Flowerheads of Erharta calycina *are narrow but loose panicles, 7–25 cm long, with spikelets hanging down towards one side when mature.*

The management of perrenial veldt grass (*Ehrharta calycina*)

Measures and associated costs

Species (scientific name)	*Ehrharta calycina* Sm. Pl. Ic. Ined. t. 33.
Species (common name)	Perennial veldt grass
Author(s)	Vernon Visser (African Climate and Development Institute)
Date Completed	25/10/2018
Reviewer	Courtenay A. Ray (Arizona State University)
Reference	Visser, V. 2018. Information on measures and related costs in relation to species considered for inclusion on the Union list: *Ehrharta calycina*. Technical note prepared by IUCN for the European Commission.

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Common names

BG	–
HR	Višegodišnja trava veldta
CZ	–
DA	Flerårig steppegræs
NL	Roze rimpelgras
EN	Perrenial veldt grass
ET	Püsik-rohtlahein
FI	Kapinnyppyheinä
FR	Erharte calicinale
DE	Steppengras
EL	–
HU	–
IE	Féar veld ilbhliantúil
IT	Erba di Ehrhart
LV	–
LT	Daugiametis strūklas
MT	Il-vertgras
PL	–
PT	Erva-das-estepes
RO	–
SK	Erharta
SL	Trajna guboplevka
ES	Ehrharta
SV	Veldgräs

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

Perennial veldt grass, *Ehrharta calycina* Sm. (Poaceae), is a perennial (sometimes annual) grass species native to South Africa and southern Namibia (Fish, 2015). It is a tufted rhizomatous grass that primarily reproduces from seed, and rarely from rhizomes (Chimera, 2015; Fish *et al.,* 2015; Wittkuhn, 2010). It is a prolific producer of seed, which are primarily dispersed by wind, but also by rodents, large herbivores and water (DiTomaso, 2013; Newsome *et al.,* 2008; Trunzo, 2015; Wittkuhn 2010). This species was introduced into many regions for pasture or for erosion control (Pickart, 2000; Quattrocchi, 2006). *E. calycina* is already established in the EU in Portugal (Bacelar, 1989; GBIF, 2018) and Spain (Bacelar, 1989; Charpin and Zarco, 1982; Fraga-Arguimbau, 2014; Valdés, 1987; Valdés, 2015). This species is invasive in Australia and California and occurs in a variety of habitats, but is most common in sandy soils (Frey, 2005; Pickart, 2000; Western Australian Herbarium, 1998).

In Australia and California, *E. calycina* is an ecosystem transformer, causing the conversion of native shrublands and woodlands into monospecific grasslands, either by preventing the growth of native plants or via a positive-feedback grass-fire cycle (Fisher, 2009; Pickart, 2000). In Australia, *E. calycina* has also caused a shift in phosphorous nutrient cycling in Banksia woodlands (Fisher, 2006).

Prevention: The most appropriate measure for preventing entry of *E. calycina* into a Member State is *a ban on keeping, importing, selling, breeding and growing* of this species. Seeds for pasture are the most likely life stage to be introduced and should be banned. *Phytosanitary measures* are likely to be ineffective for preventing entry via the principal pathways. The *establishment of containment areas around current introduction sites* should be investigated for its cost-effectiveness and suitability relative to eradication.

The use of *citizen-science and resource managers' data* is a low-cost option as a **surveillance measure for early detection** with a high chance of success. Citizen-science networks have been very successful in supporting early detection programs and suitable networks, databases and apps already exist in the EU.

Physical control, chemical control, grazing, and prescribed burning have all been proposed as control measures for *E. calycina* and most of these could be applied for either **rapid eradication for new introductions** or **management of widespread invasions**. However, there is a distinct lack of experimental trials on control measures for *E. calycina*, making it difficult to provide sound recommendations for the control of this species. Chemical control appears to be the measure of choice for *E. calycina* control (DiTomaso *et al.,* 2013), but this species' long-lived seedbank (Smith *et al.,* 1999) makes control difficult.

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. calycina*.

MEASURE DESCRIPTION

Ehrharta calycina has been planted as a forage plant and also for erosion control (Pickart, 2000; Quattrocchi, 2006). This species is available for commercial purposes in Australia. It is promoted as a forage grass in Australia and New Zealand, was previously tested as a forage grass in Tunisia (Greuter and Raus, 1998) and was introduced to California as a forage grass from Australia (DiTomaso *et al.,* 2013). *E. calycina* is already established in the EU in Portugal (Bacelar *et al.,* 1989; GBIF, 2018) and Spain (Bacelar *et al.,* 1989; Charpin and Zarco, 1982; Fraga-Arguimbau, 2014; Valdés *et al.,* 1987; Valdés, 2015), but it is uncertain how it was introduced there.

In California and Australia, *E. calycina* can dominate plant communities excluding native plant species and transforming shrubland into grasslands (Fisher *et al.,* 2009; Frey, 2005; Milberg and Lamont, 1995; Pickart, 2000). It can initiate an enhanced grass-fire cycle, promoting more frequent fires, which in turn favour this fire-adapted species at the expense of native plant species (Fisher *et al.,* 2009; Milberg and Lamont, 1995). In eutrophic Australian Mediterranean-type environments, *E. calycina* has been shown to cause a shift in phosphorous nutrient cycling, with vegetation transformation coinciding with a shift of phosphorus from biomass to soils (Fisher *et al.,* 2006).

The objective of this measure would be to prevent the intentional re-introduction and spread of this species by banning its import, selling, and growing of the species. The fact that *E. calycina* has become invasive in Australia, California and New Zealand, where it was introduced as a forage grass, strongly supports implementing this measure.

EFFECTIVENESS OF THE MEASURE

Neutral.

No specific information is available to suggest how effective banning the keeping, importing, selling, breeding and growing *E. calycina* will be in preventing its invasion. This species occurs in the EU in Portugal and Spain. Therefore, this measure can only be effective in limiting further intentional introductions of this species within the EU.

SIDE EFFECTS

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

This measure could have negative economic side effects due to the use of this species as a pasture plant. *E. calycina* was not introduced to Spain for this purpose and was probably an accidental introduction (Fraga, 2014), but *E. calycina* is found in dry pastures in Spain (Fraga, 2014; Valdés *et al.,* 1987).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Despite the use of this species for pasture in Australia, *E. calycina* does not appear to be used (or at least promoted) for this purpose in the EU. Therefore, this measure is likely to be acceptable to the agricultural community. This measure will also be acceptable due to its likelihood of reducing re-introductions and further spread of this species.

ADDITIONAL COST INFORMATION

Implementation costs for Member States will be dependent on the cost of enforcing such a ban, but figures are not readily available in the public domain. Kettunen *et al.* (2014) suggest that costs for this type of measure will be relatively high.

The **costs of inaction** can be estimated based on costs of controlling invasions in other regions around the world. However, there are few statistics even for this. In California, the cost of hand pulling and herbicide backpack-spraying of *E. calycina* is estimated to cost USD 300 (ca. EUR 262) per acre (1 acre = 0.405 ha), while aerial application of herbicides is estimated to cost USD 30 (ca. EUR 26) per acre (Kinkade, 2015).

It is unknown whether this measure would be **cost-effective.** It has been suggested that because of the high costs of implementation and the high administrative burden, bans such as those suggested by this measure, are highly unlikely to be cost-effective (Kettunen *et al.,* 2014). However, theoretical models suggest that there are major net positive economic benefits to preventing the entry of invasive species (Keller *et al.,* 2007). There are, however, no known cost-benefit studies specific to *E. calycina*.

There is no known **socio-economic cost information related to the species**.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

There is a large body of literature (not specific to *E. calycina*) that supports a ban on keeping, importing, selling, breeding and growing alien species. However, there is no information specific to *E. calycina* to support this measure, either in the EU or in third countries.

Phytosanitary inspections and measures, in particular related to the movement of hay, animals and agricultural machinery, mowers, and vehicles.

MEASURE DESCRIPTION

Ehrharta calycina has the potential to be introduced as a contaminant of hay (EPPO, 2018), as hay is imported into the EU from invaded areas (for example, California) and grass seeds have been shown to remain viable in hay imports (Conn *et al.,* 2010). *E. calycina* seeds may be dispersed on animal fur and in their dung (Chimera, 2015; Newsome *et al.,* 2008), and on agricultural machinery, mowers, and vehicles (CABI, 2018). *E. calycina* may also reproduce vegetatively from rhizomes, although rarely (Chimera, 2015).

Hay imports into the EU from areas where *E. calycina* is known to occur should not be permitted unless hay has been certified to be weed free (for example, https://www.naisma.org/weed-free-forage). Animals from areas where *E. calycina* is known to occur should be inspected for seeds attached to their fur prior to transport.

Agricultural machinery, mowers, and vehicles from areas where *E. calycina* is known to occur should be properly cleaned to prevent contamination of *E. calycina* seeds and rhizomes. An ISPM Standard has recently been drafted and adopted on ‘International movement of used vehicles, machinery and equipment’ (IPPC, 2017). This focuses on reducing the risks of transporting contaminants (soil, seeds, plant debris, pests) associated with the international movement (either traded, or for operational relocation) of vehicles, machinery and equipment (VME) that may have been used in agriculture, forestry, as well as for construction, industrial, mining, waste management and military purposes. For those VMEs that represent a contaminant risk, the phytosanitary measures recommended are detailed in the ISPM, and cover cleaning, prevention and disposal requirements. These include, cleaning using pressure washing or compressed air cleaning, chemical or temperature treatments, storing and handling VMEs that prevent contact with soil, and keeping vegetation short around storage areas or ports.

SCALE OF APPLICATION

This measure would need to be applied across the EU, as once hay, animals or VMEs have been imported into the EU they could be moved to high risk areas. No phytosanitary measures currently exist for this species.

EFFECTIVENESS OF THE MEASURE

Ineffective.

Preventing the entry of hay from regions invaded by *E. calycina*, and the inspection of animals is likely to be impractical and costly to manage. Cleaning of VMEs is likely to be impractical, particularly since *E. calcyina* already occurs in Portugal and Spain, which would mean this measure would need to be enforced in these regions and not just for imports of these objects from areas where *E. calycina* is known to occur.

It is difficult to assess whether VMEs present a risk, and therefore, when to apply the relevant phytosanitary measure (IPPC, 2017). The ISPM provides a number of elements to consider when assessing risk: distance of movement (shorter distances are a lower risk), complexity of VME structure (more complex VMEs are a higher risk), origin and prior use (VMEs in close proximity to vegetation are a higher risk), storage (VMEs stored outside, near vegetation, are a higher risk), and intended location or use (VMEs for use in agriculture, forestry, or close proximity to vegetation are a higher risk).

In addition, the inspection, cleaning and treatment will normally take place in the exporting country to meet import requirements. However, there are no EU regulations on phytosanitary requirements for imports of VMEs. Therefore, for the measure to be effective, either regulations need to be developed to regulate VME imports, or inspections and phytosanitary measures would need to be applied at EU ports and also at EU/non-EU border facilities.

1 See Appendix

EFFORT REQUIRED

This measure would have to be applied indefinitely due to the possibility of viable seeds and rhizomes being imported.

RESOURCES REQUIRED

Phytosanitary inspections and measures require trained staff and equipment, and suitable disposal facilities are also required especially if implemented within the EU. Facilities required for the inspection, cleaning, and treatment of VMEs may include: surfaces that prevent contact with soil, including soil traps and wastewater management systems, temperature treatment facilities, and fumigation or chemical treatment facilities (IPPC, 2017).

SIDE EFFECTS

Environmental effects: Neutral or mixed
Social effects: Neutral or mixed
Economic effects: Negative
Inspections would have an economic cost to those undertaking it, which may include both government and the private sector. There would also be economic costs associated with cleaning/treating infected materials, and with any delays in the transport of high risk materials due to inspections.

ACCEPTABILITY TO STAKEHOLDERS

Unacceptable.
Due to the probable ineffectiveness of the measure, and potential costs, it is likely this measure would be seen as unacceptable, especially by those sectors involved in the transport of high-risk materials.

ADDITIONAL COST INFORMATION

Implementation costs for Member States will be high because of the need for trained staff and long-term implementation of this measure, but figures are not readily available in the public domain.

For **costs of inaction**, see above sections, *Prevention of intentional introductions and spread*.

This measure is unlikely to be **cost-effective** because of the high costs of implementation, but there are no studies specific to *E. calycina* to support this.

There are no known **socio-economic aspects**.

The collar is tinged purple and hairs line the mouth of the sheath.

LEVEL OF CONFIDENCE[1]

Established but incomplete.
There is a reasonable amount of evidence to support the use of phytosanitary measures to prevent the unintentional introduction of *E. calycina*, but there is no evidence on the cost-effectiveness of this approach and on the probability that this species could be transported in hay or in agricultural objects.

1 See Appendix

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

Establishment of containment areas around current introduction sites.

MEASURE DESCRIPTION

Ehrharta calycina has only been recorded in a few sites in the EU: in Portugal in the vicinity of Lisbon and Setúbal (Bacelar *et al.,* 1989; GBIF, 2018), and in Spain in and near the Doñana National Park (Valdés *et al.,* 1987; Valdés, 2015), near Cañaveral (GBIF, 2018), near Seville (Charpin and Zarco, 1982), and on Menorca (Fraga-Arguimbau, 2014).

Natural spread rates of *E. calycina* are quite low, with seeds being primarily dispersed by wind (Mashau, 2008; Wittkuhn, 2010), although rodent dispersal has also been recorded (Trunzo, 2015). Maximum dispersal distances observed have been up to ~5 m in wind (Wittkuhn, 2010) and ~25 m by rodents (Trunzo, 2015). Apart from these natural dispersal mechanisms, it is thought that *E. calycina* may be unintentionally spread in hay, on the fur of animals and in their dung, and attached to agricultural machinery, mowers, and vehicles (see *Prevention of unintentional introductions and spread* sections above).

Given the short natural dispersal distances of this species, and the limited number of unintentional dispersal mechanisms, populations of *E. calycina* could be effectively contained through the establishment of buffer zones (Grice *et al.,* 2013). These buffer zones could encompass a ca. 25 m wide area (the maximum natural dispersal distance) around *E. calycina* populations in which grass-selective herbicides are applied annually (Wittkuhn, 2010). In addition, it would be necessary to prevent the removal of hay, livestock grazing and the use of agricultural machinery, mowers and vehicles in these zones (or have these inspected for *E. calycina* seeds).

A cost-benefit analysis would need to be performed to determine whether this measure should be applied instead of those detailed in the sections, *Rapid eradication for new introductions* (see below).

SCALE OF APPLICATION

This measure would only need to be applied around the known populations of *E. calycina* in Portugal and Spain. This measure has only been recommended (Wittkuhn, 2010), but has not been applied before.

EFFECTIVENESS OF THE MEASURE

Neutral.

It is unknown whether this measure will be effective as it has not been applied to *E. calycina* before. Invasive plant species containment programs however can be successful given sufficient resources, relatively small invaded areas, and high detectability of the invasive species (Moore *et al.,* 2011).

EFFORT REQUIRED

This measure would need to be implemented indefinitely to prevent the secondary spread of this species. As this species flowers in spring and summer (University of California, Berkeley, 2018; Western Australian Herbarium, 1998), preventing the removal of hay, livestock grazing and the use of agricultural machinery, mowers and vehicles in these zones would perhaps not be necessary during winter and early spring when there are unlikely to be many seeds on the plants.

RESOURCES REQUIRED

The cost of implementing this measure is unknown. This measure would require trained staff for (1) plant identification, (2) delimitation of the containment zones, (3) herbicide application, (4) management of potential vectors of *E. calycina* seed (such as livestock and vehicles) from late spring to autumn when seeds are likely to be on the plants.

In addition, (1) would require identification guides, and (3) would require all the necessary equipment for herbicide application (see *Management* sections).

SIDE EFFECTS

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

This measure will have negative social and economic side effects in that it could limit certain farming activities in the invaded areas (such as the grazing of livestock at certain times of the year).

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

This measure may be seen as too costly and impractical to implement. Farmers, especially from within the containment zones, may perceive it negatively if it limits their farming activities and causes production losses. However, farmers, especially from outside the containment zones, may also perceive it positively if *E. calycina* is perceived as a poor pasture species that is outcompeting more nutritious pasture species.

ADDITIONAL COST INFORMATION

Implementation costs for such a containment measure are not readily available for *E. calycina*. Costs could be approximated based on the extent of the invaded areas, the labour hours needed to implement this measure, and herbicide costs.

Costs of inaction associated with this measure are likely to be similar to those detailed in the *Prevention of intentional introductions and spread* sections above.

To determine the **cost-effectiveness** of this measure, one would need to conduct a formal analysis along the lines of Moore *et al.,* (2011).

Socio-economic aspects include the potential loss of income to farmers in the invaded areas due to the implementation of this measure.

LEVEL OF CONFIDENCE[1]

Unresolved.

While there is a large scientific literature on the containment of invasive species, the use of this strategy for *E. calycina* has never been investigated. Therefore, it is not known whether this strategy would be effective, and the data to conduct such an analysis would require a considerable investment of time and effort to acquire.

1 See Appendix

Measures for early detection of the species and to run an effective surveillance system to detect efficiently new occurrences.

Citizen-science and awareness campaigns.

MEASURE DESCRIPTION

The objectives of this measure would be (1) to promote *Ehrharta calycina* as a target for identification to invasive species citizen-science platforms, and (2) to provide citizen scientists, farmers and environmental managers with the knowledge to identify this species and means to notify the relevant authorities, thereby supporting its early detection. Citizen-science programmes need good quality assessment of the data collected, well designed and standardised methods of data collection, an explicit goal or hypothesis (for example, in this case, the early detection of *E. calycina*), and feedback to participants on their contributions as a reward for their participation (Silvertown, 2009).

Citizen-science locality data has been shown to be very useful for the early detection of invasive species (Gallo *et al.,* 2011; Maistrello *et al.,* 2016). Numerous such databases currently exist, including EASIN (https://easin.jrc.ec.europa.eu/), which is the official EU platform for reporting alien species occurrences along with the accompanying smartphone application. There are also a number of other European and national IAS awareness and citizen-science IAS monitoring programs into which *E. calycina* could be incorporated, which are important resources for environmental agencies, environmental managers and decision makers (Genovesi *et al.,* 2010).

Easy-to-use identification guides for *E. calycina* (for example, University of California, Berkeley, 2018; Western Australian Herbarium, 1998) should be developed specifically for Europe to assist with identification of this species and made available online on citizen-science platforms, and distributed to key interest groups such as farming and environmental management organisations.

SCALE OF APPLICATION

This measure would need to be applied across the EU, but countries/regions with known populations, as well as those with high climatic suitability, should be prioritised (see EPPO, 2018 for details).

EFFECTIVENESS OF THE MEASURE

Effective.

This measure has the potential to be very effective. Citizen-science locality data has been shown to increase the likelihood of success of arthropod eradication programs, and the authors suggest that awareness campaigns were pivotal in this regard (Tobin *et al.,* 2014).

EFFORT REQUIRED

This measure would need to be supported for the long term.

RESOURCES REQUIRED

This measure will require a well-designed and supported citizen-science platform, including expertise to validate records. The use of EASIN and other established national invasive alien species platforms for this purpose is possible, but the promotion of recording *E. calycina* will be required. Identification guides, and engagement with key sectors of civil society to increase awareness will also be needed.

SIDE EFFECTS

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

Awareness of additional invasive alien species, and potentially their reporting, could be a side-effect of this measure.

While citizen-science projects cost money to develop and maintain, the return on investment is estimated to be substantial and much higher than the input costs (Tulloch *et al.,* 2013).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

The public is likely to perceive a citizen-science measure favourably. Participants in citizen-science programs report having an increased appreciation of the natural world, and greater scientific knowledge, among other benefits (Toomey and Domroese, 2013). However, it has been noted that participation in citizen-science programmes is often limited to wealthier segments of society (Toomey and Domroese, 2013). Environmental managers would likely welcome information on (potentially) invasive species.

ADDITIONAL COST INFORMATION

Implementation costs of setting up and running citizen-science databases and awareness raising programs are large (Genovesi *et al.,* 2010), but databases and programs like these are already running and funded by the EU (such as EASIN). Therefore, additional costs for promoting the collection of *E. calycina* records, and raising awareness of this species, are likely to be minimal.

Costs of inaction associated with this measure are likely to be similar to those detailed in the *Prevention of intentional introductions and spread* sections.

Cost-effectiveness of citizen-science programmes is well established and justified elsewhere (for example, Gallo *et al.,* 2011; Genovesi *et al.,* 2010; Maistrello *et al.,* 2016).

There are no known additional **socio-economic aspects** to consider.

LEVEL OF CONFIDENCE[1]

Well established.

There is considerable evidence to support the use of citizen-science for early detection of invasive species.

1 See Appendix

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

Physical control.

MEASURE DESCRIPTION

Physical control, chemical control, grazing, and prescribed burning have all been proposed as control measures for *Ehrharta calycina*. Grazing is possibly the only control measure that will not work for rapid eradications due to the intensity and duration of grazing required for the elimination of *E. calcyina*. However, there are no specific measures recommended in the literature for rapid eradication of new introductions of *E. calycina*. Only physical control is likely to be practical and cost-effective for small invasions.

Erharta calycina *grass can grow up to 70 cm tall and the leaves are dull or blue-green, often tinged purple. © Harry Rose. CC BY 2.0*

With small invasions, plants can be cut out (or pulled) from the ground while ensuring that the crown is removed (Western Australian Herbarium, 1998; Ray *et al.,* 2018.), but this can also stimulate seed germination (DiTomaso *et al.,* 2013). Plant densities can be reduced if seedlings are repeatedly removed over a number of years, but the length of seed viability for *E. calycina* is uncertain, with reports of 5 years viability (Western Australian Herbarium, 1998), but possibly greater than 45 years (Smith *et al.,* 1999).

SCALE OF APPLICATION

There are no specific guidelines for the scale at which this measure can be used, but because manual removal is a labour-intensive method of control, this measure is only cost-effective for small invasions (Western Australian Herbarium, 1998). For the related *E. erecta*, Ray *et al.,* (2018) tested hand pulling in experimental treatment plots of 4 m^2 at 12 sites in Santa Cruz, California.

EFFECTIVENESS OF THE MEASURE

Neutral.

Physical control can be effective for managing small invasions if the crown is removed when plants are dug out, but this can stimulate seed germination and also requires numerous follow-up treatments. For the related *E. eracta*, Ray *et al.,* (2018) conclude that hand pulling is an effective measure to reduce species cover (by 76%) for up to 2 years, but that multiple treatments would be needed to eradicate the species at local scales.

EFFORT REQUIRED

There are no documented successful eradications of *E. calycina*, therefore the period of time over which physical control needs to be used is uncertain. *E. calycina* is a prolific seed producer (Smith *et al.,* 1999) and seed viability of *E. calycina* possibly exceeds 45 years (Smith *et al.,* 1999), but recommendations for this species' control suggest that populations of *E. calycina* can be reduced to very low numbers after just two years of treatment (DiTomaso *et al.,* 2013).

For the related *E. erecta*, Ray *et al.,* (2018) found that within a two-hour window, 21 volunteers could remove the species from 32 m^2. They also estimated that each volunteer pulled at a rate of approximately 0.75 to 1 $m^2 \cdot h^{-1}$ (32 m^2/21 people/2 h, including transit time between plots).

RESOURCES REQUIRED

Physical control only requires trained staff or volunteers (for accurate species identification) and tools (spades, trowels or clippers). Ray *et al.,* (2018) used volunteers but estimated that if they had to pay labour costs it would be more expensive than herbicide application (see *Chemical control* sections below).

SIDE EFFECTS

Environmental effects: Neutral or mixed
Social effects: Neutral or mixed
Economic effects: Neutral or mixed
Hand pulling will have lower non-target impacts than other methods of control, such as herbicide application.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.
The low effectiveness and labour intensiveness of this measure is likely to reduce its acceptability to invasive species managers as a control method. However, it may be seen by the public as a more acceptable measure than others, such as herbicide application.

ADDITIONAL COST INFORMATION

Implementation costs are unknown.

Costs of inaction associated with this measure are likely to be similar to those detailed in the *Prevention of intentional introductions and spread* sections.

The **cost-effectiveness** of physical control for rapid eradication of this species is unknown, but likely low because of the high labour costs.

There are no known **socio-economic aspects**.

LEVEL OF CONFIDENCE[1]

Inconclusive.
There is insufficient evidence to support the use of physical control for rapid eradication of this species. There is also no readily available information on the costs of using such an approach, and on the scales at which it is practical and cost-effective.

1 See Appendix

Measures for the species' management.

Chemical control.

MEASURE DESCRIPTION

A number of herbicides have been recommended to control *Ehrharta calycina*. Fluazifop, glyphosate and imazapyr have all been recommended for broadcast foliar or spot treatments (DiTomaso *et al.,* 2013; Frey, 2005; Pickart, 2000; Western Australian Herbarium, 1998), but there do not appear to be any published experimental trials for the use of these chemicals on *E. calycina*. Arrow® 2EC and Poast® have recently been trialed for aerial spraying of *E. calycina*, but no results of this study seem to be available (USFWS, 2014). Glyphosate has been suggested as the most effective chemical to use for *E. calycina* control (DiTomaso *et al.,* 2013).

Chemical control has also been recommended in conjunction with mowing and burning. Frey (2005) recommends mowing this species prior to the application of fluazifop, but only for plants that are not seeding. Chemical control has been recommended for use on plants 4 to 6 weeks post germination after unplanned fires (Western Australian Herbarium, 1998)

The objective of chemical control is to mitigate the impacts and control populations of this species. Chemical control could be used to help contain invasions of this species, but it is uncertain if this method will be effective for eradication in the long term. 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 are no specific guidelines for the scale at which chemical control can be used. Aerial spraying of Arrow® 2EC and Poast® has been trialed on experimental plots covering 40 acres (USFWS, 2014). Presumably large areas can be treated using chemical control as recommended herbicide concentrations are provided by DiTomaso *et al.,* (2013) in pints per acre.

EFFECTIVENESS OF THE MEASURE

Neutral.

Glyphosate is likely the most effective control method (DiTomaso *et al.,* 2013) and has been quoted as being able to kill (all) plants after just one application (Pickart, 2000). However, as there are no published experimental chemical control trials, it is difficult to assess effectiveness of this measure. For the related *E. erecta*, Ray *et al.,* (2018) found that spraying 4 m^2 test plots with 2.5% glyphosate solution, with a follow-up treatment using a 3% to 4% glyphosate solution, was effective to substantially reduce its cover (by 59%) for up to 2 years.

EFFORT REQUIRED

It has been recommended that chemical control be applied on actively growing plants, typically in spring just after germination until just before the plants seed (DiTomaso *et al.,* 2013; Western Australian Herbarium, 1998).

Because *E. calycina* has such long seed viability (possibly greater than 45 years; Smith *et al.,* 1999), follow-up treatments may be needed for many years.

RESOURCES REQUIRED

Herbicide application requires trained staff, equipment (such as backpack sprayers, ropewicks, spray wands, or in the case of aerial application, a helicopter fitted with a suitable spray device), herbicides and surfactants.

The only cost estimates of chemical control available suggest the cost of hand pulling and herbicide backpack-spraying of *E. calycina* to be about USD 300 (ca. EUR 263) per acre, while aerial application of herbicides is estimated to cost USD 30 (ca. EUR 26) per acre (Kinkade, 2015).

For herbicide control of the related *E. erecta*, Ray *et al.,* (2018) detail labour costs at approximately USD 39 h^{-1} for a total of USD 156 (ca. EUR 137) for 4 h (2 h per application). Approximately 7.5 l of glyphosate solution were needed to spray twelve 4 m^2 plots. Averaging the percentage of glyphosate used in the two applications to 3%, a total of 0.47 l of glyphosate was used, for a cost of USD 23.52 (ca. EUR 21).

SIDE EFFECTS

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

This measure can have negative environmental effects on native species (Pickart, 2000). The most effective herbicide for *E. calycina* control, glyphosate, is a broad-spectrum herbicide and therefore likely to affect non-target plants. The two herbicides tested for aerial spraying, Arrow® 2EC and Poast®, have both received human health ratings of '1' from the National Fire Protection Association, meaning they only present "a slight health risk to humans" (USFWS, 2014). These chemicals could also be toxic to certain animals, although the concentrations of these chemicals are likely too low to be toxic (USFWS, 2014). Ray *et al.,* (2018) found that applying a 2.5% glyphosate solution followed by a 3% to 4% glyphosate solution, led to significant reductions in native species cover.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Invasive species managers are likely to favour chemical control because of its ease of use compared to physical control. However, public perceptions of chemical control are often negative (for example, Shindler *et al.,* 2011). Moreover, chemical control is not always possible or permitted in conservation areas or in riparian areas and wetlands.

ADDITIONAL COST INFORMATION

The best estimates of **implementation costs** can be found in the *Resources required* sections above.

Costs of inaction associated with this measure are likely to be similar to those detailed in the *Prevention of intentional introductions and spread* sections.

The **cost-effectiveness** of chemical control for management of this species is unknown but will probably be higher than for other methods of control.

There are no known **socio-economic aspects**.

LEVEL OF CONFIDENCE[1]

Inconclusive.

Chemical control is recommended for controlling *E. calycina*, but there are no published experimental trials for the use of herbicides on *E. calycina*. The available guidelines for chemical control of *E. calycina* suggest a diversity of chemicals, application procedures and timing making it difficult to determine how best to implement chemical control. There are also almost no figures available on the costs of chemical control of this species, and no studies on its cost effectiveness.

Grazing.

MEASURE DESCRIPTION

Ehrharta calycina appears unable to survive heavy grazing, particularly when it is flowering (DiTomaso *et al.,* 2013; Rossiter, 1947). However, *E. calycina* was found to be able to survive the removal of up to 80% of its aboveground biomass (van der Westhuizen and Joubert, 1983), suggesting it can tolerate a certain degree of grazing, a finding similar to other studies (DiTomaso *et al.,* 2013; Rossiter, 1947).

The objective of this measure is to mitigate the impacts and control populations of this species.

SCALE OF APPLICATION

There are no specific recommendations for the scale at which grazing can be used.

EFFECTIVENESS OF THE MEASURE

Ineffective.

Grazing is only infrequently mentioned as a control method for *E. calycina*, and it has been suggested that this species is somewhat tolerant of grazing (DiTomaso *et al.,* 2013; van der Westhuizen and Joubert, 1983). Seeds of this species may also be dispersed in animal dung (Newsome *et al.,* 2008).

EFFORT REQUIRED

This species appears more sensitive to grazing during its flowering period (Rossiter, 1947), which is during spring to mid-summer (University of California, Berkeley, 2018; Western Australian Herbarium, 1998).

RESOURCES REQUIRED

This measure would require domestic livestock (sheep have been suggested) and staff to manage the animals. The cost of implementation is unknown.

SIDE EFFECTS

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

Grazing may not be suitable or desirable in all locations where *E. calycina* occurs (such as in certain conservation areas) and could have negative environmental effects.

ACCEPTABILITY TO STAKEHOLDERS

Unacceptable.

Due to the ineffectiveness of this measure, it is unlikely to be acceptable to stakeholders.

1 See Appendix

ADDITIONAL COST INFORMATION

Implementation costs are unknown.

Costs of inaction associated with this measure are likely similar to those detailed in the *Prevention of intentional introductions and spread* sections.

The **cost-effectiveness** of grazing for management of this species is unknown, but is likely low because of the low effectiveness of this measure.

There are no known **socio-economic aspects**.

LEVEL OF CONFIDENCE[1]

Inconclusive.

Since there is little mention of the use of grazing for *E. calycina* control, it is difficult to determine whether there is agreement in the effectiveness of this measure. More studies are needed to determine its cost-effectiveness and implementation.

Prescribed burning.

MEASURE DESCRIPTION

Fires are generally not recommended as a control method for *Ehrharta calycina* because (1) this species is able to resprout after fires (DiTomaso *et al.*, 2013), (2) fires can cause damage to non-target species (DiTomaso *et al.*, 2013), and (3) *E. calycina* tends to increase in abundance with increased fire frequency (Milberg and Lamont, 1995). However, intense fires can also kill off a large portion of this species' seedbank because most of its seeds accumulate in the topsoil (Smith *et al.*, 1999). Although fire does not stimulate germination of this species (Smith *et al.*, 1999), seedlings that emerge after fires can be controlled with herbicides (Western Australian Herbarium, 1998).

The objective of this measure is to mitigate the impacts and control populations of this species.

The spikelets are 5–8 mm long and 3-flowered; the 2 lower florets are sterile, covered with long shaggy hairs and have a mucro (sharp apical point). Glumes are nearly as long as the spikelet and red to purple. © Harry Rose. CC BY 2.0.

SCALE OF APPLICATION

It is unknown at what scales burning could be applied.

EFFECTIVENESS OF THE MEASURE

Neutral.

There are no studies to assess the effectiveness of this measure.

EFFORT REQUIRED

The effort required is unknown.

RESOURCES REQUIRED

Staff trained in managing prescribed burns, firefighting equipment, fuel to ignite fires. Costs are unknown.

SIDE EFFECTS

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

There may be negative environmental effects since non-target species could be killed during prescribed burns. There could also be negative social and economic effects if fires burn out of control.

ACCEPTABILITY TO STAKEHOLDERS

Unacceptable.

At present this measure is unlikely to be acceptable to invasive species managers because of a lack of evidence for its effectiveness. The general public is also likely to be wary of fires, especially if these are near to where people live or work.

ADDITIONAL COST INFORMATION

Implementation costs are unknown.

Costs of inaction associated with this measure are likely similar to those detailed in the *Prevention of intentional introductions and spread* sections.

1 See Appendix

The **cost-effectiveness** of prescribed burns for management of this species is unknown.

There are no known **socio-economic aspects**.

LEVEL OF CONFIDENCE[1]

Inconclusive.

There are a very limited number of studies that have investigated the use of fire for controlling *E. calycina*. It is not known how effective this measure is, what the costs are likely to be, and how this measure should be implemented.

1 See Appendix

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Appendix

- **Well established:** comprehensive meta-analysis or other synthesis or multiple independent studies that agree. Note: a meta-analysis is 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.
- **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.

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