

Proposal for the Biological Control of *Egeria densa* in Small Reservoirs: A Spanish Case Study

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INTRODUCTION

Egeria densa Planchon (*Hydrocharitaceae*), commonly known as Brazilian elodea or common waterweed, is a submersed perennial plant species native to south-eastern America. The original geographical distribution of this species is believed to have extended from Minas Gerais in Brazil to the estuary of the River Plate. Today its naturalized range is much more extensive as a result of the plant trade, having been sold worldwide as a water “oxygenator” plant for aquaria and ornamental ponds.

The ecology of *E. densa* has been thoroughly reviewed by Yarrow et al. (2009), who discuss its biological characteristics, environmental factors affecting its growth, and positive and negative roles it can play in aquatic ecosystems. They identify *E. densa* as an “ecosystem engineer,” given its role in stabilizing sediment and reducing turbidity and its important role in trophic dynamics: however, they highlight its invasiveness when the growth conditions are favorable. They report the optimum range of temperatures for *Egeria* growth is between 16 and 28 C according to the work done by Barko and Smart (1981), and that it does not tolerate freezing. Some genotypes can thrive at 35 C, and others are capable of overcoming very cold winter temperatures, even waters with a cap of ice (Haramoto and Ikusima 1988). The invasiveness of *E. densa* is explained by Yarrow et al. (2009) as being the result of “relatively fast growth rate, acclimatization to different light regimes, flexible nutrients uptake from water column and sediments, high productivity in low-medium nutrient environments, high phenotypic plasticity, high dispersal via vegetative fragments and high potential to colonize disturbed areas.”

At present, *E. densa* is included by the Invasive Species Specialist Group (ISSG) of the Species Survival Commission of the International Union for Conservation of Nature (IUCN)-World Conservation Union in the database of global invasive species (GISD 2009), although it is not in their top 100 list. According to Yarrow et al. (2009), the presence of *E. densa* outside its original distribution area has been reported since 1893 (Long Island, NY, USA); the first record in Europe dates back to the second decade of the 20th century

(Germany). These authors state that *E. densa* is currently naturalized in at least 27 countries around the world in subtropical and temperate regions. In an assessment of the risk posed by *Egeria* as a pest plant in Australia (Csurhes et al. 2008), some features and invasiveness indicators of *E. densa* are given a score; for example, the mark for its ecological adaptation to lentic and lotic environments is 3 (in a range of 0-3), accidental dispersal is 3 (range 0-3), cloning is 5 (range 0-5) and impact in water use is 2 (range 0-2).

Extensive research has been done on methods of controlling *E. densa*. Overviews of the latest developments in this field can be found in Yarrow et al. (2009), Csurhes et al. (2008) and GISD (2009). As with any other weed, possible control options involve physical, chemical, or biological methods. Physical removal is a very short term solution because *Egeria* quickly spreads again through fragmentation. Chemical control can be achieved with copper and herbicides such as diquat and fluridone; however, the impact on the aquatic ecosystem (i.e., accumulation in sediments, bioaccumulation or water contamination, and other outcomes that may limit the use of the water) are matters of some concern. As for biological control, two different agents have been reported as biological control organisms in the literature. One is a fungus (*Fusarium* sp.) that damages *E. densa*; research is currently being conducted on this in Brazil. The alternative is a fish, the grass carp (*Ctenopharyngodon idella*), which can feed on the plant. In some parts of the world, however, this fish is not welcomed because it is considered to be noxious. On the whole, it can be said that control of *E. densa* is currently difficult. Csurhes et al. (2008) state that: “Once *E. densa* has become established, eradication is generally impossible.”

The presence of *E. densa* in Spain is relatively new. It was reported for the first time as a naturalized species by Cirujano et al. (1995), who referred its presence in Valencia (eastern Spain). However, specimens have been collected from the Retiro Park pond in Madrid, Spain, since as early as 1912 (Cirujano 2009). Other areas in Spain in which *E. densa* have been recorded are Catalonia in 1996 (eastern Spain), the Basque country in 1999 (northern Spain), Galicia in 2005 (northwest Spain) and Seville in 2009 (southern Spain; Gros et al. 2009). Observations about *E. densa*'s invasiveness in Spain are very recent. In fact, this species was not quoted in 2001 in the Spanish catalogue of allochthonous invasive plant species (Sanz-Elorza et al. 2001).

Concerns about the invasive potential of plant species in the Spanish region of Galicia (northwest Spain) have only re-

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cently arisen (Romero 2007). Regarding the issue of invasive plant species, the government of Galicia has recently edited a reference book on the biology, distribution and control methods of high-risk invasive species in Galicia (Xunta de Galicia 2007). *Egeria densa* is one of 32 invasive species described in that work, although its presence in Galicia is reported only for a few coastal locations (Caldas de Reis, Ribadumia, Vilanova de Arousa) in the province of Pontevedra. The Xunta de Galicia (autonomous government of Galicia) aims to prevent the spread of the invasive exotic plant species and grades *E. densa* in the highest risk category as a result of its impact on affected habitats and because of the difficulty of its control.

This work reports the case of an *E. densa* invasion of a private reservoir located in Pontevedra (Galicia, northwest Spain). The results of physical and biological control methods are discussed in relation to the plant fraction and compositional characteristics.

MATERIALS AND METHODS

The subject of this case study is located in the coastal municipality of San Juan de Poyo of Pontevedra (Galicia, northwest Spain) and involves a family-run nursery specialized in woody ornamental plants (perennials and shrubs) for local customers. The nursery has a surface area of nearly 5 ha.

Nursery facilities include a small reservoir for irrigation purposes sited at 42°26'53"N, 8°41'7"W. The reservoir was constructed of reinforced concrete in the shape of an inverted truncated pyramid with a maximum depth of 9 m, an almost round-shaped surface, a square bottom of 17.5 m side length, and a capacity of 1700 m³. Inflow water comes from the nearby river (Arrancada River). In addition to rain water, it also receives drainage water from the nearby surroundings, taking advantage of the topography.

The reservoir has been in continuous operation since the 1970s. When it is needed to irrigate the nursery, water is pumped from a depth of approximately 4 m by sprinkler irrigation. The water quality is good for irrigation because foliar damage to ornamental plants has never been noticed. Fine suspended solids and sediments are estimated to be at a depth of >6 m.

Egeria densa was almost certainly introduced into the nursery by the plant trade. It is a popular ornamental species in small garden ponds, and the nursery has grown aquatic plants for sale for small ponds for many years. However, the introduction of *E. densa* into the reservoir was accidental, a side-effect of the voluntary introduction into the reservoir of some plants of *Eichhornia crassipes* (Martius) Solms (waterhyacinth) for ornamental purposes. It is believed that imperceptible fragments of *E. densa* were intertwined with the *Eichhornia* roots and once introduced in the reservoir started to grow. According to the nursery owner, that could have happened about 15 years ago.

The extent of the infestation became serious about 7 years ago. To explain the reasons, a comparison was carried out between the climate of Pontevedra and the climates of well-known locations within the original geographical distribution area of *Egeria*, using climate data available in official databases. The invasion did not represent any problem for the

surrounding natural environment because the reservoir does not release water into any watercourse. However, the amount of *Egeria* biomass present was a problem for the running of the nursery because it affected both the quality of the water and the functioning of the pumps and sprinklers.

Physical control was carried out in four consecutive years. Once per year the *Egeria* biomass was removed by dragging with the help of a 1.5 m wide (working width), ad-hoc designed rake. In the fifth year, another completely unplanned method was used. Two domestic white Peking ducks (*Anas platyrhynchos*) were put in the reservoir precinct, and during the next few years it was observed that they liked *Egeria* as a food. To learn the feeding value of *E. densa*, the tips, leaves and stems were analyzed for nitrogen and fibre content. Dry matter content and the ratio of shoot length to shoot weight were also determined as additional descriptive parameters. The nitrogen (N) content was determined by elemental analysis (Fison CHN analyzer) using three replications per sample. Fibre content was determined by sequential extraction in a Fibertec™ System M (FOSS) according to the sequential extraction by Goering and Van Soest (1970).

RESULTS AND DISCUSSION

In the Spanish context, the climate in Pontevedra is regarded as mild and rainy. According to Rivas-Martinez (2009), its bioclimate is the Temperate-Oceanic (Sub-Mediterranean) type, its thermic type is Thermotemperate and the ombrothermic type is Humid. The values for the average year are: mean temperature (tm) 14.6 C; mean maximum temperature (tmax) 19.0 C; mean minimum temperature (tmin) 10.2 C; annual rainfall (pp) 1595 mm. The warmest months are July and August, with a mean temperature of 20.3 C and a mean value for the absolute maximum temperatures (T) of 32.8 C. The coldest month is January, with a mean temperature of 5.9 C and a mean value of absolute minimum temperatures (t) of 0.0 C. In addition, the range of temperatures reported by Yarrow et al. (2009) for *Egeria* shows that the climate of Pontevedra is suitable for this species and explains the invasion in the nursery reservoir.

Physical control of *Egeria* undertaken once a year over a period of 4 years by means of biomass removal was utterly ineffective; indeed, removal seemed to enhance the growth of waterweed. The structural characteristics of *Egeria* (sparsely branched, with long, flexible and tender shoots) and its easy vegetative reproduction gave rise to skeins of biomass that made its eradication difficult because it favored stem fragmentation. Nonbranched pieces of shoots between 60 and 70 cm long were taken to determine the dry matter content and the shoot length to weight ratio. Dry matter content was on average 8.43% (coefficient of variation 13.0%). The length to weight ratio was 14.0 cm/g fresh matter (c.v. 28.4%) or 164.2 cm/g dry matter (c.v. 18.2%). Boettcher (2007) studied the biomass production of *E. densa* in the Valdivia region (Chile), where the bioclimate is Temperate Hyperoceanic (Rivas-Martínez 2009). She reported a green biomass peak (green leaves + stems) of 433.6 g d.m./m². If we extrapolate that figure to Pontevedra, it would mean a maximum of 712 m shoots/m², a figure that illustrates the "skein" feature of *Egeria*.

TABLE 1. CONTENT OF *EGERIA DENSA* PLANCHON IN CRUDE PROTEIN (CP), NEUTRAL-DETERGENT FIBRE (NDF), ACID-DETERGENT FIBRE (ADF) AND ACID-DETERGENT LIGNIN (LAD). VALUES IN % DRY MATTER.

Source	CP	NDF	ADF	LAD
Maurice et al. 1983 ⁽¹⁾	13.0	—	25.9	—
McDowell et al. 1990 ⁽¹⁾	12.51	36.96	28.65	—
Marques et al. 1999 ⁽¹⁾	16.4	44.7	36.08	—
Oliveira et al. 2004 (<i>Egeria</i> hay)	13.35	40.46	27.38	—
Dillon et al. 1998 (sun-dried <i>Egeria</i>)	13.00	—	25.90	—
Corrêa et al. 2003 (fresh <i>Egeria</i>)	15.8-16.0	—	—	—
This article ⁽²⁾ :				
- Tips	26.44 (1.1)	41.25 (10.8)	20.46(9.6)	11.32 (28.2)
- Leaves	30.41 (1.3)	40.00 (0.8)	26.21(0.9)	15.07 (3.0)
- Stems	16.61 (0.7)	34.88 (2.5)	23.30 (1.6)	10.09 (20.4)

⁽¹⁾Cited by Oliveira et al. 2004.

⁽²⁾Coefficient of variation figures in brackets.

Unlike the mechanical removal method, the ducks did prove effective in the control of *Egeria*; although they did not fully eradicate the waterweed they provided a sustainable method to control its growth. The behavior of the ducks in the reservoir was observed periodically. When feeding, the ducks preferred the tender parts of *Egeria* biomass (i.e., the tips and leaves); they also pulled on the shoots to remove the leaves, leaving pieces of stems without leaves in the water, which then decayed.

A bibliographic search carried out for this work did not produce any previous reports on ducks as a biological control agent of *Egeria*. Note, however, that the diet of the black-necked swan (*Cygnus melanocoryphus*), which is in the same family as the domestic duck (*Anatidae*), depends on *E. densa* (Corti and Schlatter 2002). Moreover, some authors have studied the potential value of waterweed as a feed ingredient to use the residual biomass resulting from the mechanical control of *Egeria* (Dillon et al. 1988, Corrêa et al. 2003, Oliveira et al. 2004). Common evaluation parameters of feeding value are the content in crude protein (CP) and in fiber.

In our current work, the shoot tips, leaves and stems of *E. densa* (the green biomass) were analyzed separately for their content in CP, neutral-detergent fibre (NDF), acid-detergent fibre (ADF) and acid-detergent lignin (ADL). For the purpose of biomass partitioning, “tip” was the apical shoot portion in which the distance between consecutive leaf whorls was <4 mm, and “stem” was the other part of the green shoot deprived of leaves. The CP, NDF, ADF and ADL results and the values are reported in the literature (Table 1). The stem content in CP was similar to the values reported for fresh waterweed by Corrêa et al. (2003); the tips and leaves were much richer in CP as a result of their high N content (4.2-4.9% N). The tips and leaves contained significantly more protein ($p < 0.0001$) and hemicellulose (NDF-ADF; $p < 0.050$) than the stems, which contained more cellulose (ADF-LAD). Ducks in this case study liked the tips more than the leaves, and both the tips and the leaves more than the stems, which can be attributed to the differences found in protein and fibre content.

This case study is the first record of *Egeria densa* Planchon in the municipality of San Juan de Poyo (Pontevedra, northwest Spain). The introduction of this exotic, invasive plant

species into the study reservoir was a side effect of the ornamental plant trade of the nursery that operates the reservoir. Climate conditions favoured the growth of *Egeria*, giving rise to the presence of a huge amount of plant biomass in the reservoir water and subsequent problems in the irrigation system. As other authors have reported previously, physical control by means of biomass removal is normally ineffective and, in this case, seemed to enhance the plant growth. *Egeria* formed skein-like masses of shoots in which the length to weight ratio reached values of 14.0 cm/g fresh matter and 164.2 cm/g dry matter. However, the effect of the introduction of white Peking ducks in the reservoir precinct provided a reasonable control of *E. densa*. The ducks preferred the tender parts of *Egeria* biomass, namely the tips and leaves; they also deprived the shoots of their leaves, leaving pieces of stem in the water, which finally decayed. The ducks liked the *Egeria* tips and leaves more than the stems, which could be attributed to the differences found in the protein and fibre content of those plant fractions. The average contents of tips and leaves in crude protein, hemicellulose and cellulose were 28.4%, 17.3% and 10.1%, respectively, versus the mean values of 16.6%, 11.6% and 13.2% found for the stems. From the results of this case study, ducks seem to be a feasible new biological control agent for *E. densa* in small reservoirs, but further studies are needed to determine the potential of this possible control agent and its effects on other plant species.

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