



Action Plan for the long term conservation of *Callitriche pulchra* in the island of Gavdos

September 2022



MEDITERRANEAN ISLANDS COLLECTIVE PROJECT

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Introduction

The ‘Action Plan for the long term conservation of *Callitriche pulchra* in the island of Gavdos’ was created in the framework of the project “Mediterranean Islands Collective: Collaborating to Protect Nature in Mediterranean islands”, Pilot action “Gavdos Island – Crete – Ultra-threatened plant recovery project” (2021-2022).

The project has been implemented by the Mediterranean Plant Conservation Unit of CIHEAM Mediterranean Agronomic Institute of Chania (MPCU-MAICh) in cooperation with the IUCN/SSC/Mediterranean Plant Specialist Group and the Municipality of Gavdos.

The aquatic plant *Callitriche pulchra* is classified as Critically Endangered (CR) in the IUCN Red List of Threatened Species, mainly due to the species' fragile habitat (Mediterranean temporary lakes). The plant was first found in Gavdos in 1905 and in recent years has been recorded in various locations on the island. Also, since 2000, MPCU-MAICh has been contributing to the complementary *ex situ* conservation of the species.

The proposed action plan aims at long-term conservation of the plant, to address any threats to its population in Gavdos and proposes appropriate management measures. It also aims to inform and raise awareness of the residents and visitors of Gavdos. Hopefully, this plan will be taken into account in the Special Environmental Study for the Natura 2000 site of Gavdos (GR4340013) with regard to *Callitriche pulchra* conservation actions, that is under preparation.

1. Description and Evaluation of the current situation

1.1 The island of Gavdos

The island of Gavdos is located 21 miles south of the southwest Cretan coast and forms the southernmost edge of Greece and Europe. The area of Gavdos is around 30 km² and maximum altitude 362 m.

Geologically the island consists of limestone of upper Cretaceous (Pindos zone). Also, there are metamorphosed rocks and extensive neogene deposits with marine fossils. In the east side, between the settlements Karave and Kastri, there are also late Pleistocene deposits (psammitic) with well conserved land snail fossils. Although Gavdos is not characterized by a high altitude, it has several valleys and seasonal streams.

The climate of Gavdos is typical Mediterranean. The average annual rainfall in Gavdos is only 311 mm, but it shows strong yearly variations since during the period 1992 to 2003, the measured values ranged from 130 mm (2001-2002) to about 550 mm (1995-1996). The wet season of the year is from November to March (87% of the annual rainfall) while during the 3 summer months there is no rain at all. December is the wettest month, followed by January and November. Prolonged rainlessness often exceeds 100 days.

The temperature in Gavdos is particularly high almost all year round and varies from 13 °C in the months of January and February, to 28 °C in the months of July and August. The average monthly value falls slightly below 15 °C only 3 months a year (January, February and March), while for more than 5 months it is higher than 20 °C.

Concerning the flora of Gavdos, 490 plant taxa have been recorded until today, one of which is endemic to the island. Furthermore, 8 plants are endemic to Crete & Gavdos (phytogeographic region of Cretan area), and 14 plants are endemic to Greece (they are also native and in other regions of Greece). About 70% of the plants of Gavdos are also present in Cyrenaica of Libya (Bergmeier et al. 1997). Last, 30 plants of Gavdos are protected by the Greek legislation (PD 67/81) and 10 plants are included in the Red Data Books of Rare and Threatened Plants of Greece (Phitos et al. 1995, Phitos et al. 2009).

With regards to the vegetation, it consists of maquis, forest (mainly pine forest of *Pinus brutia*) and phrygana, and there are extensive sand dunes with *Juniperus* spp. on the north side of the island. Also, there are many abandoned cultivated fields and terraces which have been converted to forest or phrygana.

The Gavdos's wealth of natural resources attracted people from as early as the Palaeolithic period. Today, the 151 inhabitants of the Municipality of Gavdos, which is the smallest Municipality in Greece, live in Gavdos while Gavdopoula is uninhabited. However, less than

100 people live on the island permanently throughout the year. In the summer months, the general population of the island, due to tourists, can reach 3,500, with most of them being campers. The inhabitants are mainly engaged in livestock farming and tourism.

1.2 *Callitriche pulchra* Schotsman

1.2.1 Description

A glabrous, submerged aquatic plant with slender whitish stems contrasting strongly with the colour of leaves, little to much branched. Internodes decreasing gradually in length until shortly below shoot apices. Leaves opposite, simple, almost linear, slightly broader at base, emarginate at apex, 1-veined. Flowers axillary, solitary, unisexual (a male opposed by a female, or occasionally two male or two females opposed by a single female or male), lacking a perianth. Stamen 1, erect before and after dehiscence, barely elongating. Styles 2, filiform, with basal part recurved and upper part erect. Fruit stalked recurved, 1.5-1.8 x 2.0-2.2 mm, separating into 2 to 4 mericarps; mericarps with a broad uniform wing. Ripe fruit greyish with a large seed and a well-developed linear embryo in fleshy endosperm (Photo 2).

Chromosome number: $2n = 8$ (Cook 1983).

Callitriche pulchra was originally described in 1967 by H.D. Schotsman based on specimens from Gavdos collected in 1904 by Ignaz Dörfler and 1951 by Karl Heinz Rechinger and on specimens from Cyrenaica Region of Libya collected in 1916, 1933 & 1934 by Renato Pampanini (Lansdown et al. 2016). The presence of the plant in Gavdos was later confirmed by Cook (1983) and by Bergmeier et al. (1997). According to Lansdown et al. (2008), *C. pulchra* is similar with *C. hermaphroditica*, *C. lusitanica* and *C. truncata* but no *Callitriche* species other than *C. pulchra* have been recorded in Gavdos so far.



Photo1. Photo and an illustration of the plant *Callitriche pulchra*

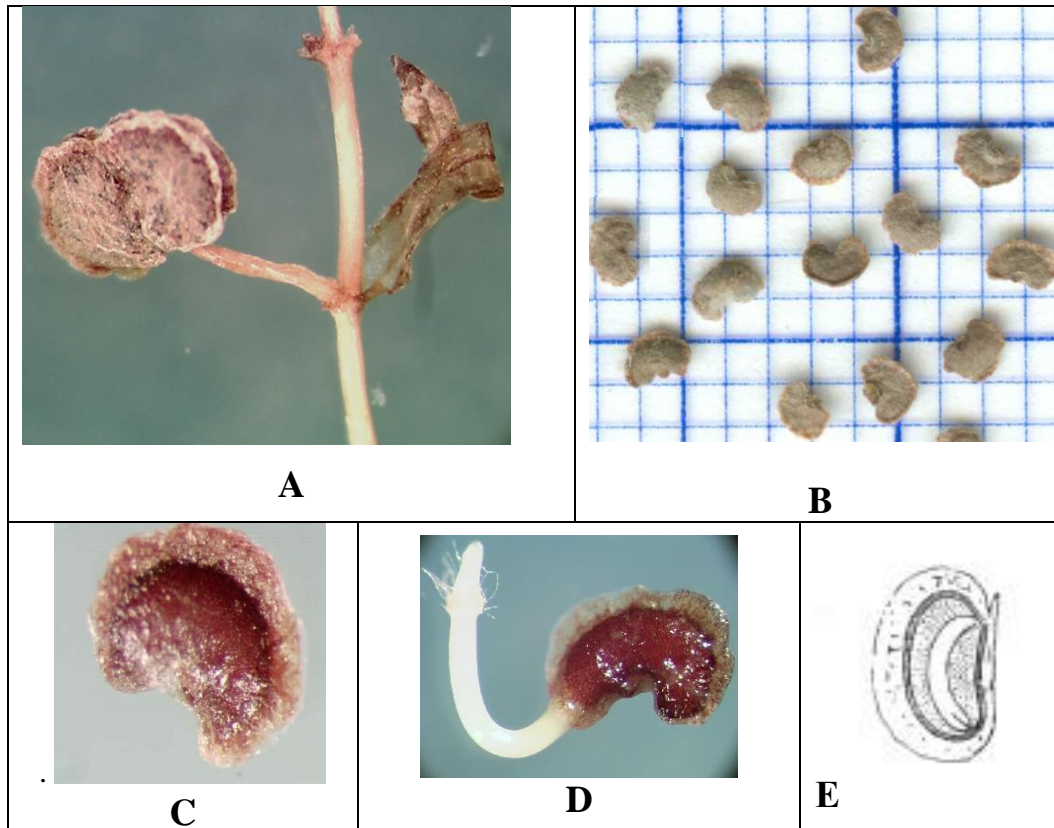


Photo 2. Mature fruits at the time of collection of *Callitriche pulchra* (A), mericarps (B & C), radicle emergence (Δ), illustration of mericarp showing the embryo (Watson and Dallwitz, 1992 onwards) (E).

1.2.2 Biology & Ecology

Life form: obligate aquatic plant, but capable of surviving for a short while after the pools in which it grows dry out (Lansdown et al. 2016)

Flowering period: February-April

Fruiting period: End of April-May

Dispersal strategy: The main dispersal vector for *Callitriche pulchra* appears to be livestock, i.e. by transport of seeds on the feet of goats, sheep and also birds. Heavy rain may also cause occasional transfer of seeds from one pool to another (Lansdown et al. 2016). Moreover, the traditional ‘cleaning’ of rock pools by local shepherds may contribute to the transfer of seeds from one rock pool to another.



Photo 3. Karstic rock pools at Agios Pandeimon of Gavdos

Habitat: *Callitriche pulchra* grows in seasonal shallow karstic rock pools (10-50 cm in depth) (Photo 3) that start to fill during autumn rains in October or November and dry out in April-May, altitude 100-350 m (Bergmeier 2001; Lansdown et al. 2016).

It is an obligate aquatic plant, although 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 (Lansdown et al. 2016).

In addition, *C. pulchra* formed two plant communities in the rock pools of Gavdos: *Zannichellia pedunculata* – *Callitriche pulchra* and *Callitriche pulchra* - *Tillaea vaillantii*, with mean pool depth 26 and 33 cm, respectively (Bergmeier 2001; Vogiatzakis et al. 2009).

Moreover, according to Lansdown et al. (2016) on Gavdos, nine other taxa occurred in more than ten pools supporting *C. pulchra*: unidentified grasses, *Nostoc* sp., *Crassula vaillantii* (Willd.) Roth, *Juncus hybridus* Brot., *Lythrum hyssopifolia* L., *Chara aspera* Deth. ex Willd., *Zannichellia palustris* L., filamentous algae and *Chara vulgaris* L.

Seed germination and dormancy: The study of seeds germination of *C. pulchra* showed that the seeds of the plant germinate relatively quickly under the influence of white light at temperatures of 10 & 15 °C (Figure 1) (Fournaraki et al. 2015 unpubl.). In a previous germination experiment (Fournaraki 2010) from the same subpopulation high germination percentages were found at all temperatures examined (10, 15 and 20 °C), reaching up to 90% germination, under the influence of white light. In constant darkness, in both experiments, germination was inhibited at all temperatures. This means that the germination of its seeds is promoted exclusively under the influence of light, and that seeds buried deep in the sediment (continuous darkness) do not germinate.

No complete experiment was performed, immediately after collection, to determine whether the seeds are characterized by primary Physiological Dormancy. In a small experiment performed at 15 °C, immediately after collection, the seeds germinated and most probably are not characterized by dormancy. However, more investigation is needed to study the primary dormancy of the species.

Seeds that did not germinate in the dark were transferred (after about 21 days) to light/dark at the respective temperature. The final percentage of germination was high (over 80%) at temperatures of 15 and 20 °C, while at 10 °C it reached around 30%. It appears that the continuous darkness only at low temperature imposes some secondary dormancy on the seeds of *C. pulchra*. In general, however, it seems that the seeds buried deep in the sediment when they emerge to the surface (sufficient light) and with the appropriate conditions (sufficient water and relatively cool temperatures) they germinate.

The aforementioned conditions exist in the rocky pools in the winter months in Gavdos. Of course, it is obvious that many other factors affect the full establishment of the plant after

germination in these sensitive ecosystems, with the main one being the competition with the other aquatic plants in the rock pool.

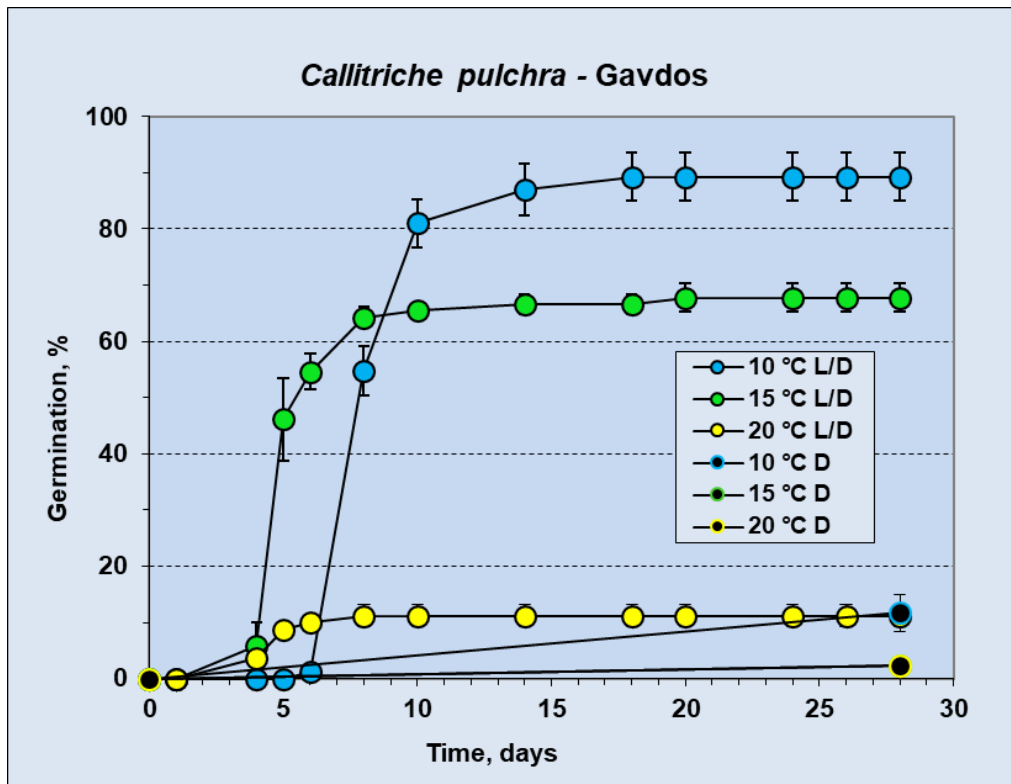
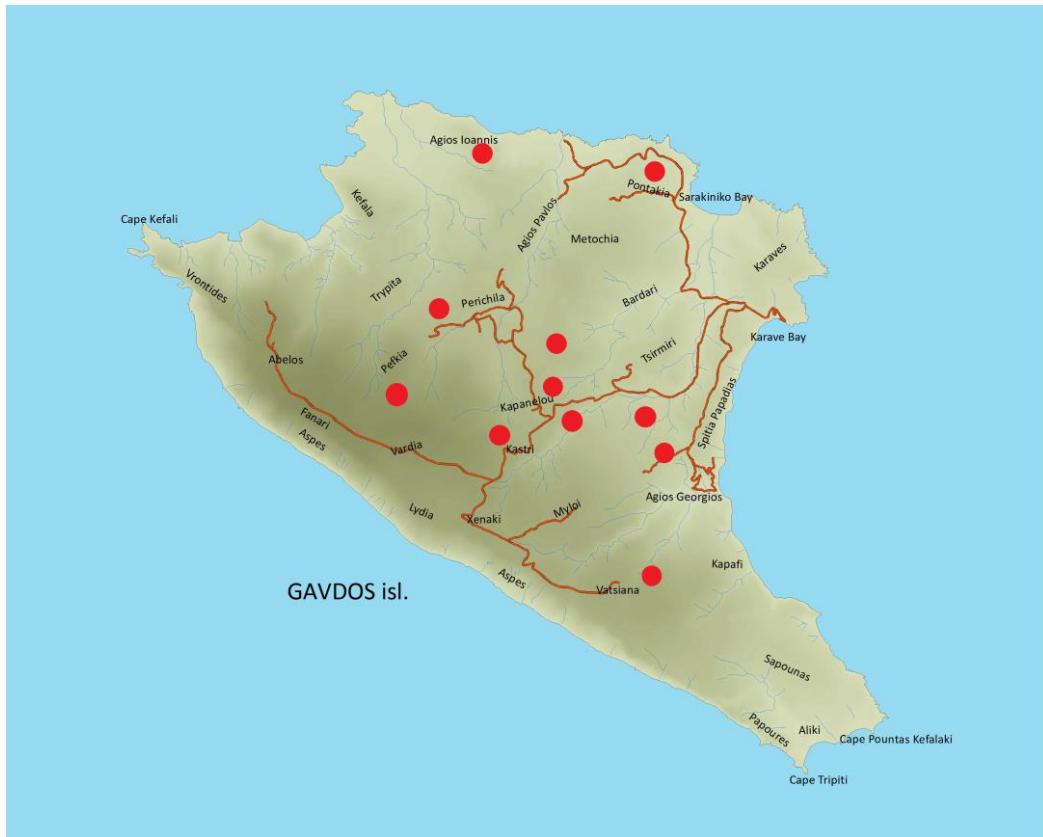


Figure 1. Time course of germination in *Callitriche pulchra* seeds in 10, 15 and 20 °C in light/darkness (L/D) (12 h/12 h) and in total darkness (D). The vertical bars represent the \pm standard error (Fournaraki et al., 2015 unpubl.).

1.2.3 Distribution

Callitriche pulchra is reported to occur in Gavdos (Crete, Greece), Cyrenaica (Libya) and E Cyprus (Lansdown et al. 2016).

In Gavdos *C. pulchra* is found at the localities Kastri, Agios Pandeimon, Ai Giannis, Fokia, Fragediana, Violiana, Sgoudiana and Vatsiana (Map 1).



Map 1. Distribution of *Callitriche pulchra* on Gavdos island (Lansdown et al. 2016 - modified).

1.2.4 Legal status

Callitriche pulchra is protected by the Greek Presidential Decree 67/1981 “*On the protection of native flora and wild fauna and the determination of the coordination and control procedure of related research*”. The habitat of *C. pulchra*, ‘3170*-Mediterranean temporary ponds’, is within the NATURA 2000 site GR4340013 and is classified as priority habitat for protection by the EU Habitats Directive.

1.2.5 Conservation status / Geographical scope

Global & Mediterranean (IUCN Red List): *C. pulchra* is listed as Critically Endangered under the criteria B2ab(iii,iv,v) (Version 3.1) – (Lansdown 2012).

Europe (IUCN Red List): *C. pulchra* is listed as Critically Endangered under criteria B2ab(iii)c(iv) (Version 3.1) – (Lansdown 2011).

Greece (Red Data Book of Rare and Threatened Plants of Greece): *C. pulchra* is listed in the Greek National Red lists as Endangered (Turland 1995) and as Critically Endangered (Lansdown 2009).

According to Lansdown et al (2016) the conservation status of the plant needs to be updated after the discovery of a new location in Cyprus, but given the threats it is exposed to as well as the small AOO, a monitoring program is needed to be designed to measure its population trends. Moreover, *C. pulchra* is not mentioned in the Flora of Libya (Jafri 1984) and its conservation status is unknown there (Lansdown et al 2016).

1.2.6 Threat(s)

Potential threats to the populations of *Callitriche pulchra* in Gavdos and their effects were published in Lansdown et al (2016):

- ✓ Livestock (goats and sheep) causing eutrophication in the rock pools which results in increased filamentous algae (Photo 4).
- ✓ Management of some rock pools by the local inhabitants as a water resource, e.g. physical modification of the pools, supplementation of water, addition of lime to water, which results in the loss of aquatic plants.
- ✓ Residential expansion and tourism development causing destruction of the rock pools.
- ✓ Expansion of the *Pinus brutia* forest. The *P. brutia* forest is causing acidification of the water which has a toxic effect on *C. pulchra*. In addition, the expansion of the *P. brutia* forest shelters the rock pools from the wind and sun, which suppresses the growth of *C. pulchra* and modifies the evaporation rate of the water in the rock pools. Finally, the *P. brutia* needles are covering the pools causing loss of all aquatic plants.
- ✓ Moreover, according to Bergmeier (2001) and Vogiatzakis & al. (2009) climate change could be another threat as survival of *C. pulchra* in pools appears to be dictated, at least in part, by water depth and duration. The Mediterranean temporary ponds depend on an annual cycle of rainfall and drought. Rising temperatures may lead to prolonged periods of drought and a general lack of rainfall in certain zones. This could significantly affect this habitat. Without sufficient water they will not be able to maintain their ecological functions.



Photo 4. The droppings of goats and sheep causing eutrophication in the rock pools where *Callitriche pulchra* grows which results in increased filamentous algae.

1.3 Past and Current Studies and Conservation actions for *Callitriche pulchra*

In this chapter, the results and achievements of past projects and conservation actions are presented along with the achievements of the current project of the ‘Mediterranean Island Collective’.

1.3.1 Mapping of the habitat of the species in Gavdos and Management Actions proposed (project LIFE-MEDPONDS)

During the period 2004-2008 the temporary ponds of Gavdos were mapped in detail, their vegetation was documented and a management plan was elaborated in the framework of the project “Actions for the conservation of Mediterranean temporary ponds in Crete - MEDPONDS” (LIFE04 NAT/GR/000105) (<https://imbriw.hcmr.gr/mediterranean-temporary-ponds-in-crete/>).

The Geoinformation in Environmental Management Dept. of MAICH participated in this project. Specifically, 99 temporary ponds in 5 localities of Gavdos (Kastri, Agios Pandeileimon, Ai Giannis, Korfos-Sgoudiana, Fragediana) were mapped (Map 2) and for each temporary pond altitude, perimeter, surface area, soil depth, water level and total depth as well as the plant species composition were recorded (Vogiatzakis et al. 2009).

According to the Management Plan (Dimopoulos et al. 2006) for the temporary ponds of Gavdos in the framework of the same project, the threats that should be addressed are the livestock water consumption, the eutrophication in the rock pools and the human interventions to the rock pools.

The management measures suggested were:

- ✓ annual monitoring of the number of goats and sheep that use the ponds
- ✓ placement of watering tanks outside the areas of the ponds
- ✓ light fencing of the habitat which will not obstruct the grazing animals
- ✓ communication actions to raise awareness of the inhabitants.

1.3.2 Detailed mapping of the species distribution in Gavdos and Management actions

Moreover, in 2015 a comprehensive assessment of the status of *C. pulchra* was carried out by Lansdown R.V. and colleagues in the framework of the project “Conservation of beautiful water-starwort (*Callitriche pulchra* Schotsm.) on Gavdos island, Greece”. Detailed mapping of the species distribution on the island took place and it was recorded in 101 rock pools (Lansdown et al. 2016). The proposed Management actions by Lansdown et al. 2016 include the following:

- Establishment of micro-reserves protecting all pool complexes that support *C. pulchra* in Gavdos
- Establishment of a monitoring protocol, applicable by non-specialists, which will enable maintenance of a quantified assessment of conservation status of *C. pulchra*.
- Development of a range of tools by which to raise awareness among the public of the importance and conservation value of pool complexes in limestone pavement.

1.3.3 *Ex situ* conservation of *Callitriche pulchra*

The main objective of the *ex situ* conservation action is to provide reproductive material for future translocations (reintroduction and/or reinforcement) activities, which will be performed for on-site (*in situ*) enhancement of natural population.

Seeds of *Callitriche pulchra* (seeds) are stored at the Seed Bank of MAICH and duplicated at the Seed Bank of the National & Kapodistrian University of Athens. The genetic material conserved is from seed collections that took place by the Mediterranean Plant Conservation Unit of MAICH in the years 2005 (Fournaraki 2010), 2015 (Fournaraki et al. 2015 unpubl.) and 2018 (Montmollin B. de et al. 2019). Moreover, the plant's germination protocol was created (Figure 1).

Protocol for seed collection, cleaning and storage of *Callitriche pulchra*

Seed collection

The methodology followed for the collection of seeds is the one proposed by the European Native Seeds Conservation Network (ENSCONET 2009) and the GENMEDA network (Bacchetta et al. 2006). The main recommendations for seed collection are: 1) a satisfactory seed collection should contain at least 3,000 viable seeds, 2) the seed collections should not exceed 10-20% of the annual seed output of a population so as not to threaten its viability 3) Each collection must ensure the greatest possible genetic diversity of the species in *ex situ* conservation.

The fruits of *Callitriche pulchra* in Gavdos mature at the end of April until May. The collection can be done at this period but also later as the fruits remain in the dried sediment of the rock pools. In May, when the previous seed collections were done, most of the ponds were dry (Photo 5), while some of them still had water and others had well developed green plants in more humid places.



Photo 5. Dry fruiting plant of *Callitriche pulchra* among the residue in the dried rock pool.

Fruits would be collected from the surface of the sediment along with dried stems of the plant (Photo 6). Most fruits remained stuck on the dry stems and immature mericarps appeared well bonded together.

It is recommended to keep separately the seeds from different plants (or ponds), because in future reintroduction or reinforcement programs, the genetic material should consist of no fewer individuals than the initial collection and it should also represent the initial genetic diversity (supposing that each pond contains different individuals).

Cleaning

The cleaning of the seeds of *Callitriche pulchra* is a time-consuming process. Initially the sediment must be completely dried and spread out in small paper boxes in the laboratory, in well-ventilated areas. The seed cleaning process is done by hand and/or using seed cleaning equipment. This period lasts about 1 month for an adequate collection. After cleaning, the seeds were transferred to the Dry Room (15-20 °C and 15-20% RH).

Finally seed germination at optimum conditions is used for seed viability testing before storage.



Photo 6. Seeds (mericarps) are collected together with part of the surface sediment.

Storage

After drying, the seeds were weighed, packaged and **stored in the Cold Room** of the Seed Bank (-18 to -20 °C).

The **Mean Seed Weight** of 10 mericarps: 1.37 ± 0.02 mg (n = 30) (Fournaraki 2010).

The seeds of *Callitriche pulchra* are characterized by orthodox storage behavior, as they were stored for about a year at -20 °C in the Cold Room of the Seed Bank of MAICH and remained viable (Fournaraki 2010).

1.3.4 Monitoring of *Callitriche pulchra* natural population

During the current project, on 25-26 March 2022 monitoring of *C. pulchra* population in Gavdos was carried out in 47 pools at 5 localities where the plant had been located in 2015.

C. pulchra was now located in only 9 of these pools (Photo 7). This could be due to the abandonment of traditional livestock practices that kept the ponds free of organic materials which lead to eutrophication. It could, also be due to the seasonality of this annual plant or the climate change. This needs to be determined in the long-term monitoring of *C. pulchra*.



Photo 7. Monitoring of *Callitriche pulchra*, in March 2022.

1.3.5 Public awareness and sensitization actions

During the current project, an **information day** took place in Gavdos island, on 10 April 2022. It was a dissemination event targeting residents, visitors, representatives of relevant authorities and other stakeholders (total 43 participants) (Photo 8). The theme of the event was “The environmental and cultural heritage of Gavdos” and it was co-organised by MAICH, the Municipality of Gavdos, the IUCN, the Management Unit of Samaria National Park and the Protected Areas of Western Crete of the Natural Environment and Climate Change Agency, and the Forest Directorate of Chania. The conservation of *Callitriche pulchra* was one of the main issues presented and discussed during this event. The event ended with a consultation with the participants in order to elaborate proposals for the protection of the environmental and cultural heritage of Gavdos. Concerning *C. pulchra* and other important plants of the island, all participants agreed that they should be protected and several residents expressed their interest to voluntarily participate in conservation actions under scientific guidance.



Photo 8. Group photo at the information day in Gavdos, 10 April 2022.

Callitriche pulchra **t-shirts and cotton bags** were prepared by MAICH and offered to the Municipality of Gavdos for distribution to residents and visitors (Photo 9 & 10). They were also offered to all participants of the information day.



Photo 9. T-shirts of *Callitriche pulchra* and *Bupleurum gaudianum* distributed at the information day in Gavdos, 10 April 2022.

Απειλούμενα φυτά της Κρήτης
Threatened plants of Crete



Photo 10. The illustration created for *Callitriche pulchra* (left) was printed on canvas bags (right) and on T-shirts.

A **booklet** entitled “Getting to know the important plants of Gavdos and Gavdopoula” was prepared in Greek and translated in English. The booklet has parts dedicated to *C. pulchra* and its habitat (Photo 11). It is printed in 500 copies in Greek and English (250 GR and 250 EN) and it is also available on the website of the Municipality of Gavdos (<https://gavdos.gr/getting-to-know-the-important-plants-of-gavdos-and-gavdopoula/>)

Callitriche pulchra Schotsman

Plantaginaceae

DESCRIPTION: *Callitriche pulchra* is an annual aquatic plant with slender stems and characteristic fruits.

FLOWERING PERIOD: February to April

GEOGRAPHICAL DISTRIBUTION: In Greece the beautiful water-starwort *C. pulchra* grows only on Gavdos. In particular, it has been recorded in the areas Kastri, Agios Panteleimon, Ai Giannis, Fokis, Fragopetra, Violana, Spodiana and Vantana. Elsewhere it grows in Libya and it has recently been recorded in Cyprus.

HABITAT: It grows in seasonal shallow karstic rock pools (few cm in depth) that have water only in winter or spring, at 100-250 m altitude. It is not found in all the seasonal pools of Gavdos and it is not found in the same pools each year. In 2015 specialist biologists of the *Callitriche* genus surveyed a total of 313 seasonal pools and *C. pulchra* was recorded in 30 pools. The plant is one of the keystone species of its habitat, which is of high ecological importance due to its floristic composition and the numerous ecosystem services it provides, e.g. collection of nutrients, water supply for livestock and wild animals, biodiversity tank and landscape cultural elements.

CONSERVATION STATUS: *C. pulchra* is a threatened plant according to the Red Data Book of Rare and Threatened Plants of Greece (2009) and is assessed as Critically Endangered (CR) in the IUCN Red List of Threatened Species.

THREATS: It is threatened by livestock causing overgrazing in the rock pools and other human disturbances to the rock pools, the expansion of the pine forest and the destruction of the rock pools due to residential expansion.

PROTECTION MEASURES: The habitat of the plant is referred to as priority habitat for protection in the Habitats Directive of the European Union, with the name “Mediterranean temporary ponds” (code 3170*), and it is protected in all the areas where it is found. The temporary ponds of Gavdos have been mapped in detail and a management plan for their conservation has been elaborated in the framework of the project “Actions for the conservation of Mediterranean temporary ponds in Crete - MEDPONDS” (LIFE04 NAT/GR000010). In addition to the protection of its habitat, the plant *C. pulchra* itself is protected by the Greek legislation. Genetic material of the plant (seeds) is conserved at the Seed Bank of MARCH. It is a species protected by the Greek legislation. In the framework of the project “Gavdos Island - Crete - Ultra-threatened plant recovery project”, an Action Plan is elaborated for the long term monitoring of the plant on Gavdos.



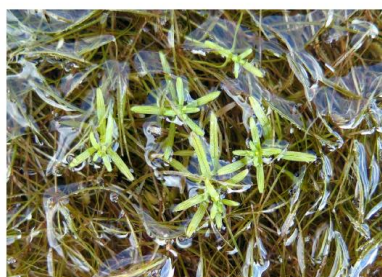
Illustration of *Callitriche pulchra* by G. Agapitos, 2022



Callitriche pulchra fruits

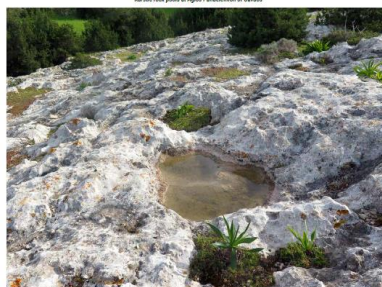


[12]



Callitriche pulchra plant

Karstic rock pools at Agios Panteleimon of Gavdos



[13]

Photo 11. *Callitriche pulchra* in the booklet “Getting to know the important plants of Gavdos and Gavdopoula” (published in September 2022)

2. Future Actions proposed for the conservation of *Callitriche pulchra*

The proposed actions for the future are based on the results of previous and current conservation actions and studies in the area:

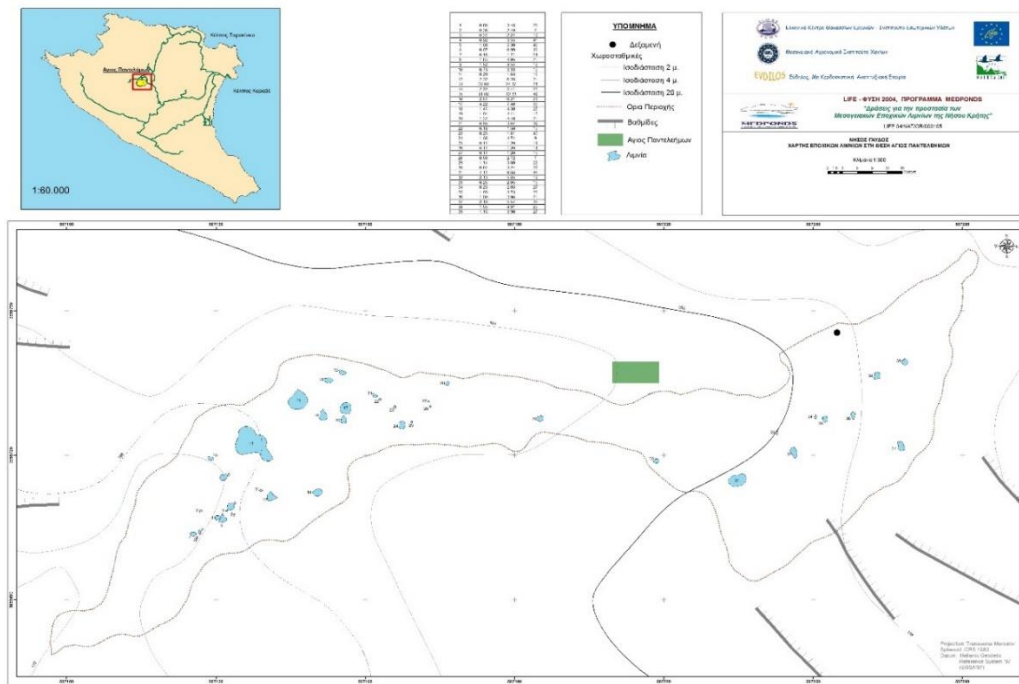
- ✓ The Management plan that had previously been elaborated for the habitat in the context of the Life project (LIFE MEDPONDS) (Dimopoulos et al. 2006).
- ✓ The suggestions and recommendations of Lansdown et al. 2016.
- ✓ The traditional management of rock pools ('arolithoi' is the local name) by the inhabitants of the island for saving water. As it has been documented the traditional management has resulted in the survival of the plant for more than a century.
- ✓ The reproductive biology of the species which has been studied by our team

The following actions are proposed in order to improve the conservation status of the species and to address the main threats related to the habitat of the species:

- the eutrophication in seasonal rock pools and other human disturbances
- the expansion of the pine forest
- the destruction of seasonal rock pools due to residential expansion.

2.1 Long term monitoring of *Callitriche pulchra* natural populations (after the current project)

The monitoring action will have at its core the existing highly detailed mapping of the plant's habitat, citizen science and digital technology. During the LIFE04 NAT/GR/000105 "MEDPONDS" project the shallow rock pools in which the plant grows were thoroughly mapped into a GIS platform. This map can be utilized and added onto a digital platform to guide the citizens to the plant. In the same platform the user will find a form or a questionnaire and will fill it with information about the conditions of the area where the plant grows. The user will be able to upload photographs of the area, comments about pressures and threats like grazing and pollution and of course comment on the presence of *Callitriche pulchra*. This data will be available to our research team, cleaned and utilized towards the long-term monitoring of this endangered plant. With this monitoring action, it is expected that many visitors of the island will be informed and sensitized towards this plant.



Map 2. Detailed mapping of temporary ponds LIFE04 NAT/GR/000105 “MEDPONDS” project (Kazakis & Ghosn 2006). Map of Temporary ponds (rock pools) at Agios Panteleimonas Gavdos.

2.2 Incorporation of the current action plan for *Callitriche pulchra* into the upcoming Special Environmental Study for the Natura 2000 site of Gavdos (GR4340013)

The habitat of the species, namely the temporary ponds, has been classified as endangered all over the world; nevertheless, they are disappearing at a especially high rate in the Mediterranean region (Dimitriou et al 2006). For the above reason, the Mediterranean Temporary Ponds (MTPs) are considered a priority habitat according to the European Union Habitats Directive and therefore appropriate management and conservation efforts should be made for their protection by country members.

Currently, the preparation of the Special Environmental Studies for the NATURA 2000 network in Greece is in progress. Among others, management actions should be proposed for the protection of the rock pools of Gavdos. The scientists responsible for the project are already aware about *Callitriche pulchra* as it is a threatened and protected by Greek legislation plant species. Also, after the foreseen consultation during this project, the MPCU of MAICH and the Municipality of Gavdos will have the opportunity to incorporate their

proposals into the Special Environmental Study for the Gavdos and Gavdopoula NATURA 2000 site.

2.3 Actions for continuing the traditional practice of cleaning seasonal rock pools

According to Lansdown et al. (2016) livestock (goats and sheep) are a potential threat to the existence of *Callitriche pulchra* as they cause eutrophication in rock pools, as well as to the use of some rock pools by local residents as a water resource. However, we must acknowledge that the traditional management by shepherds on the island resulted in the conservation of the species at least for more than a century. The plant was collected by Doerfler in 1905 (Schotsman, 1967) at that time until recently, in Gavdos, the shepherds in early autumn cleaned the pools from the dry vegetation and removed some of the sediment. In this way, the seasonal pools were not filled up by the continuous deposition of sediment. In addition, they removed anything that would prevent the collection of water such as branches, stones, garbage, trees etc. This resulted in shepherd collecting water to water their animals in clear relatively rocky pools until early spring.

Taking into account the seeds germination requirements of the plant, it seems that the traditional way of cleaning the rock pools by shepherds (removal of dry vegetation and part of the sediment) contributes to the reproduction of the plant. That is, the traditional practice contributes to the emergence of seeds on the surface to ensure light and in combination with the provision of water (rainy season) create the appropriate conditions for seed germination of *C. pulchra*.

According to the information gathered, as part of this project, it seems that this practice has almost disappeared. Today there is more water available for watering the animals through irrigation and tourism has attracted the interest of the few inhabitants of the island. However, several inhabitants of Gavdos remember this practice that was applied until recently.

In cooperation with the Municipality, it is proposed to continue this practice (by some volunteers) at least in some locations. The same volunteers could undertake the long-term monitoring of the plant.

2.4 Action for the creation of a translocation protocol

The seed germination protocol created could be used for the reintroduction and/or reinforcement of *C. pulchra* population. An experimental trial of our team has shown that

Callitriche pulchra seeds germinate after 2 to 3 days under constant temperature (15 °C) and a photoperiod (light/dark) of 12/12 h, when immersed in a cup with tap water (Photo 12).

The development of a reintroduction protocol by our team presupposes additional experimentation in field conditions. For this purpose, seeds could be placed in a selected rock pool at Gavdos where *C. pulchra* has not been previously recorded and then the successful establishment of the plant should be monitored.

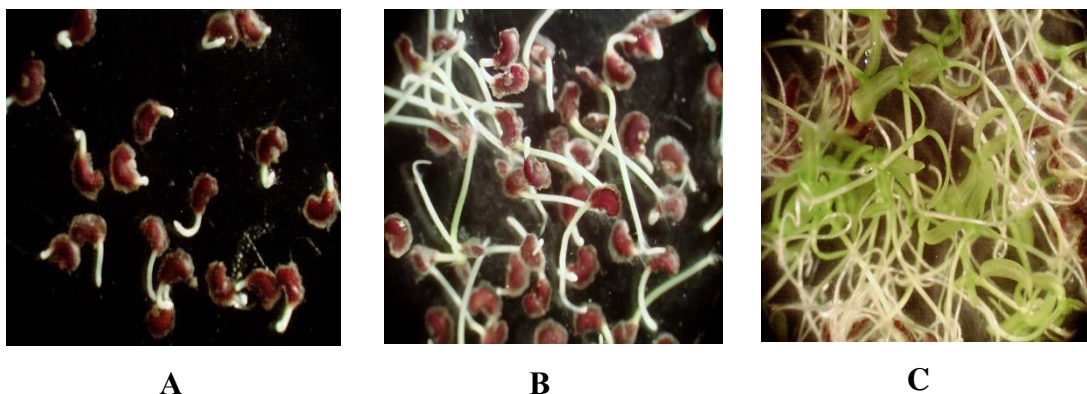


Photo 12. Various stages of the development of the seedlings, after the germination initiation (visible exit of radicle), at a constant temperature (15 °C) and a photoperiod (light/dark) of 12/12 h, in cup with tap water. **A.** After 2 to 3 days - **B.** After 3 to 5 days – **C.** After 7-9 days (Fournaraki 2010)

2.5 Future *ex situ* actions

According to the international standards for seed storage in Seed Banks (ENSCONET and GENMEDA networks), seed samples for *ex situ* conservation should be tested for their viability **every 5 years**.

After the last seed collection of 2018 for seed banking at MAICH installations, the viability of the seed samples will be tested in the next year (2023) through germination experiments. If the viability goes below 80%, then seed collection for seed banking should be renewed via a new collection. In addition, further duplication of the seedlots, in another seed bank other than that of MAICH is recommended for safety reasons.

2.6 Actions for public awareness and sensitization

➤ The municipality of Gavdos in collaboration with scientists and research centres, could organize information days for the biodiversity of the island (and include the specific plant species *C.pulchra* and its habitat) **at a regular basis**, as for e.g. once per year or every 2 years, and preferably during summer when most visitors and inhabitants are on the island.

- Communication material such as banners, posters, info kiosks, etc., with detailed information and photos on the plant of *C.pulchra* could be prepared as above and installed in various places of the island for the visitors such as the new information centre that will be created. The leaflet that was produced during the current Project will be accessible via the municipality's website; the hard copies in English and Greek have been given to the Municipality so that they will distribute them to the visitors and tourists of Gavdos.
- Social networks of the municipality of Gavdos and other groups, could be used for the promotion of the information on the endangered plant species and its habitat.

2.7 Actions of cooperation for the sustainability of conservation actions

- The cooperation between **the Municipality of Gavdos, CIHEAM- MAICH and the IUCN - Mediterranean Plants Specialist Group** in matters related to **protection of biodiversity on the island** will continue. A Memorandum of Agreement for this purpose is proposed to be signed by all entities and take into account the present ACTION PLAN.
- **The Mediterranean Plant Conservation Unit** of CIHEAM - MAICH will continue the actions that were initiated in the context of the current project by seeking to raise appropriate funds.
- The **expected Management plan** for the Natura2000 site of Gavdos and Gavdopoula from the Greek Ministry of Environment will provide the directions for the protection of biodiversity on the two islands to all stakeholders, management authorities and decision makers.

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