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Willdenowia
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New information on the status and distribution of *Callitriche pulchra* (*Plantaginaceae*), including a first record from Cyprus

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Abstract: New information has extended the known range of *Callitriche pulchra* Schotsm. (*Plantaginaceae*) to Cyprus. This, combined with a survey of populations on the island of Gavdos off the S coast of Crete, shows that it is less threatened than previously thought. Updated information is presented here on the distribution, status and ecology of this species.

Key words: *Plantaginaceae*, *Callitrichaceae*, *Callitriche*, *Callitriche pulchra*, beautiful water-starwort, Libya, Cyrenaica, Greece, Crete, Kriti, Gavdos, Cyprus, distribution, ecology, conservation, IUCN Red List

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Introduction

Callitriche pulchra Schotsm. (*Plantaginaceae*) was described by H. D. Schotsman (1967), based on specimens collected on the island of Gavdos off the S coast of Crete (Kriti) in 1904 (*Dörfler 45*, W) and 1951 (*Rechinger 9503*, W) and, only 240 km to the south, near Benghazi in the Cyrenaica region of Libya in 1916 (*Pampanini 746*, FI) and 1917 (*Pampanini 230*, FI; Pampanini 1917) and near Lamluda in 1933 (*Pampanini 4744*, FI) and 1934 (*Pampanini & Pichi-Sermolli 4745*, FI) (Schotsman 1967; herbarium codes according to Thiers [continuously updated]). Pampanini (1917) cited two of his specimens (as *C. truncata* Guss.): "Stagno temporaneo durante le stagione delle pioggie, sopra un lastrone di roccia dietro le Due Palme; febbraio 1916 (n. 746), e marzo 1916 (n. 230)", of which specimen no. 746 was presumably not seen by Schotsman. Schotsman (1969) reported that *C. pulchra* had been found by "Madame Bischler" and "Madame Jovet-Ast" in three pools between Derna and Bayda in Cyrenaica in 1968: "Près de Derna, route côtière en direction de Ras el Hilal, dans une cuvette de rocher profonde de 20 cm. Avec de jeunes exemplaires d'*Elatine*; entre Beida et Labragh, à 3–4 km W de Labragh, dans des mares peu profondes; 12 km à l'est de Labragh, entre Labragh et El Gubah, dans une mare d'eau gluante. Avec *Elatine* spec. et de jeunes exemplaires de *Limosella*. Un autre *Callitriche*, probablement *C. brutia* Petagn. s'est mêlé entre les brins de *C. pulchra*." Schotsman (1969) noted that she was sent material from

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(at least) one of these collections, but it is not clear whether she preserved any of this material. No specimens of *C. pulchra* were located during work at the Museum National d'Histoire Naturelle (P) by RVL in 2002. The lack of detail regarding the locations from which specimens were collected by Pampanini and Pichi-Sermolli means that it is not possible to establish whether any of these are the same locations as those visited by Bischler and Jovet-Ast. Otherwise there have been no other records of this species from Libya and it is not mentioned in the *Flora of Libya*, which lists only *C. brutia* and *C. truncata* (Jafri 1984). Consequently and particularly in the light of the recent conflict in the region, it is not possible to be at all confident that it persists in Cyrenaica.

Between its description in 1967 and 2015, a number of botanists recorded *Callitriche pulchra* on Gavdos (Bergmeier & al. 1997; Bergmeier 2001; Vogiatzakis & al. 2009; Lansdown 2009). However, none of these provided a thorough assessment of the conservation status of *C. pulchra* on the island, and the best available information suggested that it might be limited to around 30 pools (Vogiatzakis & al. 2009). As a consequence, it was classed as Critically Endangered in the IUCN Red List (Lansdown 2012) and Greek Red Data Book (Lansdown 2009).

A new record of *Callitriche pulchra* from Cyprus in 2015 coincided with a study carried out on Gavdos to produce a comprehensive assessment of its status on that island. In this article we describe the known status, distribution and ecology of *C. pulchra*, providing details of the new sites supporting *C. pulchra* on Cyprus and new information on the size and extent of the population on Gavdos.

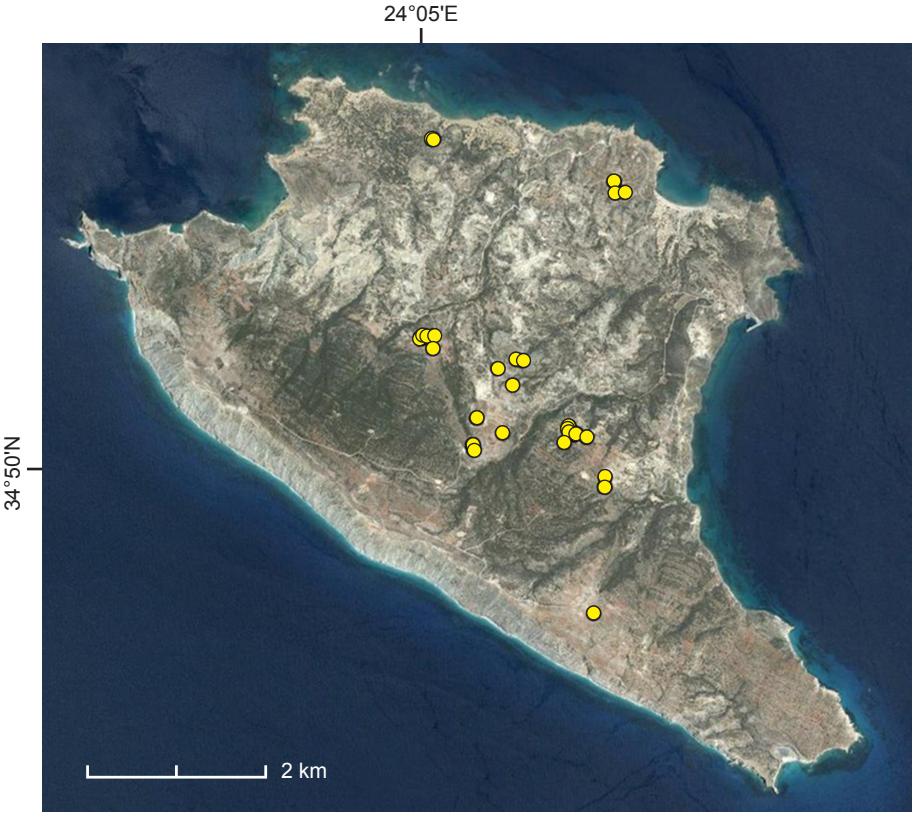


Fig. 1. Distribution of *Callitriche pulchra* on Gavdos. – Map generated with Google Earth.

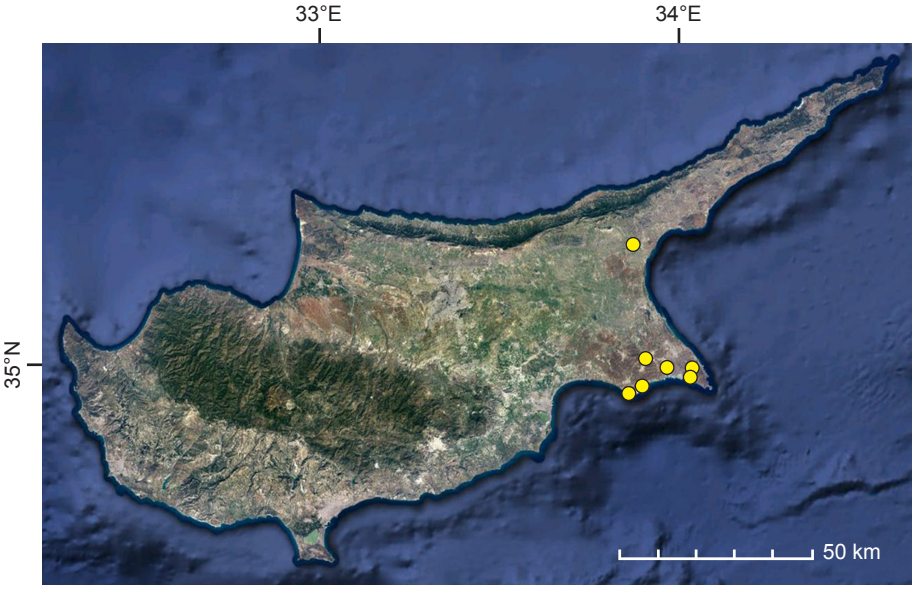


Fig. 2. Distribution of *Callitriche pulchra* on Cyprus. – Map generated with Google Earth.

Status and distribution

Callitriche pulchra has not been reported from Cyrenaica since 1969 when Bischler and Jovet-Ast carried out surveys of a number of water bodies in the area. There is an urgent need to assess the current situation of cupular pools in limestone pavement in Cyrenaica.

The populations of *Callitriche pulchra* on Gavdos (Fig. 1) and in Cyrenaica remained the only known populations

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Fig. 3. Cupular pool complex supporting *Callitriche pulchra*. – Greece, Gavdos, Agios Panteleimonas, 20 Mar 2015, photograph by Richard V. Lansdown.



Fig. 4. Cupular pool supporting *Callitriche pulchra*. – Cyprus, Protaras, Fanos, 16 Feb 2014, photograph by Kyriakos Kefalas.

until 2014, when populations were found on Cyprus (Fig. 2). The species is now known to occur at seven locations in the E part of Cyprus, mostly in the Kokkinochoria area and rarely in the E part of the Mesaoria plain (phytogeographical divisions 4 and 5). It was first discovered in 2011 by KK at Fanos hill near Paralimni and collected there in 2014. Subsequently, extensive surveys in January–February 2016 located another six populations, as follows: Division 4: Fanos, Protaras, rock pools, 160 m, 16 Feb 2014 & 19 Feb 2016, *Kefalas 6174* & *6555* (CYP) (Fig. 4); Kavallos, Frenaros, rock pools, 60 m, 8 Jan 2016 & 15 Feb 2016, *Kefalas 6511* & *6547* (CYP); Between Agia Napa and Cape Greko, rock pools, 50 m, 13 Jan 2016, *Kefalas 6523* (CYP); Potamos Liopetriou, rock pools, 0 m, 15 Jan 2016 & 23 Feb 2016, *Kefalas 6532* & *6562* (CYP); Agios Antonios, Sotira Ammochostou, rock pools, 110 m, 24 Feb 2016, *Kefalas 6569* (CYP); Division 5: NW of Trikomo, rock pools, 50 m, 13 Feb 2016, *Kefalas 6540* (CYP). *Callitriche pulchra* is now known from a total of 26 pools in seven complexes at Fanos hill (six pools), Agia Napa (six pools), Agios Antonios near Sotira Ammochostou (two pools), Frenaros (three pools), Potamos Liopetriou (seven pools) and Cape Pyla (one pool) in the Kokkinochoria area, as well as near Trikomo (one pool) in the E Mesaoria plain. The species was unsuccessfully sought in other areas with cupular pools in limestone pavement at Cape Greko, Cape Elea and Koma tou Gialou on the Karpasia peninsula. It could occur in the E, C and W parts of Cyprus such as Kavo Greko, Karpasia peninsula, Morfou area and Akamas peninsula. Further surveys are needed to clarify the distribution and population on Cyprus.

In 2015, the plants of over 300 pools on Gavdos were documented by RVL and IB. *Callitriche pulchra* was found in 101 of these, in nine of a total of 13 separate pool complexes (Lansdown unpubl.a) (Fig. 1 and 3). It occurs more or less throughout the island, except for the W paleo-beach area, which is mainly dominated by broken ground, and the E extreme of the island, E of Vatsiana, which includes little or no limestone pavement. Specifically, it occurs throughout the island wherever areas of limestone pavement are exposed in blocks greater than 40–50 m^2, except at Ambelos and Sarakiniko.

The global range of *Callitriche pulchra* is now known to extend from the Cyrenaica region of Libya in the south, north to Gavdos off the S coast of Crete and east to the E tip of Cyprus. The discovery of this species on Cyprus increases the likelihood that it will be found on other Mediterranean islands.

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Ecology



Fig. 5. *Callitriche pulchra*, fruiting plant. – Greece, Gavdos, Agios Ioannis, 22 Mar 2015, photograph by Richard V. Lansdown.

Callitriche pulchra is known only from cupular pools varying from 0.2–7 m in diameter and 0.1–0.5 m deep from sea-level to 350 m altitude in karstic, limestone pavement in the Mediterranean, and its distribution appears to be almost entirely dictated by the availability of such pools. It is an obligate aquatic, although it is capable of surviving for a short while after the pools in which it grows dry out; it does not appear to grow or produce new flowers during this period. The pools are temporary: on Gavdos they start to fill during winter rains in October or November and dry out in April as temperatures start to rise; on Cyprus the pools typically dry out in March.

On Gavdos, nine other taxa occurred in more than ten pools supporting *Callitriche pulchra* (the percentage of pools in which they occurred is given after the name): unidentified grasses (77.8 %), *Nostoc* sp. (70.8 %), *Crassula vaillantii* (Willd.) Roth (66.7 %), *Juncus hybridus* Brot. (55.6 %), *Lythrum hyssopifolia* L. (50 %), *Chara aspera* Deth. ex Willd. (42 %), *Zannichellia palustris* L. (35 %), filamentous algae (30.9 %) and *Chara vulgaris* L. (15.5 %). On Cyprus, although *C. pulchra* is usually dominant and often the only species where it occurs, it has been recorded with *Crassula vaillantii*, *Elatine macropoda* Guss., *Limosella aquatica* L., *Lythrum hyssopifolia* and *Ranunculus peltatus* Schrank, of which *C. vaillantii* and *L. aquatica* are rare on Cyprus (Tsintides & al. 2007). The most frequent associated species are all those that can survive both in water and on damp mud, as opposed to those that can only grow submerged. The pool complexes on Gavdos with the lowest percentage of pools supporting *C. pulchra* were associated with inhabited villages. However, while it is possible that nutrient enrichment has an adverse influence on the survival of *C. pulchra* and that this may be worse when it involves anthropogenic nutrients, this clearly does not fully explain the distribution of the species. The pools typically occur in areas without vegetation or with sparse phrygana vegetation growing in soil-filled hollows or breaks in the limestone pavement. Studies of the vegetation of the pools on Gavdos have proposed six different vegetation communities, ranging from the deepest to the shallowest: *Zannichellia pedunculata* Rchb. (= *Z. palustris* subsp. *pedicellata* (Wahlenb. & Rosén) Hook. f.) – *Chara vulgaris*; *Z. pedunculata* – *C. pulchra*; *C. pulchra* – *Crassula vaillantii*; *C. vaillantii*; *C. vaillantii* – *Polypogon maritimus* Willd.; and *Crassula alata* (Viv.) A. Berger – *Crepis pusilla* (Sommier) Merxm. (Bergmeier 2001; Vogiatzakis & al. 2009). *Callitriche pulchra* is listed as a characteristic component of two of the deeper pool types in association with other species that can only survive completely submerged.

Until the discovery of *Callitriche pulchra* on Cyprus, the only *Callitriche* species recorded from the island was *C. brutia* (Meikle 1977; Hand & al. 2011+), which is also rare and classed as Endangered in the Red Data Book of the flora of Cyprus (Tsintides & al. 2007). *Callitriche brutia* and *C. pulchra* have not been recorded in the same pools, although they occur in different sites in the same area around Trikomo. Pools at Potamos Liopetriou also support the only recently discovered Cypriot population of *Marsilea aegyptiaca* Willd. (Christodoulou 2011).

Cupular pools develop in karstic limestone as rainfall that has become acidic by acquiring CO_2 from the air, collects in hollows and over long periods, dissolves away the rock to increase the depth and retention capacity of the hollow, reaching a maximum of about 50 cm depth (Bergmeier 2001). It appears very likely that the process of pool formation and subsequent succession involves gradual initiation and formation of a pool, followed by gradual deepening until either the pool succeeds to a terrestrial state or erodes through into caverns below. Sediment accumulation occurs within pools from the start and may in some cases prevent the establishment of a pool, instead leading to formation of a soil-filled hollow. Sediment depth varies very widely in the pools, but was found to not have any significant effect on the vegetation (Vogiatzakis & al. 2009). At any time, any suitable area

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Table 1. Potential threats to populations of *Callitriche pulchra* on Gavdos and their effects (from Lansdown unpubl.b).

Factor	Action	Effect
Tourism	renovation of buildings	increased pressure on pools, infilling of pools
	increased use of paths	increased filamentous algae
	increased pressure on resources	over-exploitation, destruction of pavement
Pinus brutia Ten.	acidification of water	toxic effect on *C. pulchra*, increased erosion of pools
	shading	suppressed growth of *C. pulchra*
	shelter from wind and sun	modified evaporation rate
	infilling of pools with needles	loss of all aquatic plants
Management as a water resource	physical modification of pools, boulders over pool surface, supplementation of water, addition of lime to water	loss of aquatic plants
Development	destruction for construction, destruction for servives	direct loss of pools and plants
Degradation through human activity	untreated discharge to pools	increased filamentous algae

of limestone pavement may include hollows in a range of stages of development and succession. Over very long periods, potentially of hundreds of years, all plants that occur in these pools must be able to colonize new pools as they move through this process. It is likely that the main dispersal vector for *Callitriche pulchra* is livestock, although birds may also play a role, as well as occasional flushing of seeds from uphill pools into those lower down by heavy rain.

In spite of the detailed survey on Gavdos, no assessment of the seed bank was made, and it is therefore not possible to say whether or not *Callitriche pulchra* was growing in 2015 in all the pools where it has occurred. Equally, the 2014–2015 winter was wet, and the surveys carried out in the spring of 2015 may have recorded a relatively high abundance both of pools holding water and of pools supporting *C. pulchra*.

Conservation

Callitriche pulchra occurs in a very uniform habitat type within three very restricted areas: on Gavdos and Cyprus, as well as in Cyrenaica. The relationship between availability of water in pools and growth of *C. pulchra* may be fairly critical. However, at the moment, there appears to be reasonable leeway with very extensive seed set in most years (Lansdown unpubl.a; Fig. 5). As a result, while there may be some local variation, threats to its survival are relatively uniform across its range.

The survival of the population in Cyrenaica is uncertain because the species has not been recorded from there since 1968. Three of the pool complexes supporting *Callitriche pulchra* on Cyprus (Fanos, Cape Pyla and Potamos Liopetriou) are situated in small state forest areas, protected by forestry legislation, while Potamos Liopetriou is also a Natura 2000 site, but the others are on private land and not protected. The populations on Cyprus are generally threatened by habitat loss and degradation due to land development and land-use change, as well as tourism development and forestry operations. The area around Fanos is quite disturbed, including areas of private land with scattered houses, a navy camp about 300 m to the west, an army rifle range about 200 m to the north and the cave-church of Agioi Saranta (a popular tourist attraction) below and about 100 m to the east. The pool complex at Agia Napa is also surrounded by scattered houses and is threatened by building activities and tourism development. The site at Cape Pyla is threatened by military exercises and invasion of the non-native *Acacia saligna* (Labill.) H. L. Wendl., factors that have already caused the loss of one pool. The pool complexes at Frenaros and Trikomo are situated on private land and are threatened by expansion of cultivation and agricultural activities. However, these threats are not known to be currently causing the loss of *C. pulchra* populations, and the species is unlikely to become extinct on Cyprus in the foreseeable future.

In contrast, the future of the population on Gavdos is reasonably secure, at least for the foreseeable future, due to its occurrence in a large number of pools in nine separate pool complexes. In addition, as part of the work in 2015, more than 21 000 seeds of *Callitriche pulchra* were collected by Christina Fournaraki and colleagues from the Mediterranean Agronomic Institute of Chania (MAICh), where they will be stored, except for 3000 seeds that will be stored at the University of Athens (Fournaraki & al. unpubl.). However, even on Gavdos, *C. pulchra* is potentially vulnerable to a number of threats (Table 1).

It is also likely that cupular rock pool complexes are vulnerable to climate change, because the plant species that can survive in the pools appear to be dictated, at least in part, by the depth and duration of the water (Bergmeier 2001; Vogiatzakis & al. 2009). It seems very likely that even a small change in the timing, frequency or quantity of rainfall could easily cause significant changes to the

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duration of inundation of pools with knock-on effects on the ability of species such as *Callitriche pulchra* to complete their life cycles.

There is a need for five main actions to address the conservation needs of *Callitriche pulchra* (from Lansdown unpubl.b):

1. Document the *Callitriche* species occurring in cupular pools in limestone pavement throughout the Mediterranean.
2. Survey and document the vegetation of cupular pools in karstic limestone pavement outcrops in Cyrenaica and Cyprus, including assessment of threats, combined with identification of legislative and administrative tools for their protection.
3. Establish micro-reserves protecting all pool complexes on Gavdos and Cyprus that support *C. pulchra*.
4. Establish a monitoring protocol, applicable by non-specialists, which will enable maintenance of a quantified assessment of the global conservation status of *C. pulchra*.
5. Develop a range of tools by which to raise awareness among the public of the importance and conservation value of pool complexes in limestone pavement on Gavdos, Cyprus and in Cyrenaica.

In 2012, *Callitriche pulchra* was assessed as Critically Endangered (Lansdown 2012) using the IUCN Red List criteria (IUCN 2012). The new records cited here mean that this status must be updated. Although it is not clear whether the populations in Cyrenaica persist, it is equally not possible to state that they are extinct. Including the Cyrenaica records, the extent of occurrence (EOO) of *C. pulchra* can be calculated using GeoCat (http://geocat.kew.org/) as >115 000 km^2 and the area of occupancy (AOO) as 68 km^2. Even when the populations in Cyrenaica are excluded from the calculation, the EOO is estimated as >17,500 km^2 and the AOO as 56 km^2. It would be misleading to use population size as a criterion in Red List assessment for this species, as it behaves as an annual, with populations in each pool varying between years in response to a range of factors such as the extent of rainfall and the duration of standing water in the pools. Equally, there is no evidence that this species has undergone extreme population fluctuations; some form of monitoring would be needed to show this. There is no evidence that *C. pulchra* is in decline; in fact the records from Cyprus, combined with the abundance of *C. pulchra* in separate areas of Gavdos, show that there is absolutely no reason to consider that it is likely to become extinct in the foreseeable future. Applying the IUCN criteria, if there is no evidence of a decline, populations are not severely fragmented, and the populations are not undergoing anthropogenically induced extreme fluctuations, then there is no justification for classing it as threatened and it should be classed as Least Concern. However, recognizing the threats to which it is exposed (Table 1) and the small AOO, a programme of monitoring is needed designed to measure population trends so that, if there is a decline, appropriate action can be taken. The most effective way for such monitoring to be implemented would be if it could be carried out by people living in the area.

Callitriche species are badly under-recorded and frequently misidentified throughout the world. There is a need to confirm the identity of *Callitriche* populations occurring in pools in limestone throughout the Mediterranean. This may not only bring to light additional populations of *C. pulchra* but could clarify the status and distribution of the very poorly known *C. truncata* subsp. *truncata*.

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