.

SCALE OF APPLICATION

Manual control is usually only effective for small infestations as it is labour intensive. In Zimbabwe on Lake Chivero, a manual control programme was implemented in the 1980s. The manual removal team consisted of 500 workers, working 8 hrs/day, and although ~500 t of water hyacinth were removed, the rapid regeneration of the weed made the effort slow and expensive, with no obvious impact 6 months later (Chickwenhere and Phiri, 1999).

EFFECTIVENESS OF MEASURE

Ineffective.

Manual control usually results only in temporary control because of the weed's rapid rate of increase from plants that were not removed, and from seed germination following clearing. There are no examples in the literature of successful manual control alone.

EFFORT REQUIRED

Initially, continual follow ups are required to ensure re-infestation does not occur. Intensive monitoring is essential to deal with reinvasion or rapid recolonization from missed plants and germinating seeds (Julien *et al.*, 2009). Annual repetition is required to maintain control.

RESOURCES REQUIRED

Costs and staff will vary depending on the size and accessibility to the infestation. Disposal of removed material can be costly, depending on the amount to be removed. Equipment needed could include wetsuits and waders, nets, scoops, rakes, bins and bags. On bigger, less accessible infestations, canoes or boats are required to access the plants.

SIDE EFFECTS

Environmental: Negative
Social: Positive
Economic: Positive

Environmental: There are potential non-target effects, which include removal of non-target species and scouring of riparian vegetation. Wading could disturb sediments, increasing turbidity, which could have negative consequences, although not long lasting.

Social: Positive side effects include removal of breeding grounds for hosts of parasitic diseases such as malaria and bilharzia (although not prevalent in Europe). Removal of pestiferous insects would be an advantage.

Economic: Positive side effects include the use of the water body again for recreational, hydrological and other economic activities.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Opening up of infested areas would be acceptable to communities reliant on the invaded water body for recreational and economic activities. Water quality for both human and animal consumption improve with the removal of water hyacinth. Correct disposal of the removed material is vital as mounds of rotting water hyacinth will create a negative perception.

ADDITIONAL COST INFORMATION

As with all management methods, the cost of inaction is usually high and will result in spread of the target species, reducing the likelihood of future eradication and increasing management costs and time frames.

LEVEL OF CONFIDENCE[1]

Well established.

Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third countries with similar environmental, economic and social conditions (Hill and Coetzee, 2008, Julien *et al.*, 1999).

1 See Appendix

Mechanical control.

MEASURE DESCRIPTION

Mechanical control, primarily through the use of harvesters, has been used in many parts of the world to control water hyacinth with the explicit aim of biomass removal (Brundu *et al.*, 2012; Chickwenhere and Phiri 1999; Duarte, 2017; Mangas-Ramírez and Elías-Gutiérrez, 2004; Ruiz Téllez *et al.*, 2008). Machinery can remove the bulk of an infestation in accessible areas, and other control methods are then required for plants remaining close to edges, or in shallow or inaccessible areas. Mechanical removal can be broad scale or small scale.

SCALE OF APPLICATION

Some 8 km (560,000 m^2) of the River Mare Foghe (central eastern Sardinia) was covered by a dense mat of water hyacinth (mixed with *Hydrocotyle ranunculoides* L.f. (pennywort)) in 2010 (Brundu *et al.*, 2012). Mechanical control was implemented using crane trucks with grapples and pushing boats. Sites that were difficult to access were cleaned using motor boats and manual extraction means, or boats equipped with cutting devices. By December 2010, some 6,700 tonnes of plant biomass had been removed at a cost of EUR 175,000. A 400–500 m (25,000 m^2) stretch of river invaded by the mat of water hyacinth remained, and an additional amount of EUR 400,000–500,000 was set aside to continue operations up to 2013.So far (2019) the Sardinian site is still invaded, although the alien plant moved to a close area in the vicinity of the first infested site (Brundu, pers. comm.)

In Italy, water hyacinth was first recorded in the Lazio region, in the Pontine plains, in 1983 (Anzalone, 1983). In the early colonisation phases, the species did not outcompete other species (Scoppola *et al.*, 1986); and until 1995, its populations were still small, limited to a few sites on the shores of the Rio Martino river near the Fogliano lake, sometimes even in brackish waters. In the following years, the populations of water hyacinth spread to other sites within the Pontine plains, covering a total surface of 5,000 m^2 in 2004 and 2005 (Iberite and Pelliccioni, 2009). Every autumn, the weed is mechanically removed by the local authority responsible for water management (such as the Consorzio di Bonifica di Latina).

In 2006, mechanical harvesters were used to control water hyacinth in the lagoon system of Ria de Aveiro, Portugal that was approximately 50% covered by the weed. Since the operation began, the aquatic-harvester removed more than 15,500 m^3 of mats from the lagoon, which, in accordance with legislation, was transported to an old inactive quarry site.The water hyacinth in the lagoon required annual follow up and has remained free of water hyacinth, allowing navigation and the maintenance of traditional activities such as fishing and boating (Laranjeira and Nadais, 2008).

As mentioned under *Manual control*, in Zimbabwe on Lake Chivero, a manual control programme was implemented in the 1980s but the rapid regeneration of the weed resulted in a mechanical programme being implemented, using a bulldozer, boat, conveyor and dump truck, resulting in the removal of 2 ha plants per day. Even though almost 2 ha of plants was cleared daily, neither manual removal nor mechanical harvesting effectively reduced the amount of water hyacinth on the lake (Chikwenhere and Phiri, 1999).

EFFECTIVENESS OF MEASURE

Ineffective.

As with manual control, the amount of biomass that needs to be removed, coupled with the growth rate of the plant, and the remoteness of some of the infested areas means that this option has limited applicability.

Broad scale harvesting may be appropriate when:

- an infestation occurs in a priority area, such as an area where there is high recreational use, high conservation value or potable water uptake
- the water hyacinth infestation can be contained during the harvesting operation
- in tropical climates, and where the waters are eutrophic, water hyacinth can double every seven days (Julien, 2008), thus the rate of removal must exceed the rate of weed growth, and is therefore only successful where waterbodies are oligotrophic and in colder seasons
- the harvested plants can be adequately disposed of.

The remoteness and difficult accessibility of many infestations makes mechanical control unfeasible. Physical removal using booms to accumulate or control the location of mats and machines to collect and remove the weed have been used in many instances, rarely with great success and always at great expense, for example, harvesters were used at Port Bell and Owen Falls Dam on Lake Victoria, Uganda with limited success in the 1990s (Albright *et al.*, 2004)

As post treatment monitoring is expensive, it is rarely conducted over the long term, and therefore, mechanical methods usually fail to provide acceptable and sustainable levels of weed control.

One of the most prominent cases of water hyacinth invasion and control in Europe comes from the Guadiana River in Spain. The weed was first recorded on the river in 2004 (Ruiz Téllez *et al.*, 2008). Measures carried out by Spain's Ministry of the Environment managed to retain the infestation to a 75 km section of the river. Control of the weed relied on physical methods with manual and mechanised extraction and the installation of floating booms to prevent the spread of the infestation downstream. By 2008, €8 million had been spent and 2,000 tonnes of biomass had been extracted (Ruiz Téllez *et al.*, 2008). However, an EPPO International Workshop on the topic highlighted the river as a high re-infestation risk area (Martín de Rodrigo *et al.*, 2008). Water hyacinth did re-infest the river, most likely from seed, or scattered plants that the mechanical harvesting had missed, and in 2010, additional 5 tonnes of the weed were removed, more than 51,000 tonnes were removed in 2012, and 170,000 tonnes were removed in 2016. Thus, in ten years of control (2005–2015), up to €26,000,000 had been spent (Duarte, 2017). Despite this effort, scattered populations of water hyacinth had spread along 150 km of the river, just about reaching Portugal and Alqueva, the largest Reservoir in Europe. Management had thus failed.

EFFORT REQUIRED

As with manual control, initial continual follow ups are required to ensure re-infestation does not occur. Intensive monitoring is essential to deal with reinvasion or rapid recolonization from missed plants. Annual repetition is required to maintain control. The best time to carry out mechanical control efforts is during the cooler seasons when plant growth and reproduction is slowed (Julien, 2008).

RESOURCES REQUIRED

The management cost to remove nearly 200,000 tonnes of water hyacinth was EUR 14,680,000 for 2005 to 2008 in the Guadiana river, Spain (for around 75 km of river) (Ruiz Tellez *et al.*, 2008). It represented 65,723 working days and necessitated the use of crane trucks equipped with a grapple, backhoes with bucket, and 35 m boom cranes (Tellez *et al.*, 2008b).

In Portugal, the management in the Municipality of Agueda cost EUR 278,000 from December 2006 to May 2008, including the purchase of the mechanical harvester and its monthly running costs, as well as almost 1,800 labour hours. Three persons were employed for this purpose in 2006 and 2007, and one during 2008 (Laranjeira and Nadais, 2008).

For all activities from boats, personal floatation devices, skills in boat handling are mandatory for the safety of the operator.

SIDE EFFECTS

Environmental: Negative
Social: Positive
Economic: Positive

Environmental: Mechanical harvesters are not species specific and all plants are removed (Gettys *et al.*, 2014). This might include other invasive aquatic plant species as well as native species. Thus this method needs to be carefully assessed before application in conservation areas.
Social: Positive side effects include removal of breeding grounds for hosts of parasitic diseases such as malaria and bilharzia (although not prevalent in Europe). Removal of pestiferous insects would be an advantage.
Economic: However, positive side effects include the use of the water body again for recreational, hydrological and other economic activities, provided the control programme is ongoing.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Opening up of infested areas would be acceptable to communities reliant on the invaded water body for recreational and economic activities.

Water quality for both human and animal consumption improve with the removal of water hyacinth. Correct disposal of the removed material is vital as mounds of rotting water hyacinth will create a negative perception.

ADDITIONAL COST INFORMATION

As with all management methods, the cost of inaction is usually high and will result in spread of the target species, reducing the likelihood of future eradication and increasing management costs and time frames.

In cases where infestations have become extensive (usually over the summer growth period), it is important to know whether the rate of mechanical removal will exceed water hyacinth growth rates (weekly doubling rates in the summer and under conditions of eutrophication (Penfound and Earl, 1948)); where and how the removed weed will be disposed of; the associated costs of the whole operation; and whether adequate follow up can be carried out to ensure the operation is worthwhile.

Mechanical harvesting is not economically competitive compared to chemical control (see below), and the large biomass associated with severe infestations can make the use of both harvesting machines and hand removal impractical.

LEVEL OF CONFIDENCE[1]

Well established.

Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third countries with similar environmental, economic and social conditions.

1 See Appendix

Booms and containment fences.

MEASURE DESCRIPTION

The erection of booms in conjunction with mechanical and manual removal, or chemical control (see below) may aid control of water hyacinth. The objective of erecting booms and fences is to contain the infestation in a smaller area, facilitating manual/mechanical removal or herbicide application (Jones, 2001) (as opposed to using booms as a measure for preventing secondary spread, which is discussed above).

Floating booms range in size and capacity. Small water hyacinth infestations can be temporarily contained using a rope floating on the water surface, but for ongoing containment or for larger infestations, a floating boom needs to sit approximately 10 cm above and below the water surface. Commercially available booms can be hired or purchased, and smaller-scale booms can be made up 'in-house'. Booms need to be durable and strong enough to hold the considerable amount of force created by the weight and movement of the floating water hyacinth. They can be designed to accommodate rises and falls in water levels (such as leaving some slack will accommodate small rises), and should also be designed to let go when floodwaters occur, so as not to lose the boom completely. Debris can damage or displace a boom.

Floating booms and containment fences are used to:
- contain infestations of water hyacinth in one area to minimise costs and the time required to carry out herbicide treatments or physical removal
- separate areas that have had different control treatments (such as different herbicides, herbicide and biocontrol, mechanical removal and biocontrol)
- keep certain areas water hyacinth free
- separate and protect biocontrol release sites from disturbances and other control treatments
- allow for monitoring of treatment efficacy
- collect regrowth and leftover water hyacinth for further treatment or removal
- prevent downstream spread (see 'secondary spread' section above)
- allow for early detection of new infestations.

SCALE OF APPLICATION

Booms can be used in any system where there are 2 anchor points across the water body. Therefore the width of the system would constrain the use.

For example, in 1995, in an attempt to reduce the spread of water hyacinth seed and to make the chemical control cost-effective, permanent cable booms (28 mm steel) were placed across the Mposa and Nseleni Rivers, and Lake Nsezi,South Africa, at strategic points demarcated as management units (Nseleni River – 17.1 km, Mposa River – 4.9 km and the Nsezi Lake – 268 ha). The cables were placed in such a manner that they hung beneath the surface of the water, thereby catching the root system of the water hyacinth. Plastic buoys were used as flotation on the cables. Each permanent cable had a 'weak link' in it because previous experience showed that during floods, not only was there a vast volume of water, but that the cable anchors (trees) were unable to hold the weight of the water hyacinth that built up on the cables. In addition to the permanent cables across the river, temporary cables allowed the water hyacinth to back-up against them, which assisted the chemical control method (Jones, 2001). The water hyacinth infestation remained under control until 2014 when a change in management led to the abandonment of the control programme (R.W. Jones, Ezemvelo Wildlife, Pers. Comm.).

In Spain, on the Guadiana River, a water hyacinth infestation was contained using 2 types of booms, within a 75 km stretch of the river. The first type, the Huelva-type barriers were placed diagonally across the channel. They were anchored to the banks, with 30-mm corrugated steel posts and welded rings secured by padlocks and steel cables. They consisted of elliptical cross-section floats, attached to a 40-cm deep wire mesh, with a weighted tether to ensure permanent submersion. The second type, Zaragoza-type barriers were secured by two cast concrete blocks with anchor rings. Their cylindrical floater design provided containment at sites with a strong current. Altogether, 2,000 m of the first and 5,200 m of the second were used (Ruis-Tellez *et al.*, 2008).

EFFECTIVENESS OF MEASURE

Effective.

The installation of booms for integrated control (see section below) is invaluable particularly during periods of heavy rain when water levels rise, as they retain infestations in the boomed off area, preventing large scale spread downstream.

EFFORT REQUIRED

Booms and fences usually need to stay in place for the duration of the management effort (such as a number of years, possibly permanently). All booms and containment fences should be checked regularly and routinely after rainfall, and cleared of debris. When possible, booms and fences should be removed or opened before flooding occurs.

RESOURCES REQUIRED

The type of boom required is dependent on the size and extent of the infestation, as well as the waterbody type. Different booms are required in running water in comparison to still water. The cost also depends on whether the boom is homemade, or commercially sourced. For example, industrial-strength booms are available commercially for oil spill control, which are generally more durable than in-house designs, are able to cover larger spans, and can be used on a permanent basis.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

Environmental: Potential side effects of the installation of booms include build-up of material during floods, and knock on side effects.

Social: Booms can form obstructions in waterbodies thus restricting recreational activities such as water-skiing and boating.

Economic: Build of material during floods could result in damage to infrastructure such as bridges, dam walls. However, positive side effects include the use of the water body again for recreational, hydrological and other economic activities, provided the control programme is ongoing.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

The visual presence of booms and fences is often an indication that action is being taken, and although their presence may be unsightly, their benefit in integrated management is great.

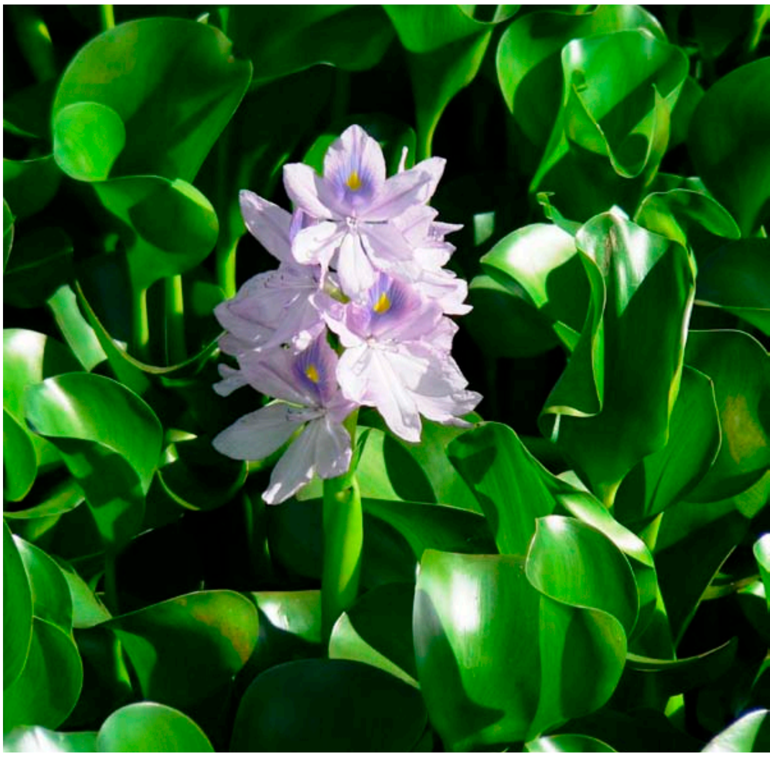
ADDITIONAL COST OF INFORMATION

As with all management methods, the cost of inaction is usually high and will result in spread of the target species, reducing the likelihood of future eradication and increasing management costs and time frames.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Information comes from published data (for example Jones, 2001; Ruiz-Tellez *et al.*, 2008) in the grey literature and expert opinion, but booms have been used successfully in South Africa (Jones, 2001) and Spain (Ruiz-Tellez *et al.*, 2008) as part of an integrated management approach (see below).



Pontederia crassipes [Eichhornia crassipes]. © *Julie Coetzee*

1 See Appendix

Chemical control using herbicides.

MEASURE DESCRIPTION

Chemical control relies on herbicides registered for use against water hyacinth. Water hyacinth is susceptible to herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D), diquat, paraquat, and glyphosate, which are the most widely used throughout the world. However, 2,4-D and paraquat are not permitted for water hyacinth control in South Africa. Herbicides are usually applied using hand guns or booms from boats, including airboats and sometimes aircraft.

The objective of herbicidal control is to reduce small to very large water infestations in all types of water bodies through death of the plant as a result of herbicidal activity.

EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

SCALE OF APPLICATION

Herbicides are used to control water hyacinth on various sized water bodies, with successful control often achieved in small, single-purpose water systems such as irrigation canals and dams of around 1 hectare in size (Wright and Purcell, 1995). Although herbicide application has the advantage of being fast acting, effective control depends on a long-term commitment to follow-up applications for possibly 20 years or more, particularly in very large water bodies subject to flooding and water level fluctuations.

Reasonably successful results were obtained in Mexico, where a combined chemical-mechanical programme, using the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) and a mechanical harvester, was implemented to control water hyacinth on the Trigomil Dam (393 ha) in the 1990s (Gutiérrez *et al.*, 1996). Similarly, in South Africa, a severe water hyacinth infestation on the Hartebeespoort Dam (2,000 ha) was brought under control using the terbutryn herbicide Clarosan 500FW in the late 1970s (Ashton *et al.*, 1979). However, this was not a long term solution as the waterbody was reinfested with water hyacinth since the 1980s and remains a problem today.

EFFECTIVENESS OF MEASURE

Neutral.

Chemical control of water hyacinth has been successful in small contained systems, particularly in combination with mechanical control, where access is relatively easy. However, despite its apparent success, herbicidal control provides only short-term relief and, subsequently, must be regularly and frequently reapplied (Center *et al.*, 1999).

The seeds of water hyacinth are long-lived, remaining viable for at least 15 years, and are therefore able to germinate and reinfest sites after exposure to light as a consequence of chemical removal of the plant. Reinfestation also occurs from any plants not killed during the herbicide operation. In addition, chemical control is neither practical nor affordable in large natural systems or in inaccessible areas.

EFFORT REQUIRED

There are no situations where a single application of herbicide will provide ongoing control of water hyacinth. Initial treatments will always need to be followed up with further treatments.

Long-term management with herbicides requires follow-up monitoring to spot-spray any plant material that survived the initial application. As a good management practice, herbicides should be routinely rotated and/or combined with other control strategies to minimize the potential development of herbicide resistance.

This is supported by research trials showing that a good initial knockdown after herbicide application can be misleading, and that regrowth is likely to occur after treatment with any of the registered herbicides (Center *et al.*, 1999). The decaying biomass of sunken herbicide-treated plants will also return nutrients to the water, creating ideal conditions for regrowth of surviving plants and making the need for ongoing follow-up and monitoring more critical.

RESOURCES REQUIRED

Herbicidal control is often prohibitively expensive, and depends on the size and accessibility of the infestation. The method of application also determines the cost of the application – costs differ significantly between aerial spraying using fixed wing aircraft or helicopters, boats, booms, and/or knapsack sprayers. In addition, the adjuvants added to the herbicide differ in cost, but are essential in order to actively target the frond material. Annual costs in the southern USA are estimated at USD 1000/ha (ca. EUR 878) for glyphosate, and USD 2800–4000/ha (ca. EUR 2,458–3,512) for 2,4-D (Gibbons *et al.*, 1999).

In the USA, ongoing annual waterway water hyacinth control programmes using herbicides costs around 3 million USD per year in Florida, and USD 2 million (ca. EUR 1.75 million) in Louisiana. They have been going on for decades and will likely continue ad infinitum (Schmidz *et al.*, 1993).

SIDE EFFECTS

Environmental: Negative
Social: Negative
Economic: Positive

Environmental: most herbicides are not specific and therefore non-target effects on native plants occur. Rapid decay of sinking plant material can reduce dissolved oxygen in the water body, resulting in noxious smells, and non-target animal death. The effects of complete coverage of a water body by water hyacinth can be equally detrimental to fish and aquatic organisms in terms of lowering dissolved oxygen levels, changing the temperature profiles in the water, changing water chemistry and reducing light penetration as chemical control.

Social: Many water hyacinth-infested sites are used for potable water, washing, and fishing, and so the use of chemical sprays may contaminate these sites and threaten human health.

Economic: Positive effects of control allow the waterbody to be used again for economic activities ranging from water provisioning through to recreational activities.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Depending on the herbicide used, water extraction for irrigation may be compromised. Water for human and animal consumption may also be affected. However, opening up of infested areas would be acceptable to communities reliant on the invaded water body for recreational and economic activities.

Water quality for both human and animal consumption improve with the removal of water hyacinth following ecosystem recovery after chemical treatment. However, because the use of herbicides to control aquatic plants is prohibited in most European countries (Hussner *et al.*, 2017), the acceptability of stakeholder and the public for the use of herbicides to control invasive aquatic plants is likely to be considered unacceptable.

ADDITIONAL COST INFORMATION

In general, the cost of chemical control is considered as low compared to mechanical control methods (Gettys *et al.*, 2014). The costs of inaction must be considered as high, as water hyacinth is largely limited in Europe (except Portugal and Spain) and any kind of control will limit its future spread and impact.

LEVEL OF CONFIDENCE[1]

Well established.

Information comes from published data (Center *et al.*, 1999; Hill and Olckers, 2001; Hill and Coetzee, 2008; Jones, 2001) or expert opinion, but it is not legislated in Europe to guarantee that the results will be transposable.

1 See Appendix

Biological control.

MEASURE DESCRIPTION

It should be borne in mind that the release of macro-organisms as biological control agents is currently not regulated at EU level. Nevertheless national/regional laws are to be respected. Before any release of an alien species as a biological control agent, an appropriate risk assessment should be made.

Biological control of water hyacinth employs host specific control agents that disrupt the competitive balance between plant species, in favour of native species through plant damage caused by feeding. It is considered the most economical and sustainable method of control throughout the world where it has been implemented (van Wyk and van Wilgen, 2002). To date, biological control agents against water hyacinth have been released in at least 33 countries (Winston *et al.*, 2014). The most successful control agents against the weed have been the weevils, *Neochetina bruchi* Hustache and *N. eichhorniae* Warner (Coleoptera: Curculionidae), the moth *Niphograpta albiguttalis* (Warren) (= *Sameodes albiguttalis* (Warren)) (Lepidoptera: Pyralidae), and the mite, *Orthogalum anterebrantis* Wallwork (Acarina: Galumnidae) which have established throughout the world, wherever biological control against water hyacinth has been implemented (Winston *et al.*, 2014). Additional control agents include the mirids, *Eccritotarsus catarinensis* Carvalho and *E. eichhorniae* Henry (Hemiptera: Miridae), the hopper, *Megamelus scutellaris* Berg (Hemiptera: Delphacidae), and the grasshopper, *Cornops aquaticum* Bruner (Orthoptera: Acrididae).

Biological control will not eradicate water hyacinth. Control agents are able to reduce an infestation to very low levels, with small amounts of plants left growing along edges or in shaded areas (Hill and Coetzee, 2017). Successful use of biocontrol allows a reduction in total control inputs (for example mechanical / chemical) over time. Other methods may still be required to maintain critical areas of open water or to keep the water hyacinth in a state that allows the control agents to be effective.

It should be borne in mind that the release of biological control agents is currently not regulated at EU level. Nevertheless national/regional laws are to be respected. Before any release of an alien species as a biological control agent an appropriate risk assessment should be made.

SCALE OF APPLICATION

Biological control is successful across a range of scales, with one of the largest successes being the control on Lake Victoria in the late 1990s where the weed was reduced from over 20,000 ha to below 2,000 ha within five years (Wilson *et al.*, 2007).

EFFECTIVENESS OF MEASURE

Effective.

In tropical countries biological control is considered to be the only method that offers economical and sustainable control of the weed (Harley *et al.*, 1996). In temperate areas (for example Southern Africa, the USA and China) acceptable levels of control have not been achieved through this method, or biological control is perceived to be too slow acting (Hill and Olckers, 2001). In tropical areas establishment of an efficient biological control of water hyacinth under ideal conditions can result in complete success in three to five years (Julien *et al.*, 1999). Established populations of the control agent lead to sustainable control of the target species, but this method will not result in eradication of the weed, but should reduce surface area covered by 80–90% under the correct growing conditions (Coetzee *et al.*, 2011).

Eutrophication reduces the success of biological control, as well as cold winter temperatures (Coetzee and Hill, 2012).

EFFORT REQUIRED

Biocontrol does not produce instant effects. Agents need time and favourable conditions to build up a population that will reduce an infestation, and it is difficult to generalise about the time required. In tropical and subtropical climates, agents usually reduce an infestation in 3–5 years, sometimes less. In temperate climates, it can take 5 or more years for agent populations to increase enough to reduce an infestation. Augmentive releases in the spring time can help build up agent populations artificially to mitigate the effects of cold winter temperatures.

RESOURCES REQUIRED

Resources required for an effective biological control programme against water hyacinth largely include the costs of setting up, identification and testing of agents including risk assessments, and maintaining mass-rearing facilities (van Wyk and van Wilgen, 2002). These include greenhouse poly tunnels, large pools, such as plastic portable pools, for growing the plants and maintaining the agent cultures, and then staff and expertise to manage the facility. Once the control agents are released into a system, there are very few ongoing costs because with time, agent populations build up, and often do not require re-inoculation, except after cold winters (Coetzee *et al.*, 2011). They are also very good dispersers, so if there are infested sites nearby, the agents often get to them unaided.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Positive

Environmental: There are no documented non-target impacts of biological control agents used for water hyacinth, due to the rigorous host-specificity requirements of biological control programmes.

Social effects: Positives effects include removal of breeding grounds for hosts of parasitic diseases such as malaria and bilharzia (although not prevalent in Europe). Removal of pestiferous insects would be an advantage.

Economic: Positive side effects include the use of the water body again for recreational, hydrological and other economic activities (Fraser *et al.*, 2016; Arp *et al.*, 2017).

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Using biological control agents might have a high acceptability, as no non-target effects on native plants will occur. Time frames required for biological control, particularly in temperate areas, are often unacceptable to managers, but the benefits of biological control far outweigh the costs, and convincing landowners and managers to see out the wait is crucial.

ADDITIONAL COST INFORMATION

A benefit: cost ratio of 34:1 for biological control of water hyacinth has been estimated in the southern USA (Wainger *et al.*, 2018). A much higher cost-benefit ratio was achieved for the biological-control programme in southern Benin, due to the direct economic effects on the local people. At its peak of infestation, water hyacinth reduced the annual income of approximately 200,000 people by about USD 85 million (ca. EUR 74.6 million), compared with the total cost of the control programme of about USD 2 million (ca. EUR 1.75 million) (in 1999 USD accrued at 6% p.a., for a total duration of 20 years), yielding a benefit: cost ratio of 124:1 (De Groote *et al.*, 2003).

As with all management methods, the cost of inaction is usually high and will result in spread of the target species, reducing the likelihood of future eradication and increasing management costs and time frames.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

Information comes from published data or expert opinion, but it is not legislated in Europe to guarantee that the results will be transposable.

1 See Appendix

Integrated control and adaptive management.

MEASURE DESCRIPTION

Integrated control uses a combination of the control strategies mentioned above to put greater pressure on the weed, or to treat the weed according to the conditions in different stages of an infestation. In most cases, managers will have to consider each control method and make decisions about how to combine them in site-specific management strategies. For example, containing floating mats with booms allows for more effective use of control methods, such as mechanical or chemical control.

If the presence of an infestation is unacceptable for any amount of time (such as if it occurs in a high-use recreation area or a high-value conservation zone), the bulk of the infestation can be removed with herbicides or physical removal. Biocontrol can then be used as part of the ongoing management.

SCALE OF APPLICATION

Integrated control is applied at all scales depending on the size of the infestation, and the combination of methods used. Integrated control has not worked in some areas, such as Florida in the USA (Center *et al.*, 1999) and some areas of South Africa (Byrne *et al.*, 2010). However, there is evidence to show that when carefully planned and implemented over a long-period of time, entire rivers can be controlled using integrated management (for example Nseleni River, South Africa (Jones, 2001). Ironically, this last site has now reverted back to a water hyacinth dominated situation due to funding cuts.

EFFECTIVENESS OF MEASURE

Effective.

Integrated control has been effective in a number of cases, and the following combinations are most successful:

Pontederia crassipes [Eichhornia crassipes]. © *Wolfgang Rabitsch*

– Herbicide spot spraying and manual removal methods are good follow-up techniques, once the bulk of an infestation has been removed through either mechanical removal or broad scale herbicide treatments.
– Herbicide strip treatments or small-scale mechanical removal can assist biocontrol by maintaining ideal control agent habitat.
– Floating booms and containment can be used in combination with all of the control methods and generally increase the effectiveness of any control strategy.

EFFORT REQUIRED

See the separate measure sections above. The effort required depends on the combination of techniques to be employed, and again, the size and accessibility of the water body. Integrated control relying on biological control in combination with another method will take longer than a herbicide strategy to achieve effective control, but the long term benefits of biological control, and the cost effectiveness often outweigh those of a herbicide approach.

RESOURCES REQUIRED

See the separate measure sections above. It is dependent on the combination of methods used, where manual and mechanical control will have high labour costs, while chemical control is very expensive due to the cost and application of the herbicides. Biological control is far cheaper, with longer term environmental benefits.

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Positive
See sections above.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.
Integrated control is likely to be the most acceptable to stakeholders, depending on the combination of methods used. Mechanical or herbicidal control resulting in a quick clearing of the infestation, in combination with biological control might be perceived as the best option in the long run, depending on the water use requirements.

ADDITIONAL COST INFORMATION

The cost of inaction far outweighs the cost of any control method. The socioeconomic benefits associated with a functional aquatic ecosystem are enhanced by the best combination of control methods for the system. Although no complete cost-benefit analysis of water hyacinth control in South Africa has been undertaken, van Wyk and van Wilgen (2002) compared the costs of controlling water hyacinth under herbicide application, biological control, and integrated control. The most expensive method was herbicidal control (USD 250/ha, ca. EUR 220/ha), while a biological control approach was much less expensive (USD 44/ha, ca. EUR 39/ha), but the best return of investment was provided by integrated methods (USD 39/ha, ca. EUR 34/ha).

LEVEL OF CONFIDENCE[1]

Established but incomplete.
Information comes from published data or expert opinion, but it is not legislated in Europe to guarantee that the results will be transposable.

1 See Appendix

Bibliography

Albano Pérez, E., Coetzee, J. A., Ruiz Téllez, T. and Hill, M. P. (2011a). A first report of water hyacinth (*Eichhornia crassipes*) soil seed banks in South Africa. *South African Journal of Botany* 77: 795–800.

Albano Pérez, E., Ruiz Téllez, T. and Sánchez Guzmán, J. M. (2011b). Influence of physico-chemical parameters of the aquatic medium on germination of *Eichhornia crassipes* seeds. *Plant Biology* 13: 643–648.

Albright, T. P., Moorhouse, T. G., and McNabb, T. J. (2004). The rise and fall of water hyacinth in Lake Victoria and the Kagera River Basin, 1989–2001. *Journal of Aquatic Plant Management* 42: 73–84.

Anderson, L.G., White, P.C., Stebbing, P.D., Stentiford, G.D. and Dunn, A.M. (2014). Biosecurity and vector behaviour: Evaluating the potential threat posed by anglers and canoeists as pathways for the spread of invasive non-native species and pathogens. *PLOS ONE*, 9(4)https://doi.org/10.1371/journal.pone.0092788

Anzalone, B. (1983). Note di flora Romana: su alcune specie nuove o ritrovate nel Lazio. [Notes on the flora of Latium (Central Italy)].*Informatore Botanico Italiano* 15: 13–17.

Arp, R., Fraser, G.C.G. and Hill, M.P. (2017). Quantifying the economic water savings benefit of water hyacinth (*Eichhornia crassipes*) control in the Vaalharts Irrigation Scheme. *Water SA* 43: 58–66.

Ashton, P. J., Scott, W. E., Steyn, D. J. and Wells, R. J. (1979). Chemical control programme against the water hyacinth *Eichhornia crassipes* (Mart.) Solms on Hartbeespoort Dam: historical and practical aspects. *South African Journal of Science* 75: 303–306.

Barrett, S.C.H. (1977). Tristyly in *Eichhornia crassipes* (Mart.) Solms (water hyacinth). *Biotropica* 9: 230–238.

Barrett, S. C. H., and Forno, I.W. (1982). Style morph distribution in New World populations of *Eichhornia crassipes* (Mart.) Solms-Laubach (water hyacinth). *Aquatic Botany* 13: 299–306.

Bartodziej, W. and Weymouth, G. (1995). Waterbird abundance and activity on waterhyacinth and egeria in the St. Marks River, Florida. *Journal of Aquatic Plant Management* 33: 19–22.

Brendonck, L., Maes, J., Rommens, W., Dekeza, N., Nhiwatiwa, T., Barson, M., Callebaut, V. *et al.* (2003). The impact of water hyacinth (*Eichhornia crassipes*) in a eutrophic subtropical impoundment (Lake Chivero, Zimbabwe). II. Species diversity. *Archiv für Hydrobiologie* 158: 389–405.

Brundu, G., Stinca, A., Angius, L., Bonanomi, G., Celesti-Grapow, L., D'Auria, G., Griffo, R., Migliozzi, A., Motti, R. and Spigno, P. (2012). *Pistia stratiotes* L. and *Eichhornia crassipes* (Mart.) Solms.: emerging invasive alien hydrophytes in Campania and Sardinia (Italy). *EPPO Bulletin* 42: 568–579.

Brundu, G., Azzella, M.M., Blasi, C., Camarda, I., Iberite, M. and Celesti-Grapow, L. (2013). The silent invasion of *Eichhornia crassipes* (Mart.) Solms. in Italy. *Plant Biosystems* 147(4): 1120–1127.

Burchnall, W. (2013). Wetland Biosecurity Officer project report. The Broads Authority. http://www.broads-authority.gov.uk/__data/assets/pdf_file/0020/405344/Biosecurity_officer__6_month_update.pdf

Buttler, K. P., and Mitarbeiter, M.T. (2017). Florenliste von Deutschland. http://www.kp-buttler.de/florenliste/. Accessed 31 August 2017.

Byrne, M., Hill, M.P., Robertson, M.P., King, A., Jadhav, A. Katembo, N, Wilson, J.R., Brudvig, R. and Fisher, J. (2010). Integrated management of water hyacinth in South Africa: Development of an integrated management plan for water hyacinth control, combining biological control, herbicide control and nutrient control, tailored to the climatic regions of South Africa. WRC Report No. TT 454/10. pp. 285.

Center, T. D., and Spencer, N.R. (1981). The phenology and growth of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) in a eutrophic north-central Florida lake. *Aquatic Botany* 10: 1–32.

Center, T.D., Dray, F.A., Jubinsky, G.P. and Grodowitz, M.J. (1999). Biological control of water hyacinth under conditions of maintenance control: can herbicides and insects be integrated? *Environmental Management* 23: 241–256.

Center, T. D., Hill, M.P., Cordo, H. and Julien, M.H. (2002). Waterhyacinth. In: Biological Control of Invasive Plants in the Eastern United States, edited by R. G. van Driesche, S. Lyon, B. Blossey, M. S. Hoddle and R. Reardon, 41–64. Morgantown: USDA Forest Service.

Champion, P.D., Clayton, J.S. andHofstra, D.E. (2010). Nipping aquatic plant invasion in the bud; weed risk assessment and the trade. *Hydrobiologia*, 656: 167–172

Chikwenhere, G. P., and Phiri G. (1999). History of water hyacinth and its control efforts on Lake Chivero in Zimbabwe. In Proceedings of the First IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, edited by M. P. Hill, M. H. Julien, and T. D. Center, 91–97. Pretoria: Plant Protection Research Institute.

Coetzee, J.A. and Hill, M.P. (2012). The role of eutrophication in the biological control of water hyacinth, *Eichhornia crassipes*, in South Africa. *Bio Control* 57: 247–261.

Coetzee, J. A., Jones, R.W. and Hill M.P. (2014). Water hyacinth, *Eichhornia crassipes* (Pontederiaceae), reduces benthic macroinvertebrate diversity in a protected subtropical lake in South Africa. *Biodiversity and Conservation* 23: 1319–1330.

Coetzee, J. A., Hill, M.P., Byrne, M.J. and Bownes, A. (2011). A review of the biological control programmes on *Eichhornia crassipes* (C. Mart.) Solms (Pontederiaceae), *Salvinia molesta* DS Mitch.(Salviniaceae), *Pistia stratiotes* L.(Araceae), *Myriophyllum aquaticum* (Vell.) Verdc.(Haloragaceae) and *Azolla filiculoides* Lam.(Azollaceae) in South Africa. *African Entomology* 19(2): 451–468.

Coetzee, J.A. Hill, M.P., Ruis-Tellez, T., Starfinger, U. and Brunnel, S. (2017). Monographs on Invasive Plants in Europe: *Eichhornia crassipes* (Mart.) Solms-Laub. *Botany Letters*. 164 (4): 303–326.

De Graft Johnson, K.A.A. (1996). Integrated Control of Aquatic Weeds in Ghana. In: Charudattan, R., Labrada, R., Center, T.D. and Kelly-Begazo, C. (Eds). Strategies for water hyacinth control. 28–43. Report of a Panel of Experts Meeting, 11–14 September 1995, Fort Lauderdale, Florida, USA.

De Groote, H., Ajuonu, O., Attignon, S., Djessou, R. and Neuenschwander, P. (2003). Economic impact of biological control of water hyacinth in Southern Benin. *Ecological Economics* 45: 105–117.

De Winton, M., Jones, H., Edwards, T., Özkundakci, D., Wells, R., McBride, C., Rowe D., Hamilton, D., Clayton, J., Champion, P. and Hofstra, D. (2013). Review of Best Management Practices for Aquatic Vegetation Control in Stormwater Ponds, Wetlands, and Lakes. Auckland Council technical report, TR2013/026, Auckland, 162 p.

Duarte, L. (2017). Water hyacinth invasion on Guadiana River. Some numbers, facts and thoughts. Steemit. Biology-Blogs. Accessed 15-06-2017 https://steemit.com/biology/@liliana.duarte/water-hyacinth-invasion-on-guadiana-river-some-numbers-facts-and-thoughts)

Eckenwalder, J. E., and Barrett, S.C.H. (1986). Phylogenetic systematics of Pontederiaceae. *Systematic Botany* 11: 373–391.

Edwards, D. and Musil, C.J. (1975). *Eichhornia crassipes* in South Africa-a general review. *Journal of the Limnological Society of Southern Africa* 1: 23–27.

EPPO (2008). EPPO/CoE Workshop: How to manage invasive alien plants? The case studies of *Eichhornia crassipes* and *Eichhornia azurea*.

EPPO (2009). PM 9/8(1): *Eichhornia crassipes*. *EPPO Bulletin* 39: 460–464.

EPPO (2014). PQR database. Paris, France: European and Mediterranean Plant Protection Organization. (http://www.eppo.int/DATABASES/pqr/pqr.htm) [Accessed 22 July 2017]

EU 2014. Regulation (EU) No. 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species. *Official Journal of the European Union* L 317, 4 November 2014, 35–55.

Fraser, G., Martin, J. and Hill, M.P. (2016). Economic evaluation of water loss saving due to the biological control of water hyacinth at New Year's Dam, Eastern Cape Province, South Africa. *African Journal of Aquatic Science* 41(2): 227–234.

Fried, G. (2017). Guide des plantes invasives. Nouvelle édition. Paris: Belin

Genovesi, P., Scalera, R., Brunel, S., Roy, D. and Solarz, W. (2010). Towards an early warning and information system for invasive alien species (IAS) threatening biodiversity in Europe. EEA Technical report No 5/2010, EEA, Copenhagen, 47 p.

Georges, N., and Pax, N..(2002). *Pistia stratiotes* L. et *Eichhornia crassipes* (Mart) Solms, deux nouvelles hydrophytes dans la vallée de la Moselle. *Willemetia* 28 : 3–4.

Gettys, L., Haller, W. and Petty, D. (Eds.) (2014). Biology and Control of Aquatic Plants. A Best Management Practices Handbook: Third Edition. *Aquatic Ecosystem Restoration Foundation*, USA, 252 p.

Gibbons, M.V., Rosenkranz, M.G., Gibbons, Jr., H.L. and Sytsma, M.D. (1999). Guide for Developing Integrated Aquatic Vegetation Management in Oregon. Center for Lakes and Reservoirs, Portland State University, Portland, OR.

GIC. Grupo de Investigación en Biología de la Conservación de la Universidad de Extremadura. (2006). Informe sobre Distribución y Biología Reproductora del Jacinto de Agua en el Guadiana 12 vols. Confederación Hidrográfica del Guadiana. Ministerio de Ambiente, Badajoz, España. 12 vols. Vol. 1 (135 pp), vol. 2 (247 pp), vol. 3 (80 pp), vol. 4 (342 pp), vol. 5 (394 pp), vol. 6 (102 pp), vol. 7 (49 pp), vol. 8 (127 pp), vol. 9 (87 pp), vol. 10 (558 pp), vol. 11 (121 pp), vol. 12 (386 pp).

Gopal, B. (1987). Water Hyacinth. Amsterdam: Elsevier Science Publishers

Green, A.J. (2016). The importance of waterbirds as an overlooked pathway of invasion for alien species. *Diversity and Distributions*, 22: 239–247.

Gutiérrez, E., Huerto, R., Saldaña, P. and Arreguín, F. (1996). Strategies for waterhyacinth (*Eichhornia crassipes*) control in Mexico. Hydrobiologia 340: 181–185.

Hansen, K. L., Ruby, FOR EXAMPLE and Thompson, R.L. (1971). Trophic relationships in the water hyacinth community. *Quarterly Journal of the Florida Academy of Sciences* 34: 107–113.

Hestir, E.L., Khanna, S., Andrew, M.E., Santos, M.J., Viers, J.H., Greenberg, J.A., Rajapakse, S.S. and Ustin, S.L. (2008). Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem. *Remote Sensing of Environment* 112: 4034–4047.

Hill, M.P. (2017). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Salvinia molesta*. Technical note prepared by IUCN for the European Commission.

Hill, M. P., and Coetzee, J.A..(2008). Integrated control of water hyacinth in Africa. *EPPO Bulletin* 38: 452–457.

Hill, M.P. and Coetzee, J.A.(2017). The biological control of aquatic weeds in South Africa: Current status and future challenges. *Bothalia* 47(2): https://doi.org/10.4102/abc.v47i2.2152.

Hung, C. and Sukkarieh, S. (2013). Robotic aircraft and intelligent surveillance system for weed detection. 17*th* NSW Weeds Conference Proceedings Corowa, New South Wales, 9–12 September 2013. pp. 90–94.

Hussner, A. (2017). Information on measures and related costs in relation to species considered for inclusion on the Union list: *Pistia stratiotes*. Technical note prepared by IUCN for the European Commission.

Hussner, A. and Lösch, R. (2005). Alien aquatic plants in a thermally abnormal river and their assembly to neophyte-dominated macrophyte stands (River Erft, Northrhine-Westphalia). *Limnologica-Ecology and Management of Inland Waters* 35: 18–30.

Hussner, A., Stiers, I., Verhofstad, M.J.J.M., Bakker, E.S., Grutters, B.M.C., Haury, J., van Valkenburg J.L.C.H., Brundu, G., Newman, J., Clayton, J.S., Anderson, L.W.J. and Hofstra, D. (2017). Management and control methods of invasive alien aquatic plants: a review. *Aquatic Botany* 136: 113–137.

Iberite, M., and Pelliccioni, I. (2009). La flora delle acque interne dell'Agro Pontino (LazioMeridionale): Indagini preliminari. [The flora of the internal waters of Agro Pontino (Southern Lazio): Preliminary investigations]. *Annales Botanici (NS)* 9: 155–164.

Jones R. W. (2001). Integrated control of water hyacinth on the Nseleni/Mposa Rivers and Lake Nsezi in KwaZulu-Natal, South Africa. In Biological and Integrated Control of Water Hyacinth, *Eichhornia crassipes*. Proceedings of the Second Meeting of the Global Working Group for the Biological and Integrated Control of Water Hyacinth, *Eichhornia crassipes*, edited by M. H. Julien, M. P. Hill, T. D. Center and D. Jianqing, 123–129. Canberra: Australian Centre for International Agricultural Research (ACIAR).

Jones, J.L., Jenkins, R.O. and Haris, P.I. (2018). Extending the geographic reach of the water hyacinth plant in removal of heavy metals from a temperate Northern Hemisphere river. *Nature Scientific Reports* 8, Article number: 11071

Julien, M.H. (2008). Plant biology and other issues that relate to the management of water hyacinth: a global perspective with focus on Europe. *EPPO Bulletin* 38: 477–486.

Julien, M. H., Griffiths, M. W. and Wright, A. D. (1999). Biological control of water hyacinth: the weevil *Neochetina bruchi* and *N. eichhorniae*: biologies, host ranges, and rearing, releasing and monitoring techniques for biological control of *Eichhornia crassipes*. Canberra: Australian Centre for International Agricultural Research (ACIAR).

Kaplan, Z., Danihelka, J.,Lepší, M., Lepší, P., Ekrt, L., Chrtek Jr, J. Kocián, J. Prančl, J. Kobrlová, L. Hroneš, M. and Šulc, V. (2016). *Distributions of vascular plants in the Czech Republic. Part 3. Preslia*, 88(4): 459–544.

Kriticos, D. J., and Brunel, S. (2016). Assessing and managing the current and future pest risk from water hyacinth, (*Eichhornia crassipes*), an invasive aquatic plant threatening the environment and water security. *PloS One* 11: e0120054.

Kurugundla, C.N., Mathangwane, B., Sakuringwa, S. and Katorah G. (2016). Alien Invasive Aquatic Plant Species in Botswana: Historical Perspective and Management. *The Open Plant Science Journal*, 9, 1–40.

Laranjeira, C. M., and Nadais, G. (2008). *Eichhornia crassipes* control in the largest Portuguese natural freshwater lagoon. *EPPO Bulletin* 38: 487–495.

Maki, K. and Galatowitsch, S. (2004). Movement of invasive aquatic plants into Minnesota (USA) through horticultural trade. *Biological Conservation* 118: 389–396.

Mangas-Ramírez, E. and Elías-Gutiérrez, M. (2004). Effect of mechanical removal of water hyacinth (*Eichhornia crassipes*) on the water quality and biological communities in a Mexican reservoir. *Aquatic Ecosystem Health and Management* 7: 161–168.

Martín de Rodrigo, E., Morán-López, R. Ruiz Téllez, T. and Sánchez Guzmán, J.M.(2008).Predicitive models of the *Eichhornia crassipes*' potential distribution in the Guadiana River (Spain). How to manage Invasive Alien Plants: The case studies of *Eichhornia crassipes* and *E. azurea*. EPPO/ CoE Workshop, http://archives.eppo.int/MEETINGS/2008_conferences/ eichhornia_files/04_martin/martin1.HTM). París: EPPO. Accessed 15/06/2017

McFarland D.G., Nelson, L.S., Grodowitz, M.J., Smart, R.M. and Owens, C.S. (2004). *Salvinia molesta* D. Mitchell (Giant Salvinia) in the United States: A review of species ecology and approaches to management. Final Report. *Vicksburg, Mississippi: US Army Corps of Engineers – Engineer Research and Development Center.* pp. 35.

McVea, C. and Boyd, C.E..(1975). Effects of waterhyacinth cover on water chemistry, phytoplankton, and fish in ponds. *Journal of Environmental Quality* 4: 375–378.

Ministerio de Agricultura, Alimentación y Medio Ambiente. (2013). Real Decreto 630/2013, de 2 de agosto, por el que se regula el Catálogo Español de Especies Exóticas invasoras. *Boletín Oficial Del Estado Num.* 185, Sec. I. Pág. 56764

Mitchell, D. S. (1985). African aquatic weeds and their management. In Geobotany Volume 6:The Ecology and Management of African Wetland Vegetation, edited by P. Denny, 177–202. Dordrecht: Dr W. Junk Publishers.

Njiru, M., Okeyo-Owuor, J.B., Muchiri, M. and Cowx, I.G.. (2004). Shifts in the food of Nile tilapia, *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. *African Journal of Ecology* 42: 163–170.

O'Hara, J. (1967). Invertebrates found in water hyacinth mats. *Quarterly Journal of the Florida Academy of Sciences* 30: 73–80.

Peña Bretón, C. and de la Cruz, A.S. (2014). Experiencias de control de *Eichhornia crassipes* en la Comunitat Valenciana.. [Experiences of control of *Eichhornia crassipes* in the Comunitat Valenciana]. Paper presented at the Jornadas sobre Especies Invasoras de ríos y zonas húmedas Generalitat Valenciana. Accessed 15/06/2017 http://bdb.cma.gva.es/ webdoc/documento.ashx?id=156535

Penfound, W. T., and Earle, T.T. (1948). The biology of the water hyacinth. *Ecological Monographs* 18: 447–472.

Pyšek, P., Danihelka, J. Sádlo, J. Chrtek Jr, J. Chytrý, M. Jarošík, V. Kaplan, Z. Krahulec, F. Moravcová, L. Pergl, J. Štajerová, K. and Tichý, L. (2012). Catalogue of alien plants of the Czech Republic: checklist update, taxonomic diversity and invasion patterns. *Preslia* 84: 155–255.

Q-Bank Invasive Plants. (2017). http://www.q-bank.eu/Plants/BioloMICS. aspx?Table=Plants%20-%20Species andRec=81 andFields=All. Accessed 31 August 2017.

Rommens, W., Maes, J. Dekeza, N. Inghelbrecht, P. Nhiwatiwa, T. Holsters, E. Ollevier, F. Marshall, B. and Brendonck, L. (2003). The impact of water hyacinth (*Eichhornia crassipes*) in a eutrophic subtropical impoundment (Lake Chivero, Zimbabwe). I. Water quality. *Archiv für Hydrobiologie* 158: 373–388.

Ruiz Téllez T., Martín de Rodrigo López, E. Lorenzo Granado, G. Albano Pérez, E. Morán-López, R. and Sánchez Guzmán, J.M. (2008). The water hyacinth, *Eichhornia crassipes*: an invasive plant in the Guadiana River Basin (Spain). *Aquatic Invasions* 3: 42–53.

Ruiz Téllez, T., Brufao Curiel, P. Blanco Salas, J. and VázquezPardo, F. (2016). Pasado, presente y futuro de una invasión biológica: *Eichhornia crassipes* (Mart.) Solms (camalote) en el río Guadiana. [Past, present and future of a biological invasion: *Eichhornia crassipes* (Mart.) Solms (water hyacinth) in the river Guadiana]. *Conservación Vegetal* 20: 8–9.

Sainty, G.R. and Jacobs, S.W. (2003). Waterplants in Australia. A Field Guide. ISBN: 9780958105514. pp. 428.

Schmitz, DC, Schardt, JD, Leslie, AJ, Dray, FA, Osborne, JA and Nelson, BV (1993) The ecological impact and management history of three invasive alien plant species in Florida. In: Biological Pollution. The Control and Impact of Invasive Exotic Species (Ed. BN McKnight), pp. 173– 194. Indiana Academy of Science, Indianapolis (US).

Scoppola, A., Iberite, M. and Palazzi, A.M. (1986). Sulla presenza di *Spirodela polyrrhiza* (L.) Schleid. ed *Eichhornia crassipes* (Mart.) Solms nelle acque interne dell'Agro Pontino (Lazio). [About the presence of *Spirodela polyrrhiza* (L.) Schleid. and *Eichhornia crassipes* (Mart.) Solms in the internal waters of Agro Pontino (Lazio)]. *Annali di Botanica (Roma), Studi sul territorio* 44: 167–176.

Tison, J.-M., and de Foucault, B. (2014). Flora Gallica. Flore de France. Mèze: Biotope

Ueki, K., and Oki, Y. (1979). Seed production and germination of *Eichhornia crassipes* in Japan. In Proceedings of the Asian-Pacific Weeds Science Society Conference, 257–260. Brisbane:Asian-Pacific Weed Science Society

Ultsch, G. R., and Anthony, D.S. (1973). The role of the aquatic exchange of carbon dioxide in the ecology of the water hyacinth (*Eichhornia crassipes*). *Florida Scientist* 36: 16–22.

van Wyk, E. and van Wilgen, B.W. (2002). The cost of water hyacinth control in South Africa: a case study of three options. *African Journal of Aquatic Science* 27: 141–149.

Verloove, F. (2006). Catalogue of neophytes in Belgium (1800–2005). *Scripta Botanica Belgica* 39: 1–89.

Villamagna, A. M., and Murphy, B.R. (2010). Ecological and socio-economic impacts of invasive water hyacinth (*Eichhornia crassipes*): a review. *Freshwater Biology* 55: 282–298.

Wainger, L. A., Harms, N. E., Magen, C., Liang, D., Nesslage, G. M., McMurray, A. M., and Cofrancesco, A. F. (2018). Evidence-based economic analysis demonstrates that ecosystem service benefits of water hyacinth management greatly exceed research and control costs. PeerJ, 6, e4824.

Winston, R. L., Schwarzländer, M.Hinz, H.L., Day, M.D., Cock, M.J.W. and Julien, M.H. eds. (2014). Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds (5th ed.). FHTET-2014-04. Morgantown: USDA Forest Service

Wright, A. D., and Purcell, M.F. (1995). *Eichhornia crassipes* (Mart.) Solms-Laubach. *The Biology of Australian Weeds* 1: 111–121.

Xie, Y, and Yu, D. (2003). The significance of lateral roots in phosphorus (P) acquisition of water hyacinth (*Eichhornia crassipes*). *Aquatic Botany* 75: 311–321.

Appendix

Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for the measure.

- **Well established:** comprehensive meta-analysis[1] or other synthesis or multiple independent studies that agree.
- **Established but incomplete:** general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognising major knowledge gaps.

1 A statistical method for combining results from different studies which aims to identify patterns among study results, sources of disagreement among those results, or other relationships that may come to light in the context of multiple studies.

Your feedback is important. Any comments that could help improve this document can be sent to ENV-IAS@ec.europa.eu