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Distribution Patterns of Characean Species Across Aquatic Habitats with Varying Salinity in Cyprus

Field trip results of the Characeae conference in Cyprus (26.04.2024 – 29.04.2024)

Abstract

During the Characeae Meeting 2024 in Cyprus, numerous field surveys were conducted to document the occurrence and distribution of characean species across a variety of aquatic environments, spanning from saline lakes to freshwater reservoirs and rivers. The surveys included both natural and artificial water bodies, focusing on notable locations such as Paralimni and Oroklini Lakes, Achna Dam, Ezousa and Diarizos Rivers, Akrotiri wetland complex including the Salt Lake, Akrotiri marsh, gravel pits and Bishop's Pool, as well as Larnaca Salt Lake. Each site represented a unique set of ecological conditions, providing a comprehensive overview of the habitats in which characeans can thrive. Key findings included the presence of *Chara connivens* and *Chara aspera*/*Chara galioides* at Paralimni Lake, which is part of the Natura 2000 network and showcases biodiversity in brackish conditions. The record of characean taxa, supports the presence of the priority habitat type 1150*-coastal lagoons in the saline/ brackish water bodies surveyed. In contrast, the freshwater systems of the Ezousa and Diarizos Rivers revealed species such as *Chara vulgaris* and *Chara globularis*, while *Lamprothamnium papulosum* was exclusively found in the saline conditions of the ditches and marshlands near Limassol Salt Lake. These observations underline the adaptability of characeans to diverse salinity levels, although species composition varies markedly between saline and freshwater habitats. This work, enhances the understanding of the ecological distribution patterns of characeans within Mediterranean ecosystems and provides valuable baseline data for conservation strategies, particularly within protected areas. The insights gained, underscore the importance of habitat-specific management for conserving the biodiversity and ecological functions of characeans in these sensitive and diverse habitats.

Keywords: Characean distribution, saline habitats, Mediterranean ecosystem, aquatic vegetation

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1 Introduction

Coastal lagoons and saline lakes are dynamic transitional water systems that serve as vital habitats for specialized aquatic species. These ecosystems are shaped by complex interactions between marine and freshwater inputs. They provide a wide range of ecosystem services, including provisioning services such as food and raw materials, regulating services such as carbon sequestration and water regulation, supporting services such as habitat provision and nutrient cycling, and cultural services such as aesthetic and educational values (NEWTON et al., 2018; PÉREZ-RUZAFA et al., 2019). However, due to their location and ecological value, they are also subject to strong anthropogenic pressures, including nutrient enrichment from agriculture, tourism, and urban development (VIAROLI et al. 2008). In such systems, macrophytes play a crucial role as ecosystem engineers, structuring habitats, stabilizing sediments, and supporting biodiversity. Among them, charophytes (Characeae, Charophyceae) are particularly relevant due to their sensitivity to environmental changes, making them valuable bioindicators for assessing ecological conditions (e.g., STEINHARD et al. 2009). Despite their ecological significance, research on benthic macrophytes, particularly charophytes, in Cypriot transitional waters remains scarce. While terrestrial flora in Cyprus has been extensively studied, knowledge of submerged macrophyte communities, especially in non-marine systems, is limited. Most of the previous research focused on fully marine environments (MALEA AND HARITONIDIS 2001, TSIRIKA AND HARITONIDIS 2005, ORFANIDIS et al. 2007), leaving gaps in the understanding of charophyte distribution and diversity in coastal lagoons and inland saline lakes. Two of the few exceptions are the studies by TZIORTZIS (2008) and CHRISTIA et al. (2011), which surveyed the charophyte flora of Limassol and Larnaca Salt Lakes, the most important coastal saline lakes in Cyprus.

The present study was conducted as part of a broader effort to expand the knowledge of charophyte communities in Cypriot transitional and inland waters. Given the island's unique biogeographical position in the eastern Mediterranean and its diverse coastal and inland areas, Cyprus offers an excellent opportunity to study the diversity of charophytes under different environmental conditions. By updating the inventory of charophyte species and evaluating their ecological preferences, this study contributes to a better understanding of macrophyte assemblages in transitional and inland water systems. The findings provide a crucial baseline for future ecological monitoring, conservation strategies, and the application of charophytes as bioindicators in Cypriot water bodies.

As part of this effort, the Characeae Meeting 2024 was held from 26 to 29 April in Cyprus, within the framework of the EU-CONEXUS project. Frederick University in Nicosia kindly provided the meeting and laboratory facilities for the event. The conference brought together 20 participants from Germany, Austria, the Netherlands, and Cyprus, who engaged in discussions, laboratory work, and field excursions.

2 Material and Methods

2.1 Procedure

The conference was opened by Mr Kounnamas and Ms Papatheodoulou on April 26, 2024, at Frederick University in Nicosia. Following the introduction of the schedule, the morning session featured a series of scientific presentations. The first talk, given by Athina Papatheodoulou, provided an overview of Cyprus' vegetation, geological structure, and freshwater bodies relevant to the planned field excursions. Petra Nowak then presented her research on the use of environmental DNA (eDNA) methods for assessing charophyte biodiversity, highlighting their potential for detecting rare species in heterogeneous aquatic ecosystems. John Bruinsma discussed the vegetation of sand and gravel pits in the Netherlands, emphasizing their ecological significance, the challenges posed by shallow lake depths, and their role in supporting specialized plant species. Silke Oldorff followed with an account of the rediscovery of *Lychnothamnus barbatus* in Germany, a species previously thought extinct in the region. Her research explored the influence of fish populations and anthropogenic factors on the species' occurrence. Julien Böhm then examined the distribution and temperature tolerance of *Sphaerochara canadensis,* questioning its classification as a strictly cold stenothermic species. Alena-Maria Maidel presented a planned one-year study investigating the maximum colonization depth using drone-based transect mapping, nutrient analysis, and exclusion experiments in an oligotrophic lake in Mecklenburg-Western Pomerania. The final presentation by Carolin Magdalene Heise focused on inorganic carbon uptake mechanisms in *Chara braunii* and the development of a pH-dependent carbon-concentrating mechanism model. Following the presentations, participants took part in field excursions to various aquatic habitats across Cyprus.

2.2 Study area

The conference excursions took place in the southern, western, and eastern parts of Cyprus (Fig. 1) covering a broad range of aquatic habitats. These included natural and artificial freshwater and saltwater lentic systems, as well as perennial rivers. All the areas visited, are of great ecological importance, for flora, fauna and/or habitats, representing key wetland habitats of high biodiversity value. They are protected either under the Natura 2000 network or under the Protection and Management of Nature and Wildlife Ordinance (Akrotiri wetland complex). Diarizos and Ezousa Rivers are of particular ecological importance, as they are among the biggest river water bodies in the island, with perennial sections along their length. Sampling sites also included areas characterized by elevated salinity, such as Akrotiri gravel pits and pool, which offers potentially suitable habitats for specific charophyte species. Furthermore, lakes such as Paralimni, Larnaca and Limassol salt lakes, were selected based on records indicating the presence of charophytes in the past. A detailed overview of the species identified in each water body, along with their specific coordinates, is provided in Table 1.

2.3 Sampling

Sample sites were located in areas where the water bodies were easily accessible. Sampling was conducted collaboratively by all participants using a randomized sampling design. Specimens were collected from various aquatic habitats and temporarily stored in plastic bags containing habitat water to ensure their preservation during transport. At the laboratories of Frederick University, species identification and taxonomic classification were carried out under stereomicroscopes following the methodology of VAN DE WEYER (2024).

3 Results

Fig. 1 provides a comprehensive spatial overview of the study area, including the locations of all sampled water bodies. The code numbers within the figure were assigned to clearly identify the sampling locations and correspond with those listed in Table 1. The figure was generated using ArcGIS Pro 3.4.2.

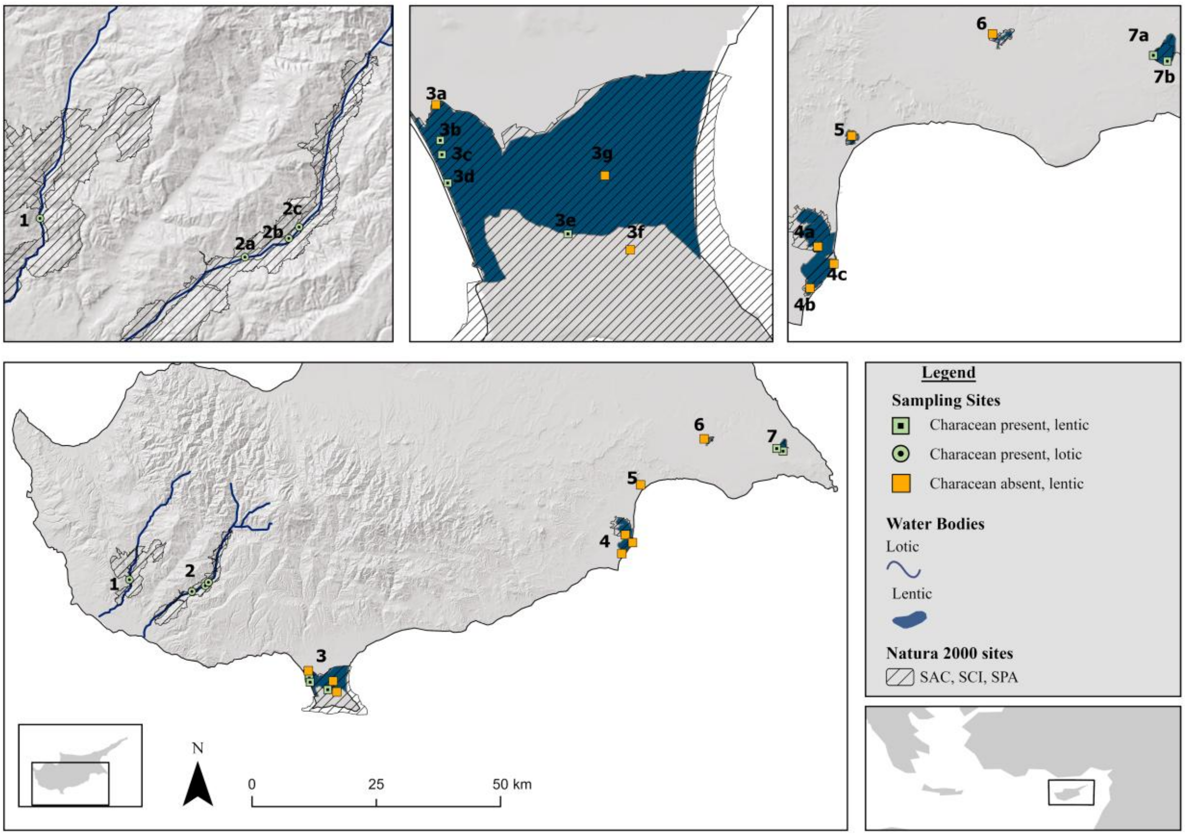

Fig. 1 Overview of the excursion sample sites in Cyprus, highlighted by numbered identifiers.

The results of our field survey are presented along a west-to-east transect across the island for clarity (Fig. 1). In the western part of the island, two lotic systems, the Ezousa and Diarizos Rivers, were examined. The Ezousa River (Fig. 1; No. 1) yielded *Chara squamosa*, *Chara vulgaris*, and *Chara globularis*. In the Diarizos River, the fourth-longest river in Cyprus, Characeae diversity was assessed at three sites under varying hydrological conditions. At the first site (Fig. 1; No. 2a), *C. squamosa* was recorded, collected, and dried for herbarium preservation (Fig. 2B). Further upstream (Fig. 1; No. 2b), a Characeae grassland was identified, comprising of *C. gymnophylla* and *C. contraria* (Fig. 2C). In a shaded bay at a more upstream location (Fig. 1; No. 2c), *C. globularis* was observed. The Limassol Salt Lake system, also known as Akrotiri Salt Lake, was surveyed (Fig. 1; No. 3a–3g). No Characeae species were detected in the main salt lake (Fig. 1; No. 3a). However, in adjacent brackish coastal regions, including gravel pits and the Akrotiri pool (Fig. 1; No. 3b - 3d), *Lamprothamnium papulosum* was recorded, confirming its occurrence in saline habitats. Further brackish ponds within the Akrotiri complex (Fig. 1; No. 3e) contained *Chara canescens* alongside *L. papulosum*. Bishop's Pool, located near Limassol salt lake (Fig. 1; No. 3f), was also surveyed, but no Characeae were found. Similarly, no Characeae were detected in the Limassol main salt lake (Fig. 1; No. 3g). Investigations were conducted at the Larnaca Salt Lake system, which comprises interconnected saline basins: Larnaca Main Salt Lake, Airport Lake (Fig. 1; No. 4a), Soros Lake (Fig. 1; No. 4b), and Spyros Lake (Fig. 1; No. 4c). No specimens were found there on April 29, 2024. Oroklini Lake (Fig. 1; No. 5) and Achna Dam (Fig. 1; No. 6) were also surveyed, but no Characeae were recorded at either site. At Paralimni Lake, Characeae presence varied across locations. In the southern section (Fig. 1; No. 7a), only desiccated remnants were found, preventing species identification. A representative image of the dry sediment is shown in Fig. 2A. However, in the eastern section (Fig. 1; No. 7b), *Chara connivens* and *Chara aspera/Chara galioides* were identified. Due to the absence of reproductive structures, differentiation between *C. aspera* and *C. galioides* at the species level was not possible.

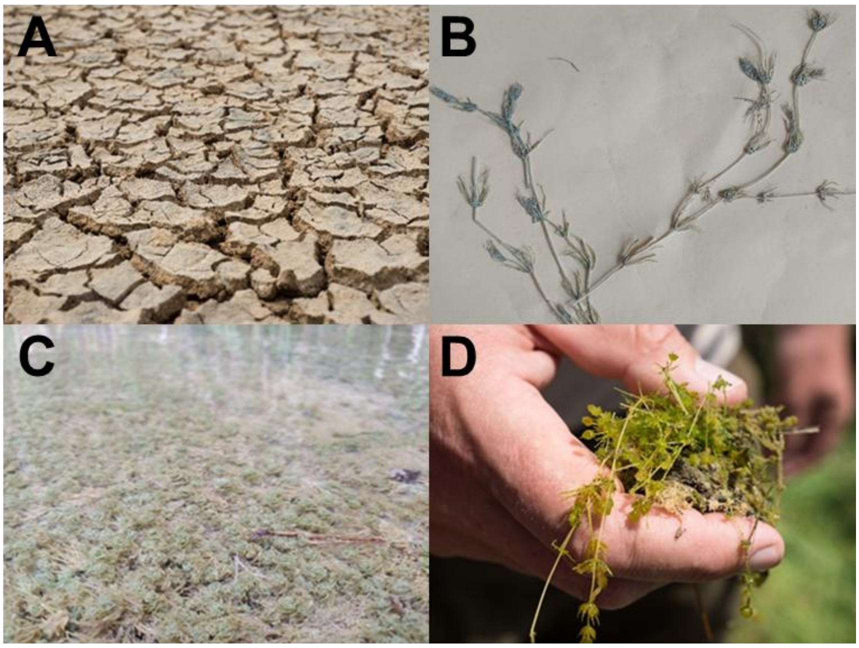

Fig. 2 Various charophyte habitats in Cyprus. (A) Dry sediment on the southern shore of Paralimni Lake (April 26, 2024). (B) Herbarium documentation from Matthias Teppke of *Chara squamosa* from the Diarizos River (April 27, 2024). (C) Characeae mat in the Diarizos River (April 27, 2024). (D) Charophytes from a ditch near Limassol Salt Lake (April 29, 2024). Images (A) and (D) were created by Julien Böhm.

4 Discussion

Charophytes are key components of freshwater and brackish ecosystems, contributing to habitat complexity, sediment stabilization, and nutrient cycling. Their distribution is strongly influenced by hydrology, light availability, and salinity, making them valuable indicators of environmental change. The findings of this study reveal distinct patterns of charophyte occurrence across different aquatic habitats in Cyprus, highlighting the role of local conditions and broader climatic trends in shaping charophyte communities.

The Ezousa River, located within the protected Natura 2000 area "Episkopi Morou Nerou" plays a crucial role in groundwater recharge and supports a diverse aquatic flora (TZORAKI et al. 2018). During this survey, multiple *Chara* species were recorded, including *C. squamosa*, *C. vulgaris*, and *C. globularis*, confirming the river's suitability for charophyte growth. Similarly, the Diarizos River, a dynamic lotic system, harboured *Chara* species at all surveyed locations, with species composition varying along the hydrological gradient. Notably, *C. globularis*, observed in a shaded bay at the northernmost site, exhibited an elongated morphology, a common adaptation to low-light conditions (KRAUSE 1997). This suggests that habitat structure and light availability significantly influence local charophyte distribution and growth forms. In contrast, the surveyed lentic systems displayed a markedly lower charophyte presence. While the main water bodies of Limassol (Fig. 1; No. 3a, 3g) and Larnaca Salt Lakes (Fig. 1; No. 4a–4c) yielded no Characeae, brackish ponds in the Akrotiri region (Fig. 1; No. 3e) supported *C. canescens* and *L. papulosum*. The presence of *L. papulosum*, an obligate brackish-water species (MARTÍN-CLOSAS et al. 2016), highlights the influence of salinity in structuring charophyte communities. The absence of charophytes in the main salt lakes, despite previous records of *C. canescens* and *C. tenuispina* (CHRISTIA et al. 2011), may be linked to environmental changes, particularly increased salinity due to the exceptionally dry spring of 2024 (WEATHERSPARK 2024). Given that *C. canescens* tolerates salinity up to 22.4 psu (BLINDOW & SCHUBERT 2004), it is possible that hypersaline conditions exceeded this threshold, preventing charophyte growth. The findings at Paralimni Lake further illustrate the importance of hydrological variability. While charophytes were absent at some locations, *C. connivens* and *C. aspera/C. galioides* were documented in the eastern section (Fig. 1; No. 7a). However, desiccated *Chara* remnants found in the southern section (Fig. 1; No. 7b) indicate temporary population losses due to water level fluctuations. The observed differences between sites emphasize the role of hydrology in shaping charophyte assemblages, particularly in Mediterranean wetlands where seasonal desiccation is common. Bemerkenswert war außerdem, dass keine Characeaen der subsection Hartmania gefunden wurden und auch, dass keine Tolypella/Spherocara gefunden wurde. Das wurde erwartet, da…?

Compared to previous studies, the overall decline in charophyte diversity suggests that environmental conditions in Cyprus' aquatic habitats may be shifting. In addition to climate-driven salinity increases, anthropogenic pressures such as groundwater abstraction and coastal development may further alter water balance and habitat suitability for charophytes. This observation is not unique to Cyprus but has also been reported from other Mediterranean regions. BECKER (2019), for example, identified Sardinia as a hotspot for charophyte diversity, particularly within temporary brackish wetlands, where species such as *Lamprothamnium papulosum* and *Tolypella hispanica* Nordst. ex Allen were found to dominate. Interestingly, Becker emphasized that many of these habitats are not only species-rich but also highly vulnerable, as they are often small, ephemeral, and lack formal protection. The situation in Sardinia underscores the broader Mediterranean-wide conservation urgency for charophytes, especially in dynamic habitats that are sensitive to both climatic and land-use changes.

Future studies should focus on quantifying seasonal salinity variations and assessing long-term trends to determine whether these changes reflect natural variability or an ongoing decline in charophyte populations.

Tab. 1 Taxa list of the Characeae meeting in Cyprus 2024. The table lists the location, dates, coordinates (latitude, longitude) and notes on species identification, which were visited during the Characeae meeting in Cyprus from 26.04.2024 to 29.04.2024. The numbers (Column 'Code') were assigned to clearly identify the specific stops, where the species were detected.

Code	Sampling Site Name	Ecosystem	Charopyhte taxa	Latitude; Longitude
1	Ezousa River @ Episkopi Morou Nerou	Lotic	*Chara squamosa* Desf.; *Chara vulgaris* L.; *Chara globularis* Thuill.	34.799271; 32.529136
2a	Diarizos River @ Ag. Georgios	Lotic	*Chara squamosa* Desf.	34.778319; 32.666624
2b	Diarizos River @ Extreme View	Lotic	*Chara gymnophylla* A. Braun in Flora 18; *Chara contraria* A. Braun ex Kütz.	34.788774; 32.696014
2c	Diarizos River@ Kourtelorotsos	Lotic	*Chara globularis* Thuill.; *Chara contraria* A. Braun ex Kütz.	34.795023; 32.702891
3a	Akrotiri marsh	Lentic	No charophytes found	34.635083; 32.922926
3b	Gravel pits	Lentic	*Lamprothamnium papulosum* (Wallr.) J. Groves	34.625644; 32.924311
3c	Gravel pits	Lentic	*Lamprothamnium papulosum* (Wallr.) J. Groves	34.621863; 32.924837
3d	Akrotiri pool	Lentic	*Lamprothamnium papulosum* (Wallr.) J. Groves	34.614329; 32.926723
3e	Akrotiri salt lake brackish pond	Lentic	*Chara canescens* Desv. & Loisel.; *Lamprothamnium papulosum* (Wallr.) J. Groves	34.600840; 32.965322
3f	Bishops pool	Lentic	No charophytes found	34.596616; 32.985352
3g	Limassol main salt lake	Lentic	No charophytes found	34.616319; 32.977179
4a	Larnaca salt lake - Airport lake	Lentic	No charophytes found	34.879949; 33.620424
4b	Larnaca salt lake - Soros lake	Lentic	No charophytes found	34.845979; 33.612441
4c	Larnaca salt lake - Spyros	Lentic	No charophytes found	34.865754; 33.636146
5	Oroklini lake	Lentic	No charophytes found	34.970317; 33.654801
6	Achna dam	Lentic	No charophytes found	35.052939; 33.795548
7a	Paralimni lake - Sotira	Lentic	*Chara connivens Salzm. ex A. Braun; Chara aspera Willd. / Chara galioides DC.*	35.034182; 33.955418
7b	Paralimni lake - Shooting range	Lentic	Dry *Chara* specimens found. Not identified	35.029339; 33.969253

Zusammenfassung

Während des Characeae Meetings 2024 in Zypern wurden zahlreiche Gewässer von Salzwasserseen bis zu Flüssen untersucht, um die Verbreitung von Armleuchteralgen zu dokumentieren. In Paralimni Lake wurden *Chara connivens* und *Chara aspera/Chara galioides* in einem salinen Natura-2000-Gebiet nachgewiesen, während in den Süßwassersystemen von Ezousa- und Diarizos-Flussarten wie *Chara vulgaris* und *Chara globularis* vorkamen. *Lamprothamnium papulosum* wurde ausschließlich in den salzhaltigen Gräben nahe des Limassol Salt Lake entdeckt. Die Ergebnisse verdeutlichen die Anpassungsfähigkeit von Characeen an unterschiedliche Salzgehalte und die daraus resultierende Artenzusammensetzung. Darüber hinaus zeigen sie die potenziellen Auswirkungen der Klimaerwärmung auf diese spezifischen Biotope und deren Ökosysteme.

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