IRGC NEWS

INTERNATIONAL RESEARCH GROUP ON CHAROPHYTES

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Species determination of some of the handmade «oospores» was a challenge, while others were quite perfect.

Dear IRGC members,

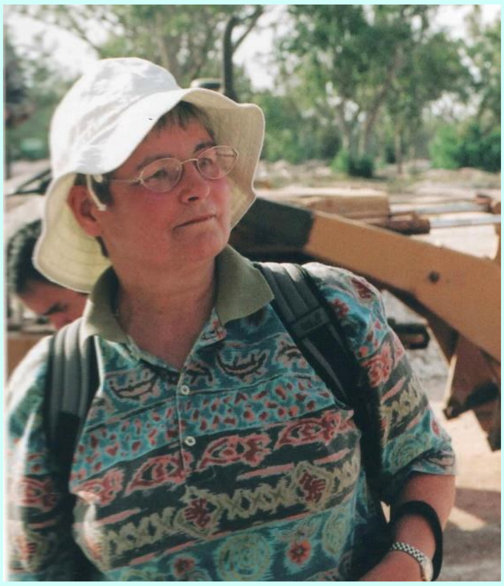
After many years without physical meetings, we finally were able to see each other again in Riga, Latvia, in August 2022. The meeting was nicely organized by Egita Zviedre and her colleagues, and we enjoyed very interesting presentations, engaged discussions, a fantastic view from the university building, delicious Latvian food, and perfect weather for charophyte sampling. Egita even showed us how to make our own "*Chara*" oospores from *Schoenoplectus* stems! The paleoecologists among us had a hard time determining which species we made. It turned out we probably made some hitherto undescribed species, and some of our oospores also seemed to have been "transported" quite some distance before they materialized in our hands (judging from the slight "damage" that some of them had). The pictures below may serve as an illustration of our little "oospore factory" in Riga. A big THANK YOU to our colleagues from Latvia for organizing such a nice and interesting meeting, and to all contributors for interesting presentations and discussions.

I particularly enjoyed the truly interdisciplinary discussions we had in Riga. Electrophysiologists discussed with paleoecologists, ecologists with molecular biologists and ornithologists. We truly benefitted from each other's experiences and knowledge, and we learned a lot about the benefits of interdisciplinary work. The key to this success was that our Latvian colleagues allocated 30 minutes to each presentation, including discussions (20 min presentation and 10 min discussion). This was more time than we get at most conferences. The presenters did not use this "extra-time" to simply present more results, but instead, they took the time to explain the background and the methods of their study, in a way that was understandable to everybody. That way, the non-paleoecologists among us understood a bit more about how paleoecology works, and we discovered how electrophysiology might help to explain paleoecological results. We also learned why waterbirds seem to find charophytes really tasty, and how much grazing "damage" birds might do to "our" charophytes. Stable isotopes, genetic methods, and many more were explained in a way that was understandable to the entire audience. I would like to encourage all organizers of future meetings to consider allocating enough time to each presentation, and I would like to encourage all presenters to explain background, methods and results of their study in a way that is understandable to an interdisciplinary audience. The experience in Riga was great, and I would really like to see the IRGC develop further into this truly interdisciplinary direction.

We have not scheduled a GEC or IRGC meeting in 2023, but the plans for the next IRGC meeting are becoming more and more concrete. Michelle Casanova will organize an IRGC symposium in Australia, likely in September/October 2024 (Michelle is currently trying to work out the best time). I truly look forward to this symposium already! We do not yet have any specific plans for future meetings, however. So, if you can imagine taking on the challenge of organizing a GEC or an IRGC symposium, please do not hesitate to contact us.

Susanne Schneider

OBITUARY



Our colleague **Ursula Winter** died in July 2022 at the age of 83. Ursula had been a member of the IRGC since the GEC-meeting in Berlin in 1991. After her first university position devoted to the study of ants during the 70-ies, she collaborated with Professor Gunter O. Kirst at the University of Bremen (Germany) about physiology and salt tolerance of the Characeae.

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WELCOME TO NEW MEMBERS

It is great pleasure to welcome our new members: Henk Janssen (The Netherlands), Gregor Thomas (Germany), Liucija Kamaitytė-Bukelskienė (Lithuania), and Lukas Petrulaitis (Lithuania) are warmly welcomed.

GEC MEETING, RIGA, LATVIA, 2022

The scientific sessions of the 23rd Meeting of the Group of European Charophytologists (GEC) took place in the beautiful and new building of the Academic Centre of the University of Latvia, in Riga.

Making oospores from *Schoenoplectus* stems certainly needs some skills! Egita did a very nice job as «oospore teacher».

The extant charophytes

The first extant charophyte talk, related to the Status report on "European charophytes", was held by **Hendrik Schubert,** who briefly summarized the current status, as well as the timeline, for the very last steps in the production of "the first pan-European multi-authored publication about all aspects of European charophytes", commonly called new European Charophyte Monograph. The project lasted more than five years and the new monograph will have more than one thousand pages related to more than 70 charophyte taxa.

Eugeniusz Pronin continued the talks showing us the results of the project in which the values of stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope composition of *Nitella flexilis* C. Agardh, 1824 were compared in softwater and hardwater lakes. Even though statistically significant differences between obtained $\delta^{13}C$ and $\delta^{15}N$ values of *N. flexilis* from those two types of lakes were not found, Principal Components Analysis (PCA) analysis showed some correlations between obtained $\delta^{13}C$ and $\delta^{15}N$ values and water's physicochemical parameters in the studied lakes. However, the authors conclude that $\delta^{13}C$ and $\delta^{15}N$ values are rather lake-specific than follow some clear pattern across two different lake types.

Andrzej Pukacz presented research related to seasonal and regional variability of carbonate precipitation in charophytes and vascular plants. The results showed charophytes were significantly more effective in dry weight production and $CaCO_3$ precipitation than vascular plants. The regions studied showed similar seasonal variability, while W Poland lakes, having lower trophy and milder climate, showed higher values of both parameters in both plant groups. Moreover, physical and chemical water parameters, as well as climatic conditions, were analysed and showed significant but different correlations in the regions studied.

Mary Bisson gave a very interesting lecture on *Chara* salt tolerance, trying to teach us, not so familiar with charophyte physiology, how salt-tolerant charophytes prevent the accumulation of Na^+ in the cells. In spite of her challenging task, she managed to explain to us the study of the evolution of a novel mechanism, called Na/H antiport, for high rates of Na^+ export from cells in salt-tolerant *Chara*, by measuring the expression of genes related to this ability.

Our next speaker was **Aleksandra Marković** who got us into the preliminary Red List of charophytes in Serbia. The latest checklist of Serbian charophytes, from December 2021, counted 25 species. Unfortunately, almost all species are Red listed in Serbia, ten being Critically Endangered (CR), seven Endangered (EN) and seven more Vulnerable (VU), except one which is Data Deficient. Lastly, she summarized factors threatening charophytes in the territory of Serbia.

Angelo Troia presented new findings for the charophyte flora of Sicily (Italy). Two new species, *C. connivens* and *C. papillosa* (or *C. intermedia*, as we like to call it), represent a valuable addition to the impressive flora of Sicily, counting 25 species so far.

Our new young colleague from Lithuania **Liucija Kamaitytė-Bukelskienė** gave a comparison of *Chara filiformis* and *Chara contraria* oospore morphological parameters. After carefully measuring and comparing different oospore parameters, the results showed that these characters are strongly overlapping and therefore should not be used for species separation when oospores are the only available material for study.

At the end of the first day, **Hendrik Schubert** dared to report the news and developments on the battlefield of charophyte species concepts. He summarized different existing species concepts and presented the advantages and limitations of each one, giving illustrative examples. Finally, he presented the newest "species-are-hypothesis" concept, aiming to pave the way to case-specific agreements instead of fundamental debates.

The second day of lectures started with fossil charophytes and continued with the lectures related to the extant charophytes. **Aleksandra Marković** showed us the results of the study related to the diversity and ecology of charophytes in Vojvodina (Serbia). Charophytes were studied along the gradient of salinity. Altogether, 7 species were found in 14 waterbodies, and among them, extremely rare male individuals of *C. canescens*. She presented their relation to different environmental parameters, such as ion composition, temperature, pH, conductivity, nutrient content and chlorophyll a.

Susanne C. Schneider led us far north, to Troll springs on the island of Svalbard, where, as amazing as it sounds, our even more amazing charophytes manage to survive, in spite of extremely harsh conditions to live in. For decades, since the first findings in 1910, up to 2018, there was a dilemma regarding the species living in these warm springs. Ultimately, DNA barcoding resolved the puzzle, discovering the presence of two species, *C. aspera* and *C. canescens*.

Antra Stīpniece presented a very interesting review of complex relationships between stoneworts and waterbirds in Europe. In the beginning, she explained why stoneworts, despite their name, attract such a great number of waterbirds, being delicious themselves but also a good shelter and habitat for different macroinvertebrate communities, which again are a good source of food. Furthermore, she gave us a review of the range and nature of waterbird species showing aggregative responses to Charales-dominated systems in Europe and the relationships between the species involved and their specific feeding ecologies. This comprehensive study also reviewed subjects like the nutritional and energetic value of charophytes relative to other angiosperm macrophytes, as well as the impacts of waterbirds on the dynamics of charophyte community, and finally, the value of waterbirds as dispersive agents to charophytes. Additionally, she talked about the re-establishment of local Charales-dominated communities, after local restoration projects, and the effects on waterbird communities.

Finally, another interesting subject focused on the impact of waterbird colonies on the charophytes vegetation in Lake Engure was presented by our host **Egita Zviedre.** The survey was conducted in three sites for three years, comparing sites with different waterbird colonies and control sites without waterbirds. The results showed significant differences between sites explained by various factors and finally suggest that proximity to bird colonies is related to a decrease in charophyte coverage and is accelerating charophyte loss in Lake Engure.

After the fruitful talks, we enjoyed a guided tour of the city of Riga, followed by the conference dinner at the Latvian National Museum of Natural History, where we had the pleasure of both exploring the museum setting and learning a new art skill of making lovely handcrafts out of rush, or Scirpus stem. Finally, we can only say a big thank you to Egita and her team for having a wonderful Riga experience enjoying science, great company, and seeing and learning new things.

Aleksandra Marković (Serbia)

The fossil charophytes

Up to 10 interesting and remarkable abstracts about fossil charophytes were presented in the meeting. The talks helped to better understand the evolution of charophytes over the geological eras.

Palaeozoic: The oldest charophyte assemblage presented in the GEC´s meeting was conducted by Dr. **Jordi Perez-Cano** et al. (*Charophytes in the Permian of the Pyrenees*) who found thalli and possible gyrogonites in Permian rocks related to floodplains (299–252 million years ago, Ma). The author pointed out that this finding would represent the oldest record of charophytes in the Pyrenees and in the whole Iberian Peninsula.

Mesozoic: Younger charophyte assemblages represented by utricles and gyrogonites was shown by Dr. **Khaled Trabelsi** et al. (*Middle*

Jurassic charophytes. New data for a poorly known period in charophyte evolution) who found them in Jurassic rocks from the north Gondwanian domain (present-day Tunisia, Morocco) and south Laurasian domain (present-day France). These new findings help to clarify the enigmatic stage in the evolutionary history of Mesozoic charophytes, between the Triassic radiation of 'Porocharaceae' and the Late Jurassic–Early Cretaceous radiation of Clavatoraceae. Also, Dr. **Khaled Trabelsi** et al. *(Charophytes across the Jurassic–Cretaceous boundary from the Middle Atlas, Morocco (North Africa)* illustrated the diversity of Clavatoraceans found in the Aït Bazza Formation (Morocco) providing new light on its relative age. The occurrence of this flora in Morocco reinforces the hypothesis that a biogeographic expansion of the Clavatoraceae family took place in the southern Tethyan Archipelago during the Middle Jurassic (~170 Ma). Dr. **Carles Martín-Closas** et al. (*Charophyte island-biogeography in the Cretaceous Tethyan Archipelago*) talked about the palaeobiogeography of charophytes within the Tethyan archipelago (present-day Europe and North Africa) during the late Barremian (time span between 129.4 and 126.3 Ma) considering the size of the paleoislands and their distance from the continents. He concluded that the highest charophyte biodiversity occurred in large paleoislands (up to 17 species) such as Iberia, while the charophyte diversity in smaller paleoisland (Subalpine Chains, Jura Mountains, Tunisia or Lebanon) was much lower. The authors stated that results fit well with the generally well-accepted rule of McArthur and Wilson (1963) that large islands hold a larger biodiversity. However, Dr. Martín-Closas indicated that differences between isolated islands and islands close to continents are not well-defined. Another abstract dealing with Early Cretaceous charophytes was presented by Dr. **Jordi Perez-Cano** et al. (*Early Cretaceous charophyte-rich wetlands from Iberia*). The authors reported a diverse charophyte assemblage dominated by Clavatoraceans from one of the most complete non-marine sections of the Barremian stage (129.4–121.4 Ma). Dr. Pérez-Cano explored the links between charophyte assemblages and type of wetland concluding that the Maestrat Basin (East Spain) hold one of the most biodiverse charophyte floras in the Early Cretaceous World. Still in the same Barremian basin, Dr. **Jordi Perez-Cano** et al. (*Double triplostichous cortication, a new type of cortication found in fossil charophytes*) showed an impressive reconstruction of a complete charophyte plant. He described a new type of cortication (*double triplostichous*) based on studying tens of thin sections from charophyte-rich limestones deposited in ancient shallow temporary lakes. Crossing the Atlantic, Dr. **Alba Vicente** et al. (*Upper Cretaceous charophytes from the Parras Basin, south-eastern Coahuila, Mexico*) described gyrogonites of 3 Characeae species in floodplain facies of the Parras Basin, Mexico. The author explained that this flora provides valuable information about the biostratigraphy and the paleoecology of the area during the Campanian-Maastrichtian ages (~83–66 Ma).

<u>Cenozoic:</u> Dr. **Josep Sanjuan** et al. (*Charophyte palaeoecology of the Middle Miocene Vallès-Penedès and Vilanova basins, Catalonia, Spain*) showed gyrogonites of 10 charophyte species found in Middle Miocene rocks (~16–14 Ma) near Barcelona, related to different aquatic environments (shallow coastal lakes, permanent freshwater lakes and coastal salina). The author pointed out the interest in studying Neogene charophytes to reconstruct the palaeolimnology of ancient wetlands and to improve their usefulness in continental biostratigraphy. In much younger lacustrine deposits, **Elvan Demirci** et al. (*Early Pleistocene charophyte flora from Dursunlu (Ilgin Basin, central Anatolia, Turkey): Palaeoecological implications*) described and illustrated gyrogonites and thalli of 9 charophyte taxa including living representatives such as *Chara hispida*, *Ch. globularis*, *Ch. vulgaris* or *Nitellopsis obtusa* from the Pleistocene of central Turkey (~800.000 years old). The author

stressed that the presence of living representatives help to reconstruct the limnological conditions that prevailed in the lake during the lower Palaeolithic, in a glacial context. Also, **Demirci** et al. (*Charophytes and other subrecent microfossils of lake Liman (Kizilirmak delta, Samsun/Northern Turkey*) showed the gyrogonite assemblage obtained from the subrecent (Holocene) sediments of the Liman lake, north of Turkey. She illustrated gyrogonites of *Lamprothamnium papulosum, Chara aspera* and *Ch. hispida* as well as several euryhaline ostracods, gastropods and benthic foraminifera.

Josep Sanjuan (Spain)

Freshwater and brackish aquatic flora from Latvia: Field trips during the 23rd GEC Meeting

Two field trips were made during the 23rd GEC Meeting, one to the southern area of Latvia, close to the border with Lithuania, and the second one to the north, close to the border with Estonia.

Location of the localities visited during the field trips.

Aquatic flora from Lielauce Lake and visit of Dobeles (August 18th 2022)

Lielauce lake is located to the south of Riga. The take-off from Riga was at 8:00 and the participants arrived at the lake after 2 hours of travelling by bus. During the travel our hosts gave us information about the plants that are around the lake and in the neighbour area. Among the data, it is interesting to mention the occurrence of the carnivorous plant *Drosera rotundifolia* in the areas around the lake.

After having a coffee or an ice-cream (or both) the participants on the fieldtrip were divided in groups of four, and during, approximately, one hour and a half they were boating in the lake searching charophytes and observing the different aquatic flora in the lake Lielauce. Charophytes were identified in the evening in the in the laboratory of Academic Centre of the University of Latvia. Among the aquatic plants identified during the boating there include

Ceratophyllum demersum, *Potamogeton lucens*. *Stuckenia pectinata*, *Sparganium emersum*, *Myriophyllum cf. verticillatum*, *Myriophyllum spicatum*, *Elodea* cf. *canadensis*, *Najas marina*, and *Utricularia* sp. among other aquatic plants Other interesting organisms identified was a freshwater sponge, *Spongilla lacustris*. It was a nice morning observing the aquatic flora and the landscape of the Lielauce lake.

After lunch at Dobele, close to the Lielauce Lake, the participants visited the Dobele's castle ruins. The origin of this castle dates from the 14th century when a stone castle was built at the place of an abandoned hillfort. After successive restorations and even reconstructions (a consequence of different wars), and also different uses of the stronghold, it was abandoned in 1736 and started its degradation. Since 2020, several works have been done in the structure of the castle with the objective of preserving these ruins. After the guided visit, the participants were walking around the centre of Dobele's, which included the visit to the fountain of *Alisma plantago-aquatica*. Later, the participants went back to Riga by bus. The travel to Riga was, approximately, two hours.

The day finished after dinner, with a charophyte determination workshop at the laboratory of Academic Centre of the University of Latvia. The samples provided by the participants were from six different Chara species were identified, including *Chara tomentosa*, *Chara subspinosa*, *Chara papillosa*, *Chara aspera*, and *Chara globularis*. The occurrence of *Chara hispida* was not clear. *Nitellopsis obtusa* was previously found in the Lielauce Lake, but it was not identified among the samples provided by the participants in the fieldtrip.

Lielauce Lake

Dobele's Castle Ruins.

Aquatic flora from Salaca River and from Randu Plavas (August 19th 2022)

This second fieldtrip started earlier than the previous one, at 7:30 the participants were on the road in direction to Mazsalaca to the north of Riga (see the map). At this town, the participants made 5km rowing boat trip in the River Salaca. The rocks around the river are from the Devonian (period of Earth History that ranges between 420 and 360 millions of years). This river was rich in freshwater aquatic plants, including *Nuphar* sp., *Hydrocharis morsus-ranae*, *Cicuta virosa*, *Sium latifolium*, *Equisetum fluviatile*, *Polygonum amphibium*, *Sagitaria sagittifolia*, *Mentha aquatica*, *Sparganium emersum* and *Scirpus lacustris* among others. *Scirpus lacustris* is a cane-shaped plant, and the participants in the meeting were constructing charophyte gyrogonites with this plant after the dinner on the second day of the meeting (17th of August). Several stops were done during this travel on the river, in order to visit several interesting points, such as a small cave or also points rich in fossils, where the palaeontologists that were on the trip stayed for some time searching for small fossils of fishes.

After lunch, the participants went by bus to Randu Plavas, located in the Gulf of Riga. This area is included in the Northern Vidzeme Biosphere Reserve, and it is a plain area rich with a wide diversity of vascular plants such as *Ruppia maritima*, *Zannichellia palustris*, and *Fucus vesiculosus*. It has also a tower prepared to observe birds from which the visitor can see the extension of the area.

The participants had the opportunity of collect charophytes in the lagoon. The charophyte species identified were *Chara baltica*, *Chara canescens*, *Chara aspera*, and *Tolypella nidifica*. *Chara aspera* was especially abundant, while *Chara canescens* and *Chara baltica* were more difficult to find.

After more than two hours on the beach searching and identifying charophytes and aquatic plants, the participants had the opportunity of eating something before coming back to the bus. After two hours, the participants arrived at Riga, and this ended the 23rd Meeting of the Group of European Charophytologists at Riga.

Randu Plavas

Jordi Pérez-Cano (Spain)

PhD THESIS COMPLETION

Michał Brzozowski, Department of Hydrobiology, Institute of Environmental Biology, Faculty of Biology, Adam Mickiewicz University (AMU) in Poznań.
Supervisor: Mariusz Pełechaty

PhD thesis title: **Recovery of the population of an endangered charophyte species**

***Lychnothamnus barbatus* in the light of climate change**

On 20th June 2022, Michał Brzozowski defended his PhD thesis at the Institute of Environmental Biology, Faculty of Biology, AMU in Poznań in front of two reviewers Józef Szmeja (University of Gdańsk) and Piotr Sugier (Maria Curie-Skłodowska University in Lublin) and scientific commission of Faculty of Biology, AMU in Poznań.

The thesis compiles 5 papers published in international peer-reviewed scientific journals: Aquatic Botany, Limnologica, Acta Societatis Botanicorum Poloniae, Aquatic Conservation: Marine and Freshwater Ecosystems, Global Ecology and Conservation.

Climate change and its impact on organisms are one of the most studied processes in the life sciences. It is predicted that environmental changes in Europe that will take place as the average annual temperatures increase will include shifting climatic zones to the north of the continent. The consequence of this will be a change in the biodiversity of European biogeographical regions. Recently, in Central and Eastern Europe, the process of recolonization and colonization of lakes by the globally endangered species of charophytes (Charophyta, Characeae) *L. barbatus* has been observed. An example of recolonization is Lake Kuźnickie (Western Poland), where this species is dominant in the littoral vegetation. An important element influencing the above-mentioned process seems to be climate warming, expressed by the influence of mild winters on *L. barbatus* communities, which show the ability to overwinter in favourable weather conditions. In this PhD thesis, therefore, the following research hypothesis was investigated:

Climate warming, by shortening the ice and snow cover time, gives a competitive advantage to the endangered species *L. barbatus*, favouring its spread and expansion in a changing aquatic environment. An integral part of the process of falsifying the above hypothesis was the realization of the following research goals:

- Determination of the variability of productivity and reproductive effort of *L. barbatus* against the background of weather conditions and variability of water chemistry in a model lake dominated by the studied charophyte;
- Analysis of the distribution of *L. barbatus* in the depth gradient against the background of the submerged vegetation structure of the studied lake in terms of the availability of photosynthetically active radiation (PAR);
- Description of the history of *L. barbatus* in Lake Kuźnickie based on the analysis of macro remains in the isotopically dated cores of the lake sediment in the context of changes in the use of the catchment area and the existing data on water quality and meteorological records;
- Modelling of past (ca. 130 ka), present and future (up to 2100) climatic habitats of *L. barbatus* by using different Spatial Distribution Models (SDMs), variable global climatic scenarios (GCMs) and various Shared Socioeconomic Pathways (SSPs: SSP 1–2.6 – low radiative forcing and emission reduction assumed – the most optimistic scenario; SSP 2–4.5 – average radiative forcing and slow CO_2 emission increase until 2040 and then decrease; SSP 5–8.5 – high CO_2 emission and continuous increase until 2080).

The research revealed that through a series of adaptations developed in the course of evolution, *L. barbatus* is a hydrobiont that easily adapts to climate warming, becoming one of the beneficiaries of this phenomenon by massive overwintering in mild winters, high phenotypic plasticity and adaptation to living in a condition of light deficit in deep phytolittoral regions. Moreover, paleolimnological studies evidenced that *L. barbatus* population in Lake Kuźnickie expanded after the Little Ice Age period which corresponds with the present phenomena of recovery of the species populations around the world. Climatic habitat modelling confirmed the results of paleolimnological studies. As result, *L. barbatus* seems to be one of the main beneficiaries of global warming among charophytes. The results of PhD thesis constitute a complete comparative material for the monitoring of water quality and management of aquatic conservation including freshwaters with rare and endangered species of submerged vegetation and could be used for habitat conservation.

The dissertation was awarded by the Council for the Discipline of Biological Sciences of the AMU in Poznań. In addition, the dissertation was awarded a distinction in the national competition "The best master's and doctoral thesis related to the issues of Ecohydrology" organised by the European Regional Center for Ecohydrology of the Polish Academy of Sciences.

The thesis can be downloaded by request from the following website:

https://www.researchgate.net/publication/361885762_Recovery_of_the_population_of_an_endangered_charophyte_species_Lychnothamnus_barbatus_in_the_light_of_climate_change

Michał Brzozowski (Poland)

OVERVIEW OF PUBLICATIONS

What's new about Chara? A short overview over some interesting charophyte studies published in 2022

It has become one of my habits to check Web of Science (WoS) for "breaking news" on charophytes, each year early in January. This year I did the WoS search on January 10, using the search terms "Chara" and "2022". And I got a whopping 216 hits!! This is almost twice as many as last year, which already was higher than the year before. After getting over my first shock, I found out that WoS has implemented some changes in their search algorithm. This means that quite many of the 216 hits I got, in fact, had nothing to do with Chara. Next to hits which simply seemed to be wrong (I was unable to find "Chara" anywhere), there were many publications on a stellar phenomenon called "Chara", but also quite many on a Russian river called "Chara" (when translated from Russian alphabet). After kicking out those papers, however, there still were quite many publications on "our" charophytes, so I had to be selective. Below I give an overview of 15 papers, which - as always - only represent my personal interests, not necessarily scientific quality. As always, I felt completely out of depth with the paleontological studies, so these are not included here.

I am happy to see that the barcoding of charophytes continues. Each year new information is being collected, published and added to publicly available databases. This includes the description of new species or, in some cases, varieties in cases where the collected specimen looked "unusual" but were not genetically different from more common species. Examples published in 2022 include *Chara zhengzhouensis* from China, which is genetically related to *Chara connivens*, but formed a separate cluster (Song et al. 2022). The species was named after the lake in which it was found. This is perfectly valid and understandable, but sometimes I wish authors could pick species names that are somewhat shorter and easier to spell correctly. Mann et al. (2022) found a strange *Chara* specimen in Newfoundland which was so spiny that they were uncertain if it belonged to the *Chara hispida* or *Chara contraria* group. Barcoding clearly placed it into *C. contraria*. The authors decided to call it *Chara contraria* var. *hispidula*, a variety which is not uncommon in Europe, but has not previously been described from Newfoundland, Canada or the USA. Romanov et al. (2022) described a new species from Israel, which already is at the brink of extinction at the point in time when it was discovered. *Chara lipkinii* is a freshwater and brackish water species, growing in small shallow inland water bodies and streams in the Eastern Mediterranean. This water body type is one of the most threatened water body types in the Eastern Mediterranean, often affected by sediment accumulation and eutrophication. *Chara lipkinii* has disappeared from all previously discovered localities, and therefore faces a very high risk of extinction.

The study by Tatipamula (2022) probably seems a bit «exotic» to most of us but nevertheless I found it highly interesting. The author tested if extracts from *Chara baltica* can be used as drug for treating diabetes, and the very short answer to this was «yes». From the paper it was not clear to me if the *Chara baltica* extracts were better than the standard drugs which are currently used (probably not), but at least some of the compounds indeed seemed to be active. The author claims that the work is the first in vivo and in vitro antidiabetic report on *Chara baltica*. I only wish they hadn't called *Chara baltica* "seaweed". But diabetes may not be the only application of charophytes in medicine. Silver nanoparticles have a broad-spectrum antimicrobial ability and have become a widely used sterilizing nanomaterial in food and medical products, for instance, textiles, food storage bags, refrigerator surfaces, and personal care products. They are commonly made from $AgNO_3$ solution, but the crystallization process needs a "particle to start from", and a reducing agent. Karm et al. (2022) found that silver nanoparticles can be manufactured by adding $AgNO_3$ to a *Chara* extract, and the authors claim that this is a "green" way to produce silver nanoparticles.

But are there more ways how charophytes could contribute to the green shift in society? We have probably all experienced that our electricity and energy bills increased quite substantially in the last year. Consequently, scientists are looking for new ways to produce «green» energy, and oil extraction from algae is one of many techniques that is being investigated. If the algae are collected from eutrophic coastal lagoons, two problems could be solved at once: (1) cleaning the lagoon from the nuisance algae and (2) producing biodiesel. Renzi et al. (2022) tested oil production and oil quality in *Chara* sp. and *Chaetomorpha linum*, collected from a lagoon in south-eastern Italy. It turned out that there was much more oil in *Chaetomorpha* than in *Chara* (2.35% compared to 0.65%). The authors conclude that *Chaetomorpha* is interesting to study further, because the extraction efficiency was higher than values reported in literature. It seems, however, that our chances of driving a car with *Chara* in the tank are not very high, at least not in the near future.

Among the ecological studies that were published last year, I found Berthold et al. (2022) very interesting. They did a study on the effects of a grazer, *Gammarus tigrinus*, on *Chara aspera* and *C. tomentosa*, and investigated how this effect would change with changing temperatures and salinity. *Gammarus tigrinus* is an invasive amphipod that has spread to large parts of Northern Europe during the last decades, including the Baltic Sea, and it turns out that it eats charophytes! Berthold et al. found that *Gammarus tigrinus* seems to think that *C. aspera* tastes better than *C. tomentosa* (grazing rates were up to two times higher on *C. aspera* than on *C. tomentosa*), that it eats most at temperatures (grazing rate peaked at 24°C), and that it tended to eat more when salinities were higher. Climate change is predicted to lead to an increase in temperature and freshwater input into the Baltic Sea. This means that the Baltic Sea will become warmer and less saline in the future. The study of Berthold et al. shows that these changes are likely to affect the grazing of *G. tigrinus* on charophytes, and that this may have knock-on effects on the biomass and distribution of charophytes in the Baltic Sea.

While some countries are worried about a decline in charophytes, the USA continue their efforts to «control» the biomass of *Nitellopsis* *obtusa.* The species is invasive in the USA and seems to be perceived as a nuisance by many. Glisson et al. (2022) wanted to understand more about the phenology and growth of *N. obtusa*, in order to find the optimal timing for removal of *N. obtusa* biomass. They found consistent late-season peaks in *N. obtusa* biomass. This suggests that *N. obtusa* has an extended growing season compared to other native and invasive macrophytes in Minnesota, and this extended growth season may contribute to its invasion success. Bulbils are important for *Nitellopsis* spread and survival, and Glisson et al. found that bulbil counts were lowest early to mid-summer and increased through fall. The best timing for removal of *Nitellopsis* biomass is therefore not so easy to determine, because it cannot be too early (to avoid harming native species) but should be before fall when the number of bulbils starts to increase. Personally, I think efforts to control macrophyte biomass by removal are likely to fail anyway. Macrophyte removal is always costly, and only treats the symptoms, not the cause of a perceived problem. When large amounts of plant biomass are removed from a water body, it is very likely that either (i) the plants will quickly grow back, or (ii) other plants take over which are equally "nasty", or (iii) algae and cyanobacteria will development massively, and these algal blooms are likely to be perceived even worse than the macrophyte species that was removed. If you are interested in mass developments of macrophytes, you can find more information here: https://www.niva.no/en/projectweb/madmacs/madmacs-key-messages.

Charophyte algae, however, can not only be invasive in themselves, but they can also be the substrate and vector for other invasive species. Zebra mussels (*Dreissena polymorpha*) are an aquatic invasive not only in Europe but also in the USA, and they can attach to almost everything. The importance of organic substrates, however, for zebra mussels was less clear. Londo et al. (2022) studied organic substrates for zebra mussels in Minnesota and found that *Chara* sp. is indeed a suitable substrate. They also found that more juvenile, i.e. small, mussels were found on organic substrates than were adults. I have personally seen lots of zebra mussels (a different but very similar species) on charophytes in lake Ohrid, and I am guessing that zebra mussels will also use *Nitellopsis obtusa* as substrate. So, if you are not careful when moving your boat from one lake into another, you might not only spread *Nitellopsis*, but also juvenile zebra mussels «hiking» on it.

But luckily, charophytes are still seen as beneficial in some countries, and construction of artificial wave shelters is a promising measure to stimulate submerged vegetation in large wind-exposed lakes. Van Zuidam et al. (2022) tested whether the construction of shelter results in the colonization of submerged vegetation and whether grazing by waterbirds hampers vegetation development under those sheltered conditions. They studied the effect of breakwaters that were constructed between 1992 and 1996 in the large, wind-exposed and turbid Lake Markermeer, The Netherlands. Van Zuidam et al. found that in the sheltered area, a dense charophyte dominated vegetation developed over 16 years, while submerged vegetation remained very sparse outside the breakwaters. The area also attracted many herbivorous birds, especially molting Mute swans during summer. After the breakwaters had been completed, 10 years passed before the development of the charophyte vegetation started. This delay was probably not caused by bird grazing, but more likely due to unfavourable light conditions in the first decade. An exclosure experiment confirmed that while grazing reduced macrophyte biomass by 50% and plant height by 45%, it did not affect vegetation cover, which remained high (90-95%) throughout summer. The water depth in most of the study area exceeded the depth range at which Mute swans prefer to forage and this probably prevented overgrazing. The authors conclude that building artificial wave shelters is an effective measure to stimulate submerged vegetation in large wind-exposed lakes.

As we all know, charophytes are beneficial for many reasons. One of these benefits is that green biomass and oospores of charophytes are important food for waterbirds. Grazing on charophytes may be particularly intense during bird migration in spring and autumn, or during molting in summer. Generative reproduction and overwintering biomass of charophytes are therefore important from a wider ecosystem perspective. Brzozowski and Pelechaty (2022) studied overwintering of *Lychnothamnus barbatus* in a lake in Poland and found that mild winters supported the overwintering of submerged vegetation, including *L. barbatus*. High overwintering macrophyte biomass may also improve lake water quality in the following spring. Brzozowski and Pelechaty also found that *L. barbatus* can produce numerous oospores, which probably is good news both for the reproduction of *L. barbatus*, but also for waterbirds that may feed on the oospores.

There generally still is a lot to be learned about *Chara* reproduction. We all know that gametangium morphology is important for species differentiation and determination of charophytes. The trouble is that the size and width of gametangia changes drastically while they develop. So how can we know when gametangia are ripe, and when their dimensions are truly representative for the specimen we collected? Calero and Rodrigo (2022) developed mathematical models which describe the growth of gametangia in *C. aspera*, *C. hispida* and *C. canescens*. They found that oogonia undergo first a period of elongation, followed by a swelling process related to ripening. They developed a method how to differentiate swollen (= ripening) from non-swollen (=unripe) oogonia. This can be useful for phenological studies, e.g. when we want to find out if and when sexual reproduction of *Chara* species is successful and leads to ripening oogonia.

Although it is not always easy, oospore morphology can sometimes be used to separate closely related *Chara* species. Since oospores may stay in the sediment of ponds and lakes for decades, they can be used to reconstruct past *Chara* species distribution. Milovanovic et al. (2022) measured oospore morphology to see if they could separate *Chara baueri* from *Chara braunii,* and *Chara globularis* from *Chara* «*connivens*» in Serbia (the name is in quotation marks because barcoding showed that the specimens are genetically distinct from other *C. connivens*). The authors indeed found clear differences between closely related species within their samples. These differences, however, are likely only valid locally. This means that the same species in other countries may have slightly different oospore morphology. The authors argue, however, that local keys are useful to aid species determination and reconstruction of past vegetation in the area where the key was developed. In other words, although maybe not be globally applicable, such local data may be important for local freshwater management.

Various types of scientific studies need clean algal cultures, i.e. cultures that are not contaminated by other (at least no other algal) species. Many of us have kept charophytes in beakers on the windowsill, so we know that keeping «clean» *Chara* cultures seems almost impossible. Holzhausen et al. (2022) solved this issue, and published cultivation protocols for *C. braunii*, allowing maintenance of vegetative as well as generative cultures, including protocols for germination induction and growth of sterilized and unsterilized oospores.

One of the scientific disciplines that need *Chara* cultures is electrophysiology. Electro-physiologists are trying to find out under which conditions certain ions move in and out of cells. This field of science uses a lot of equations and scientific terms that are not commonly used in other scientific disciplines. In other words: «we» ecologists often do not understand what the electrophysiologists try to tell us. The trouble is that the relative ability to take up or export ions, including nutrients and toxins, may explain why certain charophytes occur preferably in nutrient-rich or oligotrophic habitats, why some can grow in brackish water or only in freshwater, or why growth is limited to a particular range of pH. So the electrophysiologial results are really important for ecology, if only we could understand them. Beilby et al. (2022) tried to bridge this gap, and present the main electrophysiological findings on the transport of ions in and out of cells, in a way that is accessible to ecologists. They explain the mechanism by which Characean algae generate the electrical voltage difference across their membrane, its effect on the transport of ions, and the mechanisms by which ions can be moved against the gradients that determine passive movements. This is important for understanding how nutrients and carbon are taken up, and why changing habitat salinity is an enormous challenge for charophytes. Personally, this was one of the most interesting papers I ever had the honour to co-author. Bridging scientific disciplines is challenging, but extremely rewarding. The paper is open access, so please have a look if you are interested. We hope you enjoy reading it, and we hope it will trigger more cross-disciplinary studies.

Susi Schneider (Norway)

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Study on and about charophytes

Below you will find a list of publications that appeared in 2022 and (new for this issue!) the beginning of 2023 that deal with charophytes. The list is based on the publications which you sent to us or searches on databases (Web of Science, Scopus, Google Scholar as well as ResearchGate, performed in February 2023, using the terms: charophyte, stonewort, gyrogonite, Charophyceae, Charales, Characeae, *Chara*, *Nitella*, *Tolypella*, *Nitellopsis* and *Lychnothamnus*.) Of course, you will not find here those publications that Susi described above. We hope that each of you will find something interesting in this list. For a complete list of co-authors, please check the databases. We hope that each of us will find something interesting in this list.

Andrzej Pukacz (Poland)

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NEWS FROM MEMBERS

An additional locality for *Lychnothamnus barbatus*

A long, long time ago…….three charophyte specialists went to southeast Queensland, Australia, to see if they could collect *Lychnothamnus barbatus* at the same locality where it was collected by R.D.Wood in 1960. Monique Feist, Adriana García and I found a small specimen at Warrill Creek in October 1996, and made vouchers. This material contributed to genetic studies (McCourt et al. 1999) and several other papers (Casanova et al. 2000a; Casanova 2000b; García 2000). Later (December 1996), Michelle and Adriana went to the same place but failed to find the species. Instead, they found it in near-by Wallace Creek. Later, García and Chivas (2004) reported two additional localities near the Gulf of Carpentaria in far north Queensland (about 1000 km away from southeast Queensland).

Fast forward to 2022…..The recent floods in south east Queensland damaged the foundations of the bridge on Warrill Creek, so the Queensland Department of Transport (responsible for road mending) needed a survey to determine if *Lychnothamnus barbatus* populations would be further endangered by bridge-works. I went to Warrill Creek with two assistants to see 1) if *Lychnothamnus barbatus* was present in Warrill Creek or the adjacent Washpool Gully, 2) if the population at Wallace Creek was still present and whether the species was safe there, and 3) if additional populations could be found.

Despite thorough searching, *Lychnothamnus* was absent from its original habitat (or any place) in Warrill Creek/Washpool Gully, perhaps because of more permanent flow, high flows (flooding) or the addition of nutrients from the surrounding agricultural land.

The population at Wallace Creek was still present, but appeared to have declined in health and abundance since 1996, perhaps because of more intensive catchment land-use.

We were fortunate to find another population, in the Sunshine Coast hinterland, as we searched for Charophytes around Dalby (where some of the type material of *Chara preissii* var. *bancroftii* was collected), Bribie Island, and in streams around the city of Brisbane. Charophytes were last collected in Ithaca Creek and Enoggera Reservoir around the early 1900s, and much to our surprise, charophytes still grow in urban streams in Brisbane.

In all, over 90 gatherings were made, deposited in herbaria (BRI, MEL, NY) and many have been posted on iNaturalist so that the distribution data can be accessed. The social platform iNaturalist was also useful for locating sites where citizen scientists had found charophytes. However, the condition of

Nitella species from Enoggera Reservoir; *Lychnothamnus* in situ, Detail of *Lychnothamnus* shoot

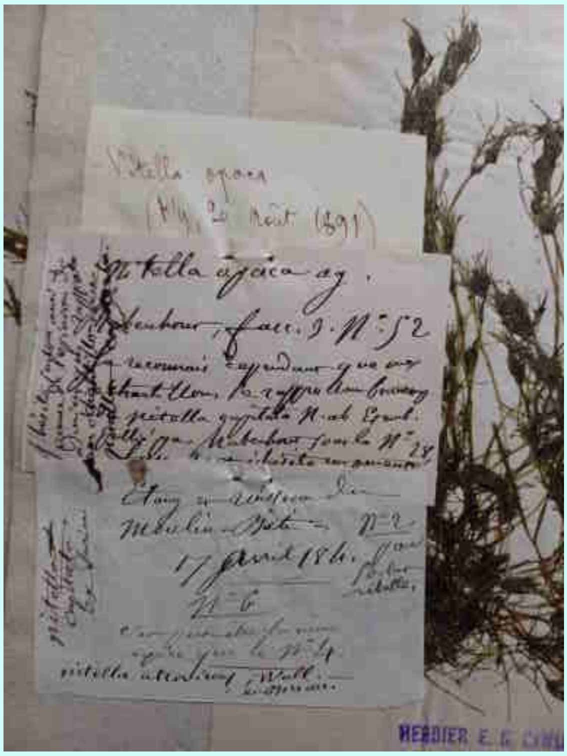
charophyte taxonomy in Australia (many species, many of them without names, or erroneous names) means that many cannot yet be identified to species. I hope this will change in the future! The study contributed to the training of young botanists, and will contribute to more work on Queensland charophytes.

Michelle T. Casanova (Australia)

Two months in the Paris Cryptogamic Herbarium (PC)

In September and October 2022 I was fortunate to be a Visiting Professor at the Paris Cryptogamic herbarium at the invitation from Prof. Line Le Gall. My husband, Anthony, is much better at speaking and understanding French than I am, so he came too, to assist in translation of the labels on the herbarium specimens. Our job was to database and bar-code the Characeae specimens in the herbarium, so that they would be easier for visitors to find. In the past I had spent some weeks in Paris, and it was difficult to locate specimens. This work was intended to make it easier and more accessible to visitors.

Line thought there might be about 4000 specimens to curate, so we started work with little anticipation that we could complete it in two months. However, between the two of us, we managed to curate over 5000 specimens. The collection in Paris consists of two parts, a general collection where species are arranged alphabetically, and a number of personal collections that remain pretty much as they were deposited, sometimes 100 years ago. Of course the majority of specimens are from France, along with the common exsiccatae, but there are also significant foreign collections from former French colonies, particularly in Africa and the Caribbean.



Example of a label on a specimen in PC herbarium.

We were not free to rearrange the material, so we mapped the specimens on the shelves, referring to the shelf row, column, and folder, so that a bar-coded specimen could be easily located if necessary. At first reading the handwritten script of the collectors and determinators was difficult, but we got to know the most common French collectors. Some labels were more difficult than others.

During this work we were able to find several specimens that might be type material, and placed it in red folders. There are probably another couple of thousand specimens left to be curated, and we hope to return to Paris in 2024 to complete the work. If anyone would like a transcript of the data (in Excel or Access programs) we can provide a copy. The specimens are also being scanned and made available on the internet, along with images of the oospores where I was able to undertake electron microscopy. I am very happy to share the data if it is of use to anyone.

Michelle T. Casanova (Australia)

Studying the current status of the charophyte meadows in a world biosphere reserve site (Lagunas de Ruidera Natural Park, Spain)

During the last year, the Integrative Ecology lab (led by Dr. Maria Rodrigo) in collaboration with the wetlands-related non-profit association Gemosclera executed a pioneering study in the area of the Lagunas de Ruidera Natural Park to carry out a quantitative evaluation of the state of the charophyte beds.

The Lagunas de Ruidera Natural Park (which was visited in one of the field trips during the 21st Meeting of the Group of European Charophytologists held in Valencia in 2017) consists of a chain of 16 lakes fed basically by groundwater, which originates in springs and pools to form a 35-kilometer-long series of steps with a difference in height of 120 m between the highest and lowest. It is a unique system in the Iberian Peninsula, and very similar geomorphologically-speaking to the Plitvice lake complex in Croatia. Most of Ruidera lakes have dense meadows of charophytes of the *Chara hispida* complex. This is a sign of the good ecological status of this lake system. However, the study, and especially the quantitative monitoring, of such an important element has been scarce so far. In fact, the only quantitative study of the meadows biomass dates back 20 years, an only in Lake Colgada (the largest in the park). That is why the management team of the Natural Park (from the Castilla-La Mancha regional government) commissioned a study by specialists in the field to obtain an updated view of the state of the submerged vegetation in the park and to try to discern the factors that are causing its loss in some of the lakes. Thus, the present study will serve as a basis for future monitoring of the aquatic vegetation of the Park and, in this way, to be able to offer management strategies to conserve the meadows, as a central element for the preservation of the good ecological quality or health of this magnificent ecosystem.

Surface and underwater samplings were carried out between October 2021 and October 2022, the latter performed by the divers of the Gemosclera association, under the advice and assistance of members of the Integrative Ecology group of the Cavanilles Institute of Biodiversity and Evolutionary Biology (Universitat de València) (Fig. 1). In each lake and depending on its extension, between 1 and 4 transversal transects were studied, (except for Lake Colgada, in which 9 transects were performed for comparison, coinciding with those carried out in 2003 and 2004 in a previous study). From the sampled material the species were identified, their biomass was determined, a diagram of each transect was made and the vegetation map of each lake was drawn (Fig. 2).

Fig. 1. The divers of Gemosclera association taking samples of the charophyte meadows (with a square sampling unit, marked with arrows) in different lakes of the Lagunas de Ruidera Natural Park.

In total, we identified 15 hydrophyte taxa, 6 of which were charophytes. These values are slightly lower than those indicated in previous qualitative studies. In general, the biomass of the charophyte meadows was very high (approx. 1 kg of dry weight per square meter). It should be noted that, in a small waterbody adjacent to one of the lakes, which had never been sampled before, we obtained a record biomass value of more than 11 kg of dry weight per square meter!

The dominant species in these lakes belong to the *Chara hispida* complex, although we have also identified patches of other charophytes such as *Nitella hyalina* and *N. confervacea* as well as submerged phanerogams such as *Myriophyllum spicatum*, *M. verticillatum*, *Stuckenia pectinata* and *Utricularia australis*, among others. Several amphibious plants were also growing totally submerged in some of the lakes.

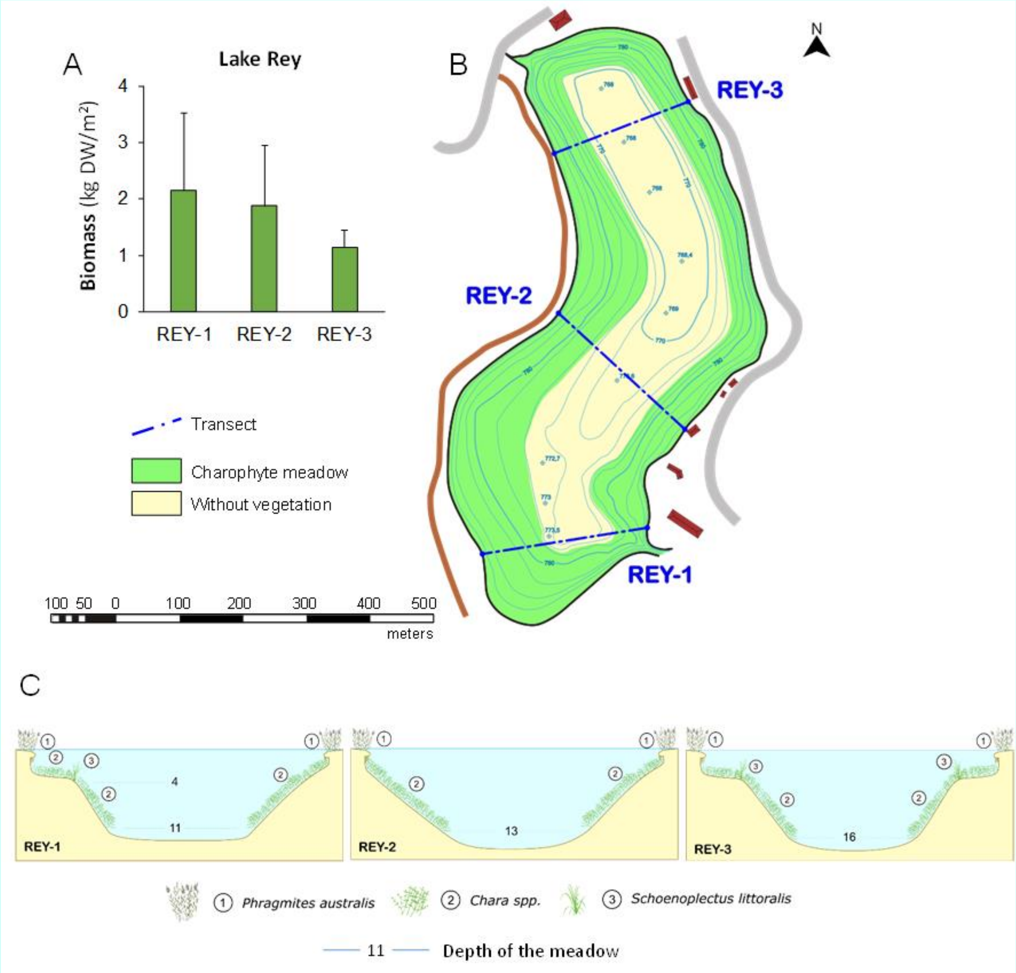


Fig. 2. As an example, the results of the Lake Rey: A) the charophyte biomass (in kg of dry weight per square meter) in each transect, B) the vegetation map of the lake and C) the scheme of each transect with the identified species and the depths where the meadows are.

Despite the lack of quantitative data prior to the present study, it is known that, in recent decades, there has been a general trend towards the decrease of macrophyte meadows extension due to anthropic pressures with direct effects on them, particularly in the upper lakes. However, it is difficult to define the reasons causing this decline since many factors are acting simultaneously and it is necessary to have longer-term data to address these issues.

With this study, the foundations have been laid for future qualitative and quantitative monitoring of said submerged vegetation in the Lagunas de Ruidera Natural Park. In this way, it will be possible to follow the state of this essential component in the aquatic systems that make up the Natural Park and its relationship with environmental factors, especially within the context of global change in which we find ourselves. Continuous and exhaustive monitoring of basic limnological variables, the concentration of different pollutants (particularly pesticides used in the catchment area where agriculture fields are located), etc., are crucial to analyse, on a broad time scale, the changes that have occurred in the water quality of these aquatic systems and their possible relationship with the progressive deterioration of macrophyte meadows, and what is more important, their recovery. With all the information collected in this study, we are preparing a scientific manuscript that we hope it will come to light soon.

Eric Puche, Maria A. Rodrigo (Spain)

New findings connected with charophytes research from China

Based on charophyte biostratigraphy, we investigated the Cretaceous-Paleogene (KPg) boundary transition layers in the Pingyi and Jiaolai basins, eastern China. We then used mercury concentrations and isotopic compositions, a proxy for volcanic activity, to assess the impacts of the Deccan Traps large igneous province eruption on terrestrial environments. The timing and ecological impacts of the Deccan Traps large igneous province eruption are vigorously debated. Pre–KPg boundary impacts of Deccan volcanism have been widely identified in marine sediments, but direct evidence of terrestrial impacts remains rare. We studied two drill cores across the KPg boundary in eastern China that represent two different depositional environments: clastic deposits in the Jiaolai Basin and carbonate deposits in the Pingyi Basin. Both drill cores exhibit strong Hg enrichment prior to the KPg boundary. Near consistent mass-independent fractionation (MIF) of odd-Hg isotopes (odd-MIF) in the Jiaolai Basin likely indicates a volcanogenic source of Hg spikes below the KPg boundary. Odd-MIF isotopes in the Pingyi Basin likewise suggest a volcanogenic Hg source but with a terrestrial Hg signature of lower Δ199Hg values before and after the Hg spike interval. The Hg enrichment level can be stratigraphically correlated to the beginning of the Latest Maastrichtian warming event (LMWE) and is consistent with a strong, negative carbon-isotope excursion (CIE) in both δ13Corg (organic matter) and δ13Ccarb (carbonate), suggesting a disturbance of the global carbon cycle induced by a major pulse of Deccan Traps volcanism. Our discovery of a terrestrial record of pre-KPg boundary Deccan volcanism provides robust evidence of global influence of the Deccan Traps large igneous province during the LMWE.

Sha Li (China)

Activities in Switzerland

*There are preparations for a new red list for Charophytes in CH and it will probably start in 2024. The last one I made, together with Dominique, was published in 2010. Aurelie is also involved and has the lead and coordination of the work.

*In the canton of ZH, there are more action plans to be published this year. After *Nitella hyalina* in 2019, now (within the next weeks) the plans will be published for *Chara filiformis, Chara intermedia, Nitella confervacea* and *N. tenuissima*. The publications will be for free as a pdf on this website:

https://www.zh.ch/de/umwelt-tiere/naturschutz/artenschutz.html#-519320646

*Moreover, a new publication about *Chara filiformis* and *N tenuissima* in the north-eastern part of CH is on the way and will be published in Bauhinia.

Arno Schwarzer (Switzerland)

FORTHCOMING MEETINGS

IRGC meeting

The next IRGC meeting will be held in Melbourne, Australia, in the austral Spring (September or October) 2024. At the moment I am arranging a booking for the venue at the Royal Botanic Gardens Melbourne (Mueller Hall). There is a great range of accommodation in the city, near to South Yarra (where the gardens are), ranging from as little as $90/night for a hotel room, or even less for a back-packer accommodation. There is also good public transport on the iconic Melbourne trams. Of course there are more expensive hotels too. There will be two field trips, one to the south-west of Victoria to see extant charophytes in seasonal wetlands, saline lakes, and freshwater lakes; the second to a fossil locality. I have been looking for fossil localities near Melbourne (Bacchus Marsh), and will visit Buchan soon to check out the fossil locality identified by Monique and Raymond Feist. I anticipate that there will be 2-3 days of meeting, and 3-4 days of excursions. I will provide more details when they have been confirmed.

Michelle Casanova (Australia)

IRGC HOMEPAGE

IRGC homepage is available: http://www.sea.ee/irgcharophytes/ Members are welcome to send relevant information to Kaire Torn (kaire.torn@ut.ee).

IRGC IN FACEBOOK

We have created group in Facebook – International Research Group on Charophytes. This is an unofficial group for IRGC members to share information. The group is closed, so only IRGC members can see the posts.

You are welcome to share your photos, field works, research questions etc. among our community. We are looking forward to see your photos from the past meetings or getting information/photos about your current activities.

Please contact Kaire Torn (kaire.torn@ut.ee) for details.

MEMBERSHIP FEES

Please do not forget to send your membership fee for 2022. Multiple year payment is encouraged to reduce banking costs.

INTERNATIONAL RESEARCH GROUP ON CHAROPHYTES

Membership fee annual amount – € 20
Multiple-year payment is encouraged to reduce mailing and banking costs.
Any questions about membership fees should be addressed to:
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E-MAIL ADDRESSES OF IRGC MEMBERS

Please **send any address changes (both surface mail and e-mail)** to the IRGC-Secretary, Kaire Torn (kaire.torn@ut.ee) to ensure you receive forthcoming information. Updated April 2023.

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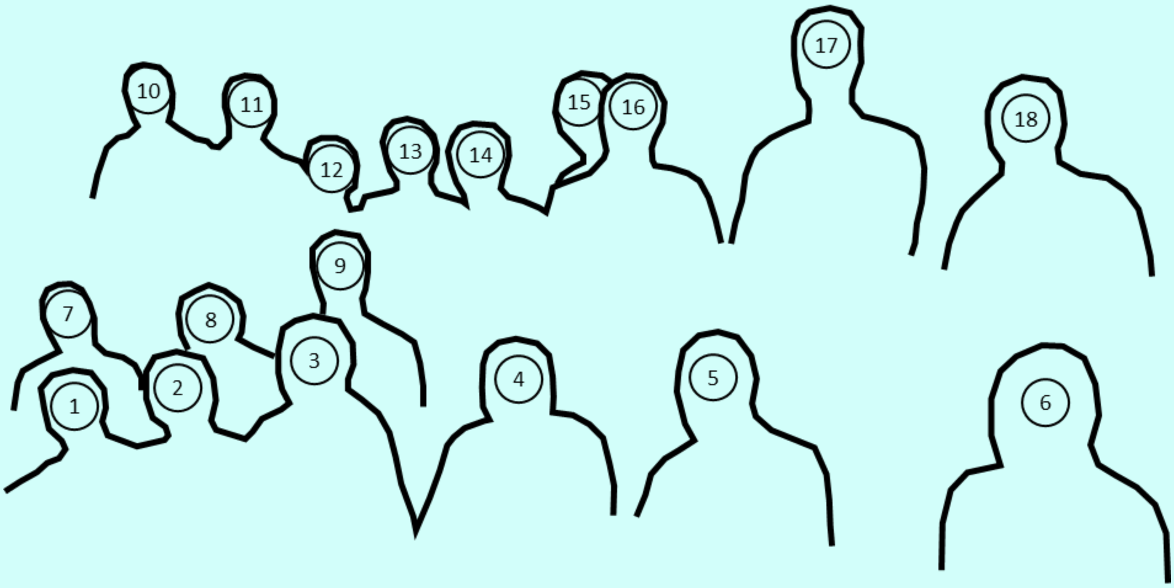

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