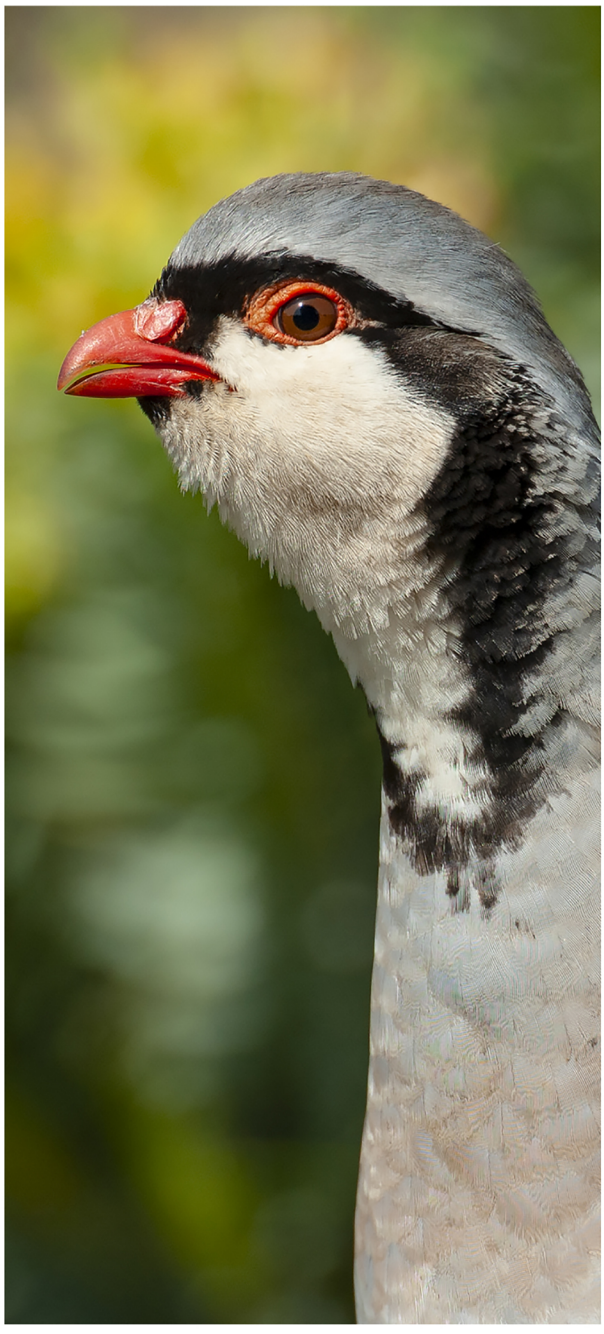
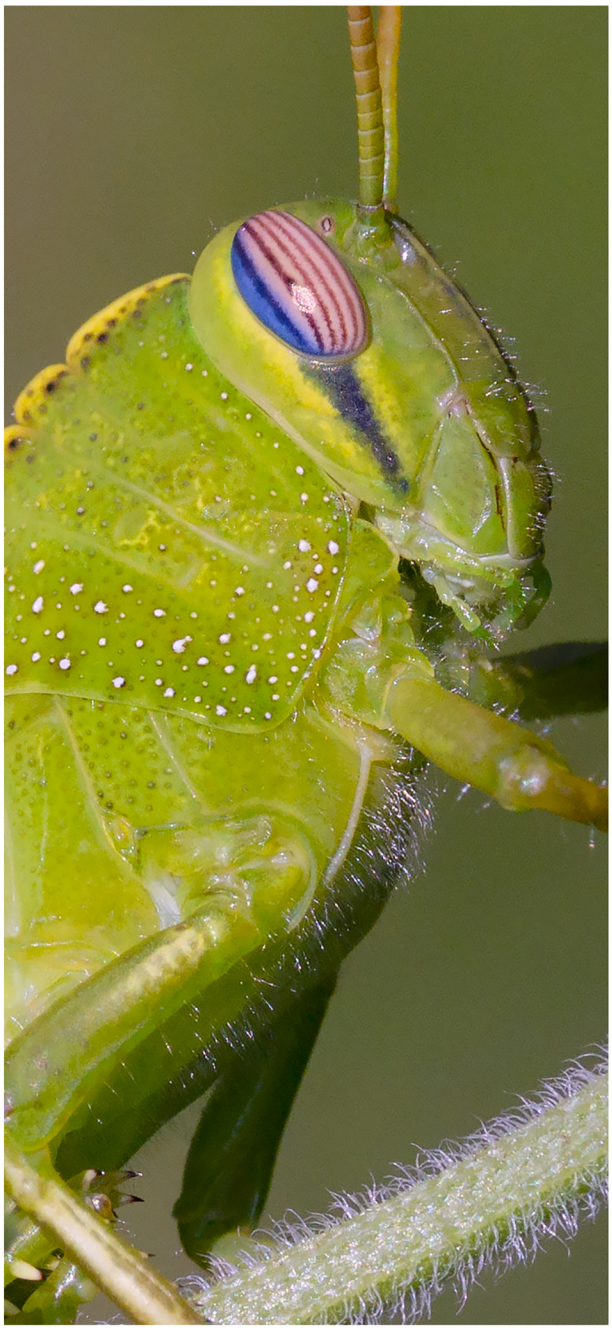
LIFE ON ISLANDS

BIODIVERSITY IN SICILY AND SURROUNDING ISLANDS

Studies dedicated to Bruno Massa





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Tommaso La Mantia, Emilio Badalamenti, Attilio Carapezza,
Pietro Lo Cascio & Angelo Troia (Editors)

LIFE ON ISLANDS. 1

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On the front cover a Sicilian rock partridge, *Alectoris graeca whitakeri* Schiebel, 1934 and an Egyptian locust, *Anacridium aegyptium* (Linnaeus, 1764); on the back cover a summer image of Linosa Island (photos T. Puma).

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HOMAGE TO PROSERPINA, OR: WHY DID THE CHAROPHYTES OF THE PERGUSA LAKE VANISH?

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Summary: An important bisexual population of the charophyte *Chara canescens* Loisel. (Characeae, Charales, Charophyceae) was reported in the XIX century for the Pergusa Lake (Sicily). A recent field survey to check its presence revealed that it has disappeared. After a bibliographic research to understand when and why this happened, the input of freshwater from outside the basin and the introduction of the carps were identified as the two main causes for its recent extinction. Some possible management measures to try to restore the lake ecosystem are proposed.

Key Words: biodiversity; invasive alien species; limnology; macrophytes; saline lake.

Riassunto: *Omaggio a Proserpina, ovvero: perché le carofite del Lago di Pergusa sono scomparse?* - Un'importante popolazione bisessuale della carofita *Chara canescens* Loisel. (Characeae, Charales, Charophyceae) è stata segnalata nel XIX secolo per il Lago di Pergusa (Sicilia). Una recente indagine di campo volta a verificarne la presenza ha rivelato che questa specie è scomparsa. Dopo una ricerca bibliografica per capire i tempi e le ragioni della sua scomparsa, le principali cause recenti sono state identificate nella immissione di acqua dolce dall'esterno del bacino e nella introduzione delle carpe. Vengono proposte alcune possibili misure di gestione per tentare di ripristinare l'ecosistema lacustre.

Parole chiave: biodiversità; specie aliene invasive; limnologia; macrofite; lago salino.

INTRODUCTION

Pergusa Lake is a shallow polymictic endorheic lake (Calvo *et al.* 1993), located in the centre of Sicily at 667 m a.s.l. (Fig. 1). The lake is famous because connected - since classic Roman period - with the myth of the Rape of Proserpina, but also for its recurring "red waters" caused by the bloom of phototrophic sulphur-bacteria, in turn caused by recurring dry periods (Calvo *et al.* 1995); the hydrologic balance is in fact mainly controlled by rainfalls, because of the limited extension of the basin (ca. 10 Km^2). The lake today has an area of ca. 1.4 Km^2, with the maximum depth at ca. 2.2 m, and is protected as a Nature Reserve as well as a Natura2000 site (cod. ITA06002) (Papini *et al.* 2009).

During ongoing investigations on charophytes in Sicily (Romanov *et al.* 2019), it emerged that an important bisexual population of the charophyte *Chara canescens* Loisel. (Characeae, Charales, Charophyceae) was reported in the XIX century for this lake (Ross 1905). The species is widely distributed in northern hemisphere and Australia (Nowak *et al.* 2019), but limited to saline habitats (salinity range between 4 and 16‰) (Winter & Kirst 1991); it does not tolerate more than a temporary enhancement of salinity up to that of seawater or decrease in salinity to that of freshwater (Winter & Kirst 1991).

The species is dioecious, but most populations all over the world are made only by female plants: currently, only two bisexual populations are known, namely in the National Park Neusiedler See-Seewinkel at the border between Hungary and Austria, and in a single site in Sardinia (Nowak *et al.* 2019). Hence, the reported bisexual population of Pergusa could represent the third one in the world.

MATERIAL AND METHODS

Available published data on the charophytes and aquatic vascular plants occurring in the Lake of Pergusa have been collected, and field investigations were made to locate the population of *Chara canescens*.

In addition, literature on the history and limnology of the lake has been analysed.

RESULTS

Historical records of charophytes and aquatic plants in the Pergusa Lake

Herman Ross (1862–1942) was a German botanist who spent some years in Sicily at the end of the XIX century (Stafleu & Cowan 1983). He was the first, as far as we know, to describe the presence of charophytes in the Pergusa Lake: in June 1893 he visited the water body and saw a single species covering most of its bottom and often reaching the water surface (Ross 1905).

Figure 1. View of the Pergusa Lake (photo T. Puma, July 2010).

Ross collected specimens and sent them to another German scientist, Ludwig Holtz, specialist based in Greifswald, who identified the charophytes from Pergusa Lake as *Chara crinita* Wallr.; moreover, he found that Sicilian specimens were different from the "typical" *C. crinita*, so that he described a new form: *Chara crinita* f. *pseudo-spinosissima* (Holtz in Ross 1905: 255). Today, that form is considered not being different from the typical *C. crinita*, which in the meantime has been considered a synonym of *Chara canescens* Loisel.

The area of Pergusa has not been well studied, as far as the aquatic vascular flora is concerned. Few years after the visit of Ross, Lopriore (1901) confirmed the presence of *Chara* (sp.), adding the sporadic presence of *Potamogeton pectinatus*. Also Forti (1933) wrote that in July 1928, after a long dry period (between 1921 and 1927) interrupted by heavy rains, the submersed vegetation was constituted by *Chara crinita* (= *C. canescens*) and *Potamogeton pectinatus*; four years later, in Autumn 1932, red waters will characterize again the lake (Forti 1933).

In the following decades, between 1920 and today, a lot of things happened: dry periods and red waters, a project of reclamation of the area, the construction of houses, public and private wells (closed in 1988) and a racetrack around the lake (still active), the release of alien species (fishes, turtles, etc.), blooms of ichtyotoxic microalgae.

In recent years, Calvo *et al.* (1993) were the last authors reporting *Chara* meadows in the lake, observed during their visits to the lake between April 1987 and March 1988: in spring "*dissolved oxygen percentage saturation increases from the surface to the bottom and pH values are close to 9.0, probably because of the presence of* Chara *sp., which colonizes the lake's bottom*" (Calvo *et al.* 1993). Although the species reported by Calvo *et al.* (1993) is probably *C. canescens*, we cannot confirm: the only herbarium charophyte collected in this lake and preserved in the Herbarium Mediterraneum (PAL) of the University of Palermo is a XIX century specimen of *C. canescens* (without collector and date) (!) (Ferreri 1998).

Between 1988 and 1989 a dry period caused the lake to dry out almost completely. The same happened between 2000 and 2002. After that second event, water from the Ancipa reservoir (located about 40 km NE from Pergusa) was directed to the lake of Pergusa, a first time between December 2002 and May 2003, a second time between March and May 2004 (Amore & Termine 2005). As a consequence, the lake was "restored" and filled, also thanks to abundant rains of those years and the closure of the wells. The salinity of the lake changed according to these events: it was up to 127 g/l in summer 1990 (Battaglia *et al.* 1991), 57.6 g/l in 2001-2002, 8.5 g/l in 2003–2004, 5 g/l in 2005–2006 (Amore & Termine 2007).

After the water input from outside the basin, large amount of Characeae oospores in the sediments are reported in 2004 (Amore & Termine 2005) and in 2006 (Amore & Termine 2007); but between April and September 2006 those oospores significantly decreased (Amore & Termine 2007), totally disappearing in 2008-2010 (Termine 2012). In the same time, in July 2006 an increased presence of the macrophyte *Ruppia* sp. (already reported for the lake by Amore & Termine 2005) was highlighted (Amore & Termine 2007), as well as the first reports of the common Carp, *Cyprinus carpio* (Linnaeus, 1758), in the lake (Termine *et al.* 2008).

The Management Plan of the Natura2000 site (Papini *et al.* 2009), on the basis of field investigations probably made in the previous couple of years, reports the presence of *Chara globularis* Thuill. (sub *Chara fragilis*), together with *Ruppia* sp.; Termine (2012) confirms that *C. globularis* was present till 2007, but notes that from 2008 to 2010 (period covered by that last report) no charophyte or vascular aquatic plant occurred in the lake.

Submerged macrophytes today

After several visits to the lake during 2017 and 2018, including an exhaustive tour in boat together with the colleague Rosa Termine (using a hook to check the bottom of the lake, considering the turbidity of the water), we never found any charophyte.

On 28 July 2018, during the tour in boat, we found some plants of *Zannichellia* cf. *palustris* (Fig. 2) in a restricted area of the lake. Also Abita *et al.* (2019), in the same period, collected *Zannichellia palustris* as the only submerged macrophyte, in just one of the five areas they studied.

Figure 2. Detail of the fruits of *Zannichellia* cf. *palustris* collected in the Pergusa Lake (photo A. Troia).

During our visits, the water of the lake was always yellowish and turbid; according to Abita *et al.* (2019), on the basis of samplings and analyses made during 2018, the chemical and ecological status of the Lake was "not good".

DISCUSSION

It is not easy to homogenize data about salinity, reported in different ways in the last 130 years, but it is clear that Pergusa Lake - in spite of the input of freshwater from outside the basin - is a saline lake (sensu Hammer 1986), subject (as other saline endorheic lakes) to fluctuations in salinity, area and depth (Afonina & Tashlykova 2020).

Before 2007, the Pergusa Lake was a *Chara*-lake (sensu Azzella 2014, Pukacz *et al.* 2016 and references cited therein). Probably the most significant way in which charophytes affect aquatic ecosystems is through biomass production, which is an important factor in nutrient cycling (Kufel & Kufel 2002). Charophytes are also able to decalcify the ambient water (influencing alkalinity and pH) resulting in the storage of a large portion of incorporated carbon in the sediment. Additionally, the deposition process is accompanied by the co-precipitation of inorganic phosphorus. All the above effects stabilize the trophic status and stimulate the clear water state of a lake (Pukacz *et al.* 2016).

The scenario is definitely complex, but it seems evident that the concurrence of two new factors (namely, the input of freshwater from outside the basin, and the introduction of the carps), in addition to other factors (such as the racetrack caging the lake, or the impact of "black" waters from human settlements, etc.), contributed to the destabilization of the lake ecosystem, with an upset of the water chemical-physical traits and a revolution in the trophic chain, starting from the destruction of the primary producers i.e. the *Chara canescens* meadows. Graphs in Amore & Termine (2007, Fig. 15), Barone *et al.* (2008, Fig. 7) and Naselli-Flores *et al.* (2016, Fig. 2A) clearly show the temporal relationship between the input of freshwater and the decrease of salinity/conductivity. As noted in the introduction, *Chara canescens* is connected to saline habitats (Nowak *et al.* 2019), and the current salinity is probably not compatible with its needs; after freshwater input, another freshwater charophyte (*Chara globularis*) seems to have tried to establish (or expand) but without success, probably because of the carps. So today charophytes and vascular plants are absent (with the exception of some rare individuals of *Zannichellia* cf. *palustris*). Also the observed variation in the bird community composition, namely the decrease of herbivorous species and the increase of piscivorous ones, attributed to a bloom of a microalga (Barone *et al.* 2008), could be indeed ascribed to the disappearance of the *Chara* meadows.

In the turbid state (which we see today), the development of submerged vegetation is prevented by low underwater light levels. The unprotected sediment frequently is resuspended by (alien) fish searching for food causing a further decrease of transparency. Since there are no plants that could serve as refuge, zooplankton is grazed down by fish to densities insufficient to

control algal blooms (Scheffer 2001). On the effects of a carp invasion on the macrophytes of a Mediterranean shallow lake, see Florian *et al.* (2016).

Restoration of non-vegetated turbid shallow lakes to the clear vegetated state is notoriously difficult, but strong measures such as the removal of part of the fish stock and changes in the water level have been used successfully as a way to break the feedback that keeps such lakes turbid (Scheffer 2001).

Oospores of *Chara canescens*, adapted to long time survival in a dormant state (Rodrigo *et al.* 2010), are probably (and hopefully) still present in the sediments of the lake; so that we hope that - after an attempt to apply strong measures as suggested above - no further disturbances will affect the lake, allowing the recovery of its cycles of floods and droughts, including red waters and all the micro-organisms involved.

CONCLUSIONS

The basic error in the recent management of the Pergusa Lake is probably in wanting to consider the basin as a classic "lake"; if not really a "pond" (as defined by Forti 1933), it should be considered a shallow lake naturally subject to cyclical or irregular oscillations (Forti 1933), with periods of partial or total desiccation that fall within the normality of the basin; in this sense, see also figures 7 and 9 in Sadori & Narcisi (2001), where the pollen of aquatic or hygrophilous species during the last 10,000 years occurs discontinuously ("*In the last 2000 years, (...) unstable shallow waters possibly causing temporary emersions may account for sediment filling of the lake besides the climate aridification which started in the mid-Holocene*", Sadori & Narcisi 2001).

However, natural variability cannot be an excuse for inaction, and some possible measures have been suggested (at the end of the discussion) to face the two recent disturbances affecting the lake. In any case further studies and more attention to the lake are needed.

Finally, the case of the Pergusa Lake is important to appreciate the difference between protection of the landscape and protection of the ecosystems: often the two go together, but not always. Not in this case.

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Homage to Proserpina, symbol of the rebirth and perennial return of Spring after Winter: may the Pergusa Lake come back to its saline Spring and its alternating of wet and dry periods.

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