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Charophytes from four Cyclade Islands (Mykonos, Naxos, Paros and Antiparos) in Greece

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I have shortly described eleven localities from the Cyclade islands Mykonos, Naxos, Paros and Antiparos, one of which has freshwater, two have brackishwater and the rest are salt lakes. Of special interest are the salt lakes. These lakes are situated close to popular beaches and are therefore exposed to human activities. The lakes at Ag. Prokopios, Kamari, Mikra Vigli, Naxos airport and Fanari beach should be protected. The brackishwater lake near the airport at Naxos has special qualities and should also be protected. The charophytes *Lamprothamnium papulosum*, *Chara canescens*, *C. galioides* and *C. aspera* were found in this lake. Typical species in the salt lakes are *Lamprothamnium papulosum* and *Ruppia maritima*. The salt content in these lakes varied between 1.3% (2003) and 20% (2002). In such environments, *L. papulosum* can only survive by oospores and/or bulbils. In Kamari, I found specimens of *L. papulosum* with swollen lower branchlets. In the brackishwater poll at Ormos Amiti I found *Chara vulgaris,* while *Chara globularis* was found in freshwater on Mykonos. Totally six species of charophytes have so far been found in the islands.

Key words: Greece, salt lakes, charophytes, *Lamprothamnium papulosum, Chara canescens, C. vulgaris, C. galioides, C. aspera, C. globularis.*

INTRODUCTION

In the summers of 2002 and 2003 I have visited four Cyclade islands in Greece. In June/July 2002 I have visited Naxos, Paros and Antiparos and in May/June 2003, Naxos and Mykonos. On these islands there are several salt lakes and brackishwater localities. In Mykonos, there is one small freshwater pond with vegetation of charophytes. In 2003, the water volume of all lakes visited was much higher than in 2002. This was due to the precipitation during winter and early spring. In late spring and summer, when rain is scarce, water evaporates increasing this salt concentration.

Since there are no special references on these localities and on charophytes therein, I want to publish my finds. The locations of the examined lakes can be seen in Fig. 1.

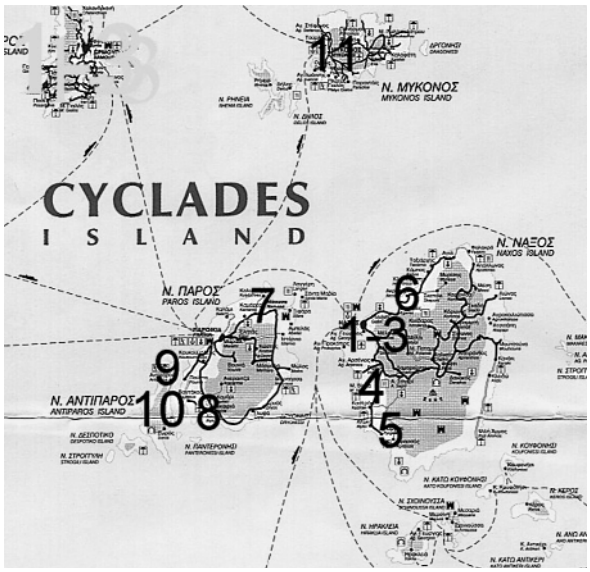

FIG. 1. Map showing the examined localities.

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MATERIALS AND METHODS

This work is based on material collected by the author in the given localities in 2002 and 2003. The charophytes were later determined and photographed.

The saltcontent of the water was measured with a Hack Conductivitimeter (Model 44600/CND/TDS).

RESULTS

A. NAXOS

1. Brackishwater lake north of Naxos city, by the airport (Figs 2 and 3).

This is a large eutrophic lake with well-developed vegetation of halophytes. The vegetation in the water was dominated by *Ruppia maritima* L. and charophytes in dense stands (*Lamprothamnium papulosum*, *Chara canescens, C. galioides* and *C. aspera*). Deeper down, *Ruppia* seemed to dominate. The bottom was black sandy, silt.

The northern part of the lake was filled out with soil, stones and different kinds of organic material (Fig. 3). This has affected the vegetation and presumably also the water quality. The locality is biologically unique and has a high protective value. Until more detailed investigations are done, the dumping of sewage in the lake should be stopped.

The salt content was 8.56 gl^{-1} in 2002 and 1.77gl^{-1} in 2003.

2. Salt lake north of Naxos city, by the airport

This locality is situated just southern of locality no. 1, on the beach. It is a small salt lake, with shallow water. In 2002, the salt content was 96 gl^{-1} and the shores were white, because of the salt crystals. In

FIG. 2. Locality no. 1 seen from north, Naxos city to left. Photo 29. June 2002.

FIG. 3. Northern part of locality no. 1. In this part the locality is polluted. Photo 29. June 2002.

2003, the area was at least twice as big (300 m × 200 m) and the salt content was 23 gl^{-1}. The bottom was a fine sand mostly covered by vegetation of *Ruppia maritima* and the charophyte *L. papulosum*. Both taxa were scattered in shallow parts and in dense stands in places with deeper water (10-30 cm). In 2002, the charophytes were slightly incrusted with salt and had only black, ripe oospores. In 2003, the plants were healthy green and richly fertile.

3. Lakes at Ag. Prokopios (Fig. 4)

As it can be seen from Fig. 4, there are three lakes. In 2002, the water level was low and the borders between the three lakes were more obvious. In 2003, the water level was much higher. The salt content was 30.90 gl^{-1}, which is high compared to the other salt lakes.

In 2002, the lakes were clearly polluted with brown water. Parts of the mid lake had been used for dumping garbage. In 2003, the water was yellow to brown and the production of insect larvae was very high. No higher vegetation was found, but there were crusts of blue -green algae at the bottom.

4. Lakes at Mikra Vigli (Fig. 5)

At Mikra Vigli there are three salt lakes, two small on either side of a large one. This locality has been visited only in 2003. All lakes are without in- or outflow.

1. The small pond in the north is about 30 m × 50 m

FIG. 4. Ag. Prokopios seen from the north. In 2003, the borders between the three lakes were more or less merged. Photo 1. June 2003.

FIG. 5. Mikra Vigli. Western shore of the large lake. The sea to the right side. Photo 1. June 2003.

in area and very shallow (maximum 10 cm deep) with white sandy bottom. It is filled with dense stands of *Ruppia maritima* and the charophyte *L. papulosum* scattered in more open places. The locality has been affected by a newly built house. The salt content of the water was 27.20 gl^{-1} in 2003.

2) The large lake, which is approximately 250 m × 400 m in surface, is 40 cm deep and has white sandy bottom. The lake bottom is filled with mats of *R. maritima* and *L. papulosum*. In this locality, *L. papulosum* was optimal developed. The salt content was 23.30 gl^{-1} in 2003. The locality is not affected by human activities, and it has, therefore, high protective value.

3) This small lake is quite different from the other two, as it has softer, silty/sandy bottom and is rich in *Salicornia europaea* L.. It is deeper (40-50 cm) and is mostly filled with *Ruppia maritima*. In more open places, *L. papulosum* grew in dense stands. The salt content was 13.00 gl^{-1} in 2003.

5. Lakes at Kamari (Figs 6, 9 and 10)

In 2002, there was only one visible big lake, while in 2003 there were three (one big and two small) lakes.

When I visited the lake in 2002, it had white shores of salt crystals (Fig. 6). The bottom below the salt crystals was black mud, with a special smell. In the salty beds, *L. papulosum* was incrusted with salt crystals (Fig. 6), and bore ripe, black oospores. The only halophyte which I observed was *Phragmites communis* Trin., which grew on scattered stands.

In 2003, the big lake had greybrown coloration, presumably due to the bloom of the flagellate *Rebecca salina* (Carter) Green. In spite of the miscoloured water, I found *L. papulosum* both in the southern and northern parts of the lake. The specimens, which at least for a period had been growing in nearly total darkness, had swollen branchlets at their bases. This was presumably an adaptation to such environments (Fig. 10).

Southern of the big lake (8-900 m × 1-200 m) there were in addition two other small ponds. The one closest was miscoloured, while the other lake had clear water with a rich growth of *R. maritima* and *L. papulosum*.

The locality is very interesting and it has high protective value.

The salt content was 197.6 gl^{-1} in 2002 and only 17.40 gl^{-1} in 2003. This means a reduction from 20% to 1.7%.

FIG. 6. The big lake at Kamari. The shores are white because of the crystallized salt. Photo 28 June 2002.

6. Ormos Amiti

This is a brackishwater poll. The salt content was 4.47 gl^{-1} in 2002. The poll is close to the sea, highly eutrophic with dense growth of filamentous algae and *Ruppia maritima*. On shallow, open parts, *Chara vulgaris* grew scattered among other vegetation.

B. PAROS

7. Ag. Anargiri - Par Santa Maria

This is a large lake behind a popular sandy beach. The human influence was easily visible; a high brick wall and garbage. There were tracks of car driving in the dry parts of the lake. There was no visible vegetation. The shores were covered with white salt crystals.

8. Ormos Aliki

This lake has earlier been very big, but now is filled with stones. A road and a tennis court are built upon this dump. The remaining part of the lake is covered with white salt. The charophyte *L. papulosum* was found incrusted with salt crystals.

C. ANTIPAROS

9. Fanari beach close to Antiparos city (Fig. 7)

Close to Antiparos city there are two lakes covering a large area behind Fanari beach. Human activities have changed the area a lot, as several houses are built close to the lakes and a road crosses one of them.

1. The first lake close to the town is a typical salt lake with vegetation of *Ruppia maritima* and *L. papulosum*. The shores are covered with white salt crystals. The salt content of the water was 156.8 gl^{-1} (16 %) in 2002.

FIG. 7. Fanari beach. The southern lake with reeds of *Arundo donax*. Photo 30. June 2002.

2. The second lake lies in a short distance southern of the first lake. This lake is principally different from the other as it has reeds of *Arundo donax* L., and it has a brown-red surface (Fig. 7). Populations of *L.Lamprothamnium papulosum* were found there. The bottom was black, muddy. Parts of this lake have been filled up with soil, a process which must be stopped, as the lake has a high protective value.

10. Par Glifa

This is a small typical salt lake, which is partly filled up with soil after a road expansion. On the dry, white salty bottom there are tracks of car tires. No charophytes were found.

D. MYKONOS

11. Pond by airport

This is a small freshwater pond by the entrance of Mykonos airport. The surface is more or less covered with filamentous algae (*Oedogonium capillare* (L.) Kütz.). *Chara globularis* grew in small open places on the sandy bottom. The salt content was measured to be 0.31 gl^{-1} in 2003.

THE CHAROPHYTES

Of the eleven localities described, eight are salt lakes (if small ponds and bigger lakes are co-counted, the total number is 15), two are brackishwater lakes and one is a freshwater lake. These three types of environments have different vegetation, due to the differences in salt content. Of the charophytes, *L.Lamprothamnium papulosum* was the only species found in the salt lakes. The species was also found in the brackishwater lakes. In addition, four other species were found in the two brackishwater localities in Naxos. *Chara globularis* is the only species found in freshwater.

Lamprothamnium papulosum (Wallroth) J. Groves

This species was found in six of the localities, four in Naxos, one in Paros and one in Antiparos. Five of the localities are salt lakes and one is a brackishwater lake at Naxos airport. In 2002, all specimens collected in the salt lakes were white, incrusted with salt crystals, and consequently dead, but they had black, ripe oospores. The specimens were mostly small, dwarf forms, 1-8 cm high, covered with white salt crystals, often with very long protonemal terminal processess (see Fig. 8). That year, the best developed specimens were found in the salt lake by Naxos airport. Specimens here were longer than in the other salt lakes (8 cm) and had longer oogonia (900 μm) and oospores (650 μm long and 300 μm wide).

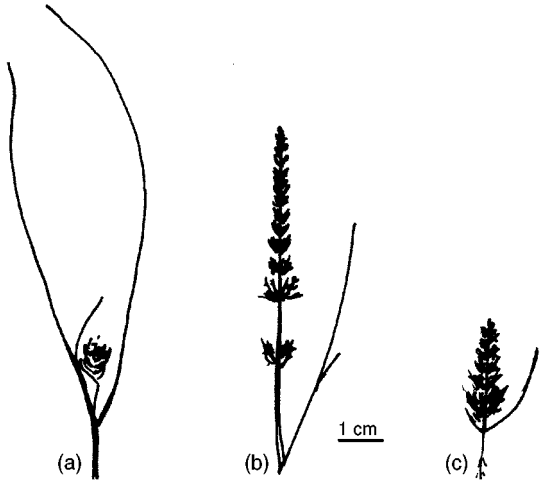

FIG. 8. Different specimens of *L. papulosum* from Fanari beach, Antiparos. Collected 30. June 2002.
(a) Specimen with two extreme long terminal processes (10 cm).
(b) 7 cm long, with 14 whorls, and long (5 cm) terminal process.
(c) 3 cm long, whorls in a dense head. Terminal process 1.5 cm long.

In 2003, the situation was different. All specimens collected were living, they were normally green and rich fertile, with both young gametangia and ripe oospores. In the salt lake by Naxos airport I found living specimens up to 12-13 cm long, with ripe, black oospores, and at the same time young gametangia, red oogonia and orange antheridia.

In 2002, specimens found in Kamari (loc. 5) were only 2-3 cm long and covered by white salt crystals (Fig. 9). Oogonia found on these specimens were up to 750 μm long and oospores up to 500 μm long and 300 μm wide.

As mentioned before, the big lake at Kamari was miscoloured in 2003. Still, *L. papulosum* was found, but as light penetration was limited, the specimens found had developed swollen branchlets at their lowest whorls (Fig. 10). This is most probably an adaptation to low light level.

Round, white bulbils (c. 750 μm in diameter) were found in Mikra Vigli, Fanari and Kamari, three localities with extreme conditions. Bulbils, together with oospores, are important strategies to survive in these environments.

In the brackishwater lake at Naxos airport, the specimens were of "normal" type both in 2002 and 2003, up to 13 cm high, uninstructed, fertile, with both oogonia and antheridia and a low number of ripe, black oospores.

FIG. 9. The charophyte *Lamprothamnium papulosum*, covered by white salt crystals. Kamari. Photo 28. June 2002.

FIG. 10. Specimens of *L. papulosum* from Kamari (loc. 5). The swollen lower branchlets are of special interest (cfr. Text). Total length is 5 cm. Photo of specimens collected 1. June 2003.

Chara canescens Desvaux et Lois.

The collected specimens were up to 30 cm long, thin and rich fertile, with a large number of ripe, black oospores. The species was found in 2003, together with *Chara aspera* (brackishwater, Naxos airport).

Chara vulgaris L.

The collected specimens were up to 25 cm long and greatly incrusted. The specimens were fertile, but did not yet have any ripe oospores. The one known locality (Ormos Amiti) is slightly brackish (0.5% salt).

Chara aspera Deth. ex Willdenow

The collected specimens were up to 10 cm long and incrusted. The stem diameter was up to 300 μm. The cortex was irregular triplostichous and the spine-cells were single, having the same length as the stem diameter. Most of the specimens were extremely rich fertile and all of them were female plants with ripe, black oospores. The oogonia were up to 750 μm long and 450 μm wide, the oospores up to 550 μm long and 300 μm wide, and the antheridia up to 750 μm in diameter.

Chara galioides De Candolle

This species was found in association with *C. aspera* in the brackish lake by Naxos airport. The specimens were coarse, up to 20 cm long with a stem diameter up to 1 mm. In the field, the collected specimens were similar to *Tolypella*. The specimens were very rich fertile. The antheridia were 750-1000 μm in diameter.

Chara globularis Thuill

Typical specimens were up to 13 cm long, rich fertile, with red oogonia and antheridia. This is the only freshwater species found on the islands so far.

DISCUSSION

In the Cyclade islands there are a few natural freshwater localities e.g. small ponds or artificial reservoirs for drinking water. One example is the freshwater pond at Mykonos. More common are the saline lakes where five charophytes have been found. These lakes can be divided into 1. brackishwater lakes with relatively low salinity [(Par Amiti, Naxos airport lake (Table 1)] and 2. salt lakes with varying and at the end of summer with high salinity (salt lake by Naxos airport, Kamari, Mikra Vigli, Fanari beach (Table 1) and the other localities examined). Similar types of saline lakes have been described in the Mediterranean climatic zone of Australia (Burne *et*

TABLE 1. Salt content (%) in some of the examined localities in Naxos, Antiparos and Mykonos (2002 and 2003)

Locality	**Salt content (%) 2002**	**Salt content (%) 2003**	**Charophytes**
Naxos Par Amiti	0.5	–	*Chara vulgaris*
Naxos brackishwater airport	0.9	0.18	*L. papulosum, Chara canescens, C. aspera, C. galioides*
Naxos salt lake - airport	10	2.3	*L. papulosum*
Naxos Kamari	20	1.7	*L. papulosum*
Naxos Mikra Vigli	–	1.3	*L. papulosum*
Antiparos Fanari beach	16	–	*L. papulosum*
Mykonos pond by Airport	–	0.03 (fresh)	*Chara globularis*

al., 1980).

In the brackishwater localities, the variation in salinity throughout the summer season is relatively small, e.g. from 0.18-0.9% in Naxos airport. In the salt lakes, the variation is much higher. In the examined salt lakes, the salinity varied between 10-20% in 2002 and 1.3-2.3% in 2003 (Table 1). The seasonal variation in salinity is dependent on the climatic conditions. It is lower in the spring because of the dilution with rainwater and it increases in the summer during water evaporation.

Charophytes were found both in fresh- and brackishwater (Langangen *et al*., 2002). In the three Cyclade islands, six species of charophytes were found:

Chara canescens
C. vulgaris
C. globularis
C. aspera
C. galioides
Lamprothamnium papulosum

Chara vulgaris and *C. aspera* are found in both fresh- and brackishwater (Langangen, 1974), *C. galioides* and *L. papulosum* only in brackishwater (Corillion, 1957) and *C. globularis* only in freshwater (Langangen, 1974).

L. papulosum is of special interest, as it can tolerate salinities varying from those close to freshwater to those of three times the sea water (9.5%) (Bisson & Kirst, 1980; Wichmann & Kirst, 1989). *L. papulosum* has been adapted to the extreme environment in the salt lake, by favouring production of bulbils and ripe black oospores instead of growing the thallus. In the examined localities, the salinity increases during the summer. The lakes are shallow, 10-40 cm deep, and as water evaporates the temperature will also rise and the growth season will be short. As a consequence specimens from such localities are small (see Fig. 8) compared to specimens from brackishwater where the growth season is longer. This is also supported by the fact that the salt lake by Naxos airport with the lowest salinity (10%) had the longest and most developed specimens. According to Dubois (1968) dwarf forms of *L. papulosum* develop at higher salinities (>3%).

The presence of specimens of *L. papulosum* with swollen branchlets is interesting. This is presumed to be an adaptation to low light regime.

In similar localities in Australia, Delroy (1974) found considerable amounts of *L. papulosum* in the guts of ducks, and it is believed that the species is distributed between the islands by such birds.

The increasing tourism might be a threat to many coastal habitats in Greece. On Naxos, Paros and Antiparos, I found negative development, e.g. the two salt lakes at Paros and Par Glifa in Antiparos were damaged. Visible interventions were also seen in several other localities, the Naxos brackishwater lake and the Ag. Prokopios and Fanari beaches in Antiparos. The only three localities without visible changes are the salt lakes by Naxos airport, Mikra Vigli and Kamari. From a protectional point of view, these three localities should be protected according to the EU Directive 92/43/EC. I also suggest that the three other, slightly affected localities should be protected for the same reasons. The two localities at Fanari beach are of particular interest, since they are salt lakes with higher vegetation, and therefore quite different from the others.

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