

## Aquatic Invasions Records

## First report of an invading population of *Colocasia esculenta* (L.) Schott in the Iberian Peninsula

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### Abstract

*Colocasia esculenta*, or taro, is an emergent aquatic and semi-aquatic plant, native to Asia, which is cultivated for its edible corm in several parts of the world. This species has colonized or invaded wetlands and rivers in different parts of the world (e.g., Southeast USA, Southwestern Australia, Southern Africa, etc.) thus suggesting that early detection of this species should be conducted. Here we present the first report of an invasive population of *C. esculenta* in the Iberian Peninsula (Southern Europe). Characteristics of the patches found that serve as an early diagnosis of the degree of invasion and the origin of introduction are given. The current population consists of a number of patches that are heterogeneously distributed along the stream (ca. 7 km). Monospecific Taro patches displace native species and provoke the narrowing of river sections, similar to rivers and wetlands in Australia or the United States where this species is considered an invasive plant. This new record also suggests the ability of this tropical species to withstand the long dry summers typical of the Mediterranean climate within permanent streams.

**Key words:** *Colocasia esculenta*; Iberian Peninsula; Spain; invasion; freshwater stream

### Introduction

*Colocasia esculenta* (L.) Schott (taro, elephant ear or cocoyam), is an emergent, perennial, aquatic and semi-aquatic herbaceous species of the Araceae family, native to Asia (between Myanmar and Bangladesh) (Plucknett 1976). In its native range, *C. esculenta* colonizes tropical areas with high rainfall (1,800–2,500 mm) and warm temperatures (25–35°C). This plant usually colonizes freshwater (< 5 mM NaCl) wetlands, but can also grow in dry lowland environments (Fujimoto 2009). The salinity tolerance threshold (95% of maximum growth) is 4 mM NaCl (Hill et al. 1998).

Taro is a traditional root crop of the tropics grown for its edible corms and leaves. It is one of the earliest crop plants used as food in the Solomon Islands and New Guinea where it has been used for more than 10,000 years (Loy et al. 2002). Nowadays, *C. esculenta* is considered the fifth most consumed root vegetable worldwide

(Rao et al. 2010). It is also used as an ornamental plant (Wirth et al. 2004). As a consequence, Taro has been transported around the world, thus favouring the plant's eventual dispersal outside cultivable or gardened areas. Taro has been found naturalized, for example, in the Galapagos Islands (Tye 2001), in different parts of Africa (Cufodontis 1953–1972; Henderson 2007) and in the Canary Islands (García-Camacho and Quintanar 2003; Kunkel 1975). Invaded wetlands and rivers from different continents have been reported in southeast USA (Florida, Alabama, Mississippi, Louisiana and Texas) (Atkins and Williamson 2008; FLEPPC 2000; Visser et al. 1999), some Hawaiian islands (Wester 1992) and Australia (including Western Australia, Queensland and New South Wales) (Brown and Brooks 2003). In Texas and Southwest Australia, extensive stands of elephant ear alter the vegetation composition, structure and dynamics of riparian plant communities. These consequences have led to the implementation of management actions to

control invasive populations (Atkins and Williamson 2008; Brown and Brooks 2003).

The history of invasion elsewhere in the world recommends the early detection of new records for this species. The objective of this paper is to report the first record of *Colocasia esculenta* in continental Europe and to assess the incipient degree of invasion to provide a basis for management.

## Material and methods

### Area of study

This study was carried out in the province of Seville (Southern Spain), as part of the search for new exotic species carried out by the Regional Andalusian Government (Consejería de Medio Ambiente). The area has a Mediterranean climate, with a wet season from October to April and a dry season from May to September. Mean temperature and rainfall is 18.6°C and 534 mm, respectively. In this area, *C. esculenta* was first found in June 2008, colonizing a permanent, freshwater stream (Hornillo stream, N37°14.4', W5° 58.7', 20 m.a.s.l., water conductivity = 925-1058  $\mu\text{S cm}^{-1}$ ) near the city of Dos Hermanas. In this locality, *C. esculenta* grows within a gallery forest dominated by *Populus nigra*, *P. alba*, *Olea europea* var. *sylvestris*, *Typha* sp., *Mentha suaveolens*, *Phragmites australis* var. *australis*, *Iris pseudacorus* and *Polygonum salicifolium*. A sample of leaves, petioles, flowers and corm was deposited at the Herbarium of the Department of Vegetal Biology of the University of Málaga (Spain) (MGC-Cormof 73470).

### Species description

Taro shows numerous leaf stems sprouting from the upright tuberous root stock, or corm. Large dark green velvety leaves (60 cm long and 35 cm wide) are supported by thick succulent leaf stalks (petioles), with colouring from green through red to a deep purple (Figure 1). Stalks are attached near the centre of the leaf base. Under ideal growing conditions, a single plant can grow up to 2.4 m tall with a similar spread in width. Reproduction of elephant ear is mostly vegetative, and occurs when whole corms divide in winter or early spring. Only a portion of the corm crown and petiole is needed to establish a new plant. Taro can also reproduce by cormels (tiny offsets from the mother corm) and by

stolons around 1 metre long with cormels on the end (Onwueme 1999). Inflorescences and reproduction by seed are rare in natural conditions (e.g., Lebot et al. 2004). Inflorescences are light yellow in colour and occur on a shorter stem. They show a free spadix that protrudes above the neck of the spathe, with a very short (sometimes reduced or vestigial) sterile appendage (Figure 1d,e).

### Population characterization

The population was characterized in July, 2011. The whole stream (7.1 km) was explored on foot along the shore in search of *C. esculenta*. Each plant patch found was GPS positioned and their total size (surface) measured. Within each patch, the plant cover and the height of  $n = 10$  plants within the patch were measured by using a portable hard meter (allowing the measurement of those plants with partially submerged stems). Other wetlands located downstream (such as Natural Reserve Brazo del Este) were also explored to detect other patches of *C. esculenta*.

### Statistical analysis

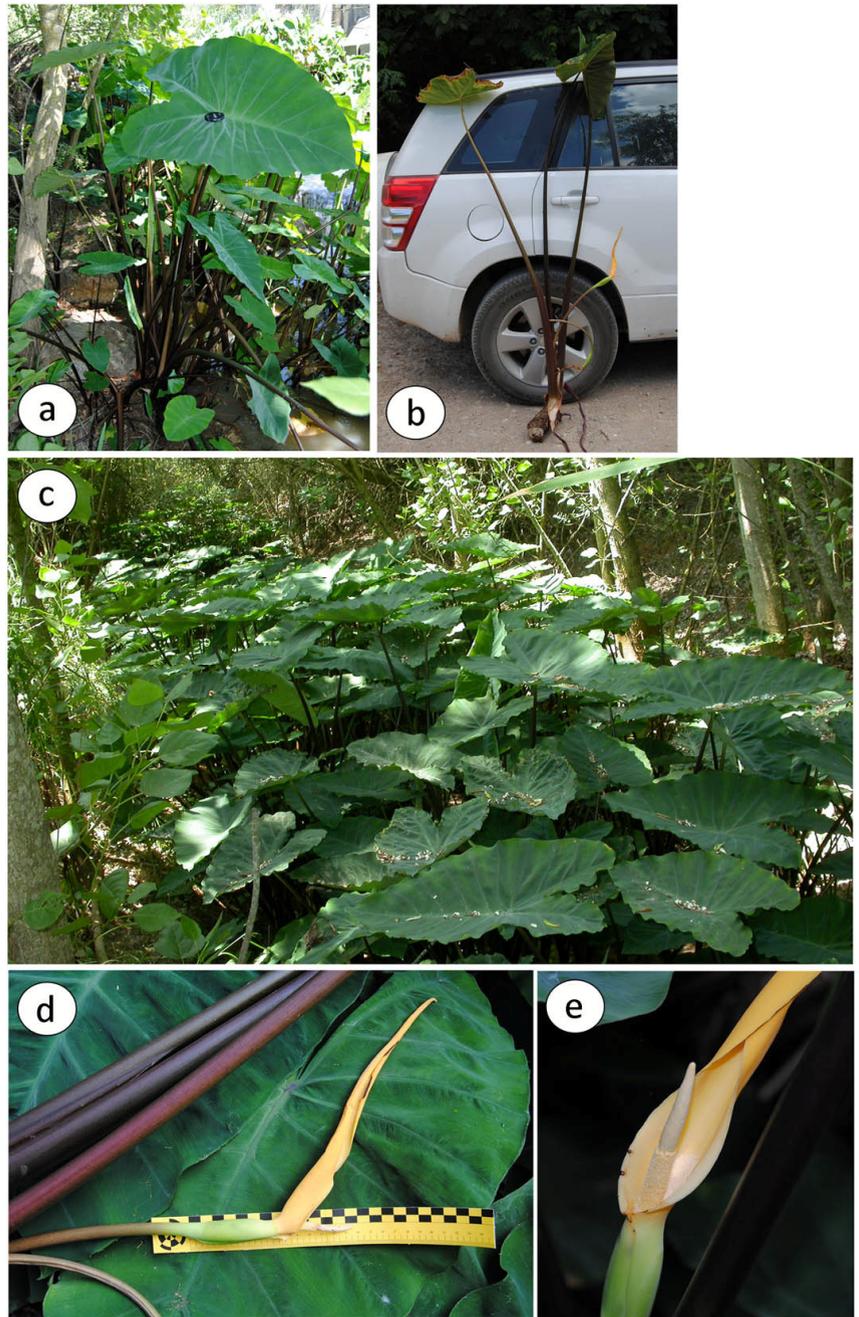
Plant height data were tested for a normal distribution by a Kolmogorov-Smirnov test. As data were not normal, the Spearman's rank correlation coefficient ( $\rho$ ) was analysed in search of statistical dependence between plant height and stream distance. A significant correlation was considered when  $P < 0.05$ .

## Results and discussion

*Colocasia esculenta* completely covered different patches of the river course and shores (Figure 1a, c), growing in both sun-exposed areas and shadowed zones. To our knowledge, this is the first record of an invading population of *C. esculenta* in the Iberian Peninsula and Continental Europe, as only naturalized patches have been documented in the Canary Islands (García-Camacho and Quintanar 2003; Kunkel 1975).

The population consisted of patches of different sizes and cover, including two monospecific patches of 200 and 800  $\text{m}^2$  in the first 260 m of the stream and a number of dispersed, low density patches of 10-77  $\text{m}^2$  in the 6500 m thereafter (Figure 2a). In total, all patches summed an effective area (total size of

**Figure 1.** Aspect of *Colocasia esculenta* in Hornillo stream. Leaves and petioles of *Colocasia esculenta* (a-b). Dense stands of *Colocasia esculenta* completely invading the stream (c). An inflorescence (d), and a detail of the spathe and flower tenon, with the spadix sterile at the apex (e). Scales: (a) the camera lens cap on the leaf is 0.05 m in diameter; (b) the height of the vehicle shown is 1.6 m; (d) the yellow scale is 0.25 m.



the patch colonized  $\times$  % plant cover within the patch) of 1600 m<sup>2</sup>, thus suggesting a recent invasion. The current pattern of patches distribution suggests that the invasion initiated in the northern limit (N37°14.4', W5°58.7') and that invasion edge corresponds to the lower stream, at ca. 6500 m from the northern limit.

The size of plants within patches showed a significant decrease ( $\rho = -0.543$ ,  $P < 0.001$ ) downstream (Figure 2b), supporting the hypothesis that the initial introduction occurred upstream. This northern limit of the stream is besides a private pond, where taro was probably used as an ornamental plant.

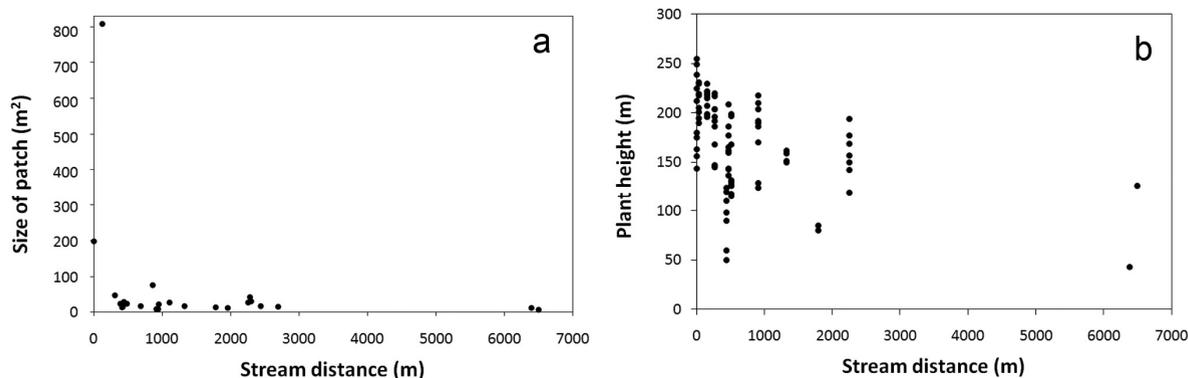


Figure 2. Distribution of *Colocasia esculenta* patches (a) and height of plants (b) along the stream.

After visiting the locality in the different seasons, flowering was found to occur in early summer (July) (Figure 1d) but comprised only a minor percentage of the population (<1%), coinciding with the flowering pattern under native, natural conditions (e.g., Pardales 1981). In fact, since first detection in 2008, only 5 adult flowered plants growing on drier shores were observed. The dominance of vegetative reproduction is a common feature of helophyte species and is associated with the maintenance of species in one site (e.g., under stable water levels). In contrast, sexual reproduction is more important for the colonization of new sites (e.g., during low water levels) (Álvarez et al. 2005; Barrat-Segretain 1996). This general pattern agrees with the presence of flowers on drier shores, where vegetative reproduction by corm propagation may be inefficient and might encourage an energy investment in flowering.

The widespread use of *C. esculenta* as a food source contrasts the small number of documented cases of invasion. This would suggest a relatively low invasive potential than other aquatic or helophyte species native to tropical and subtropical climates that have had less extensive human use but represent some of the most severe cases of biological invasions (such as *Eichhornia crassipes*, *Pistia stratiotes* or *Arundo donax*). However, this small number of invasive records may be the result of the fact that in Taro production areas (e.g., Africa, Asia and the Pacific; Rao et al. 2010) invasive processes may have received less attention (Pyšek et al. 2008). In any case, three pieces of evidence (either empirical or theoretical) suggest the

utility of detecting -and eventually managing- incipient invasive populations of *C. esculenta*: (1) our results show monospecific patches displacing native species (e.g. *Mentha suaveolens*, *Iris pseudacorus*, *Polygonum salicifolium*) and the narrowing of river sections, similar to other scenarios in Australia or United States; (2) rivers and wetlands are highly vulnerable habitats to invasion (Hood and Naiman 2000) and their conservation has been recognized as a priority (e.g. European Water Framework Directive 2000/60, Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat, Council Directive 92/43 on the conservation of natural habitats and of wild fauna and flora); (3) costs derived from invasive weed control increase as the invader spreads and eradication becomes expensive and often unfeasible (Myers et al. 2000).

Interestingly, native tropical climates supporting *C. esculenta* (Cook 1985) clearly differ from the climate present in the locality here reported. This suggests its ability to withstand the long dry summers typical of the Mediterranean climate within permanent streams. Therefore, further studies on its potential invasion in freshwater wetlands in the Mediterranean basin are recommended.

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