Short thesis for the degree of doctor of philosophy (PhD)

Ecological Consequences of Lake Utilization on Zooplankton: Cladocera Community Shifts Induced by Anthropogenic and Research-Driven Disturbances

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Abreviations

- **OL:** Oxbow lakes
- **AFL:** Abandoned fishing lakes
- **IFL:** Intensive fishing lakes
- **NMDS:** Non-metric Multi-Dimensional Scaling
- **CCA:** Canonical correspondence analysis
- **L:** Represents Látóképi víztározó lake
- **KE:** Represents Kerek-erdei-tó lake
- **SZ2:** Represents Szíki-tó lake
- **S:** Represents Sáska-tó lake
- **KV:** Represents Kék Víz lake
- **TI:** Represents Tímári Holt-Tisza lake
- **SZO:** Represents Szögi Holt-Bodrog lake
- **KMT:** Represents Kis-Morotva-tó lake
- **SZ1:** Represents Szabolcsi Holt-Tisza lake
- **KBM:** Represents Keleti Holt-Bodrog lake
- **R:** Represents Rókás-tó lake
- **KTP:** Represents Kenu-pálya lake
- **VE:** Represents Vekeri-tó lake
- **V01-12:** Represents Viss Oxbow lake, sampling points from 1 to 12
- **TDS:** Total dissolved solids
- **SS:** Suspended solids
- **Orto-P:** Orthophosphate
- **NO3-N:** Nitrate nitrogen
- **NO2-N:** Nitrite nitrogen
- **NH4-N:** Ammonium
- **SO4:** Sulfate
- **Cl-:** Chlorine anion
- **LOI550:** Loss on ignition at 550 degrees Celsius
- **LOI950:** Loss on ignition at 950 degrees Celsius

1. INTRODUCTION

1.1. Introduction – Lakes Role in Society

Water is essential for the existence of life on Earth, and the availability of water directly influences human populations worldwide (Jorgensen et al., 2005). Throughout history, civilizations have thrived near bodies of water due to their abundant resources and the crucial role they play in sustaining life (Maltby and Acreman, 2011). The use of water by humans - for drinking, washing and recreation - requires water free from biological, chemical and physical sources of contamination. Clean water is also necessary for animals, plants, and the ecosystems that maintain biological diversity. A specific water quality is required for industrial operations, city power generation, and food cultivation (Mp, 2017).

Freshwater ecosystems support diverse biota and provide essential services to human societies. The availability of the water is crucial, as is its quality. A growing number of water bodies in the modern world are losing their ability to support the life of the species that inhabit and surround them. Factors influencing the quality of waters are increasing over time, but anthropogenic activities driven by humans remain the primary cause. These ecosystems encompass a variety of habitats, such as rivers, lakes, wetlands, and groundwater, harboring significant biodiversity and regulating global biogeochemical cycles. Climate change, pollution, habitat degradation, and invasive species are just a few of the challenges facing lakes and the diverse array of species that inhabit them (Bhattarai, 2017; Weiskopf et al., 2020). As the biological significance of lakes and the risks to their sustainability become more widely acknowledged, limnology research and lake knowledge have grown in importance (Dodson, 2005). Presently, water quality assessment can easily rely on the aquatic organisms inhabiting the water body. Notably, phytoplankton and zooplankton taxa have gained considerable attention for their utility in determining the quality of a water body. Cladocera, a zooplankton type of organisms belonging to phylum of Arthropoda, subphylum of Crustacea, and class of Branchiopoda, inhabit a wide range of inland water bodies (Likens, 2009). They are primarily herbivorous species that aid in recycling nutrients within water bodies. Their significance in the food web is unquestionable, as they serve as a preferred food source for invertebrates and planktivorous fishes (Korhola and Rautio, 2001) They are preferred subjects for experimental design due to their physiological appearance. Their life cycle, interactions with environmental conditions and physiological characteristics are well studied and understood (Likens, 2009). We used Cladocera species as well as their remains in our experiments.

1.2. Problem Statement

1.2.1. Mediation of Cladocera species by researchers Chest-wader

Cladocera are organisms that disperse very easily and are found almost in all freshwater bodies around the world. There are more than 600 species of Cladocera recognized worldwide. They have different optimal conditions and requirements. They compete with each other for food (Threlkeld, 1988), occasionally leading to a scenario where the population of one species increases at the expense of a decrease in the population of others (Vanni, 1986). Zooplankton species have high dispersal capacities De Meester et al. (2002). Cladocera exhibit good dispersal capabilities across various water bodies. In newly constructed water bodies, they can establish their own populations within a matter of weeks. There are a lot of mechanisms facilitating the dispersal of Cladocera, including wind, birds and even human activities (Dodson et al., 1997). However, the role of scientists in this dispersal process has not been extensively investigated, particularly in the context of shallow lakes where sampling involves direct entry of the scientists into the water body. A chest wader worn by scientists to remain dry during such activities may sometimes function as an unintentional vector for the inter-ecosystem transportation of Cladocera. As Cladocera already tend to present a dormant stage, these chests immersing themselves, as well as several other factors into any water body might accidentally facilitate possible movement from one aquatic environment to another (Downing et al., 2006). Oxbow lakes are mostly found along the banks of the Tisza and Danube rivers in Hungary. Our research has concentrated on shallow lakes with diverse utilization patterns, mainly in the northeastern parts of the country. To study the possible different effects of different lake, use types may have on Cladocera species mediation, we conducted investigations on protected, abandoned, and actively used fishing waters.

1.2.2. Impact of utilization on Cladocera species composition

Shallow lakes are widespread around the world and hold significant ecological importance (Downing et al., 2006). This lakes are among the fastest ecosystems to be affected by external factors like climate change (Jeppesen et al., 2009). Due to many changes in environmental conditions, shallow lakes are facing changes in their water quality, which directly affects the aquatic species as well as the surrounding environment. Nutrient load and fish populations are the main factors influencing the condition of these water bodies. Some shallow lakes exhibit a variety of utilization patterns. This is the case with our studied shallow lake, which has three utilization patterns: a protected zone, an agriculturally influenced zone and a recreational zone. Cladocera have become widely adopted in different areas of scientific research, from monitoring aquatic system health to assessing the impacts of climate change (Jeppesen et al., 2009). Today, contemporary sampling methods for Cladocera mostly record contemporaneous events or very short-term environmental change effects. On the contrary, sub-fossil sampling is performed to obtain historical data about previous periods of water bodies (Zawisza et al., 2016). Cladocerans show high preservation potential; most of them are also easily identifiable. Although specific sampling techniques offer their own benefits and yield intriguing data for analysis, it was very important for our study to show which of the two methods would be more suitable for research objectives, like studying a shallow lake with three different types of utilization.

1.3. Objective of the study

The objectives of this PhD study were twofold: firstly, to enhance our understanding of the mediation capacity of Cladocera by researcher's chest wader as a vector in variously utilized water bodies, during sampling activities; secondly, to investigate the disparities between contemporary and subfossil Cladocera species sampled within an oxbow lake. A key aspect of this investigation was to determine the most suitable sampling method for accurately representing the Cladocera species assemblage within the lake. During our research, we aimed to address the following questions:

1. Mediation of Cladocera species by researcher’s chest wader

a) *What is the potential for Cladocera species to be dispersed through scientists' chest waders during sampling procedures?*
b) *How do different types of lake utilization affect the extent of Cladocera dispersal facilitated by chest waders?*
c) *What impact does inadequate cleaning of chest waders prior to sampling have on the accuracy and integrity of collected data?*

2. Comparative analysis of contemporary and subfossil Cladocera assemblages with respect to lake utilization and environmental factors

a) *How do contemporary and subfossil Cladocera assemblages differ in composition across distinct utilization zones within a multi-utilized lake?*
b) *To what extent do different types of lake utilization influence the composition of Cladocera assemblages?*

2. MATERIAL AND METHODS

2.1. Mediation experiment study area

2.1.1 Studied lakes for mediation experiment

The studied lakes are in the northern and north-eastern Hungary (Figure 1.) representing the micro-region of the Great Plain. During the experiment (summer of 2021), we collected samples from 13 different standing waterbodies with three different types of utilization. The oxbow lakes (green marking) are function as a natural habitat, with naturally existing fish stock, but without fish introduction nd fishing activity. Lakes with red markings are utilized as fishing lakes with intensive fish installation (and intensive fishing), while lakes with blue markings are abandoned fishing lakes. These lakes were once used intensively for fishing but dried out several times during the last decade and without a proper water supply, operators left them behind.

2.1.2. Field work

A total of thirteen shallow lakes, exhibiting varying degrees of utilization, were selected for sampling in the northeastern region of Hungary. Fieldwork was conducted over a weekend under favorable weather conditions, ensuring optimal sampling circumstances.

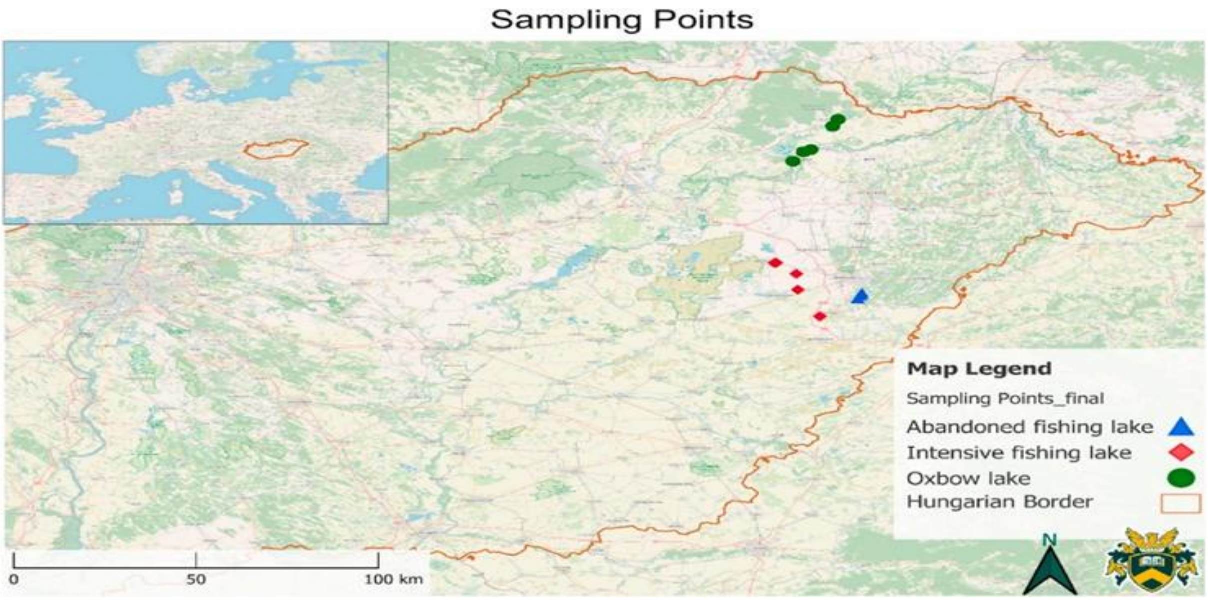

Figure 1: This map displays the locations of the studied lakes, marked according to their utilization categories and their proximity to the Hungarian border. Abandoned fishing lakes are indicated with blue triangles, intensive fishing lakes with red squares, and oxbow lakes with green circles. The inset map highlights Hungary's geographical position within Europe. (Source: Author, 2024)

2.1.2.1. Sample collecting

A single scientist equipped with chest wader carried out the sampling process. Before sampling, researchers thoroughly cleaned their chest waders using soap and water, scrubbing with a stiff brush, and rinsing with de-ionized water. They entered the lakes up to the top edge of the chest wader, at a distance of around 10 meters from the shore. Based on prior sampling protocols, researchers remained stationary for 10 minutes to collect samples. Upon exiting the water, the scientist stepped into a plastic container, where the chest waders were carefully rinsed with filtered water to dislodge and collect any residues and sediments adhered to the gear. The samples were sieved through a 35 µm mesh from the container and transferred into 50 mL centrifuge tubes and preserved in 96% Patosolv alcohol. Cleaning was carried out before and after sampling at each site. The same was repeated three times in order to confirm the tenderness of data.

2.1.3. Laboratory work

In the laboratory, the samples were processed using 100 mL of a 10% KOH solution following the standard protocol outlined by Korhola and Rautio (2001). The mixtures were placed in plastic beakers and heated for 30 minutes at 70°C in a Stuart SWB6D laboratory water bath. Post-treatment, the samples were filtered through a 35 µm sieve to eliminate larger particles. Samples were preserved with 96% Patosolv alcohol, added with a few drops of Safranin-glycerin for the staining of easily identifiable chitinized particles. An Olympus BX53 microscope and an Olympus DP26 digital camera were employed for species identification. For each slide, 100 µL of the sample was used, and a total of 1 mL was examined. Cladocera species were identified according to the methods described by (Frey, 1982).

2.2.3.1. Microscopic identification and counting

Identification of Cladocera species and their subfossil residues were made based on identification books like: Atlas of Subfossil Cladocera from Central and Northern Europe (Szeroczyńska and Sarmaja-Korjonen, 2007).

2.1.4. Data analysis

Applying a logarithmic transformation to abundance data, which is positively skewed, makes the data suitable for subsequent statistical analyses. Levene's test gave a p-value of less than 0.05 ($p < 0.001$) for the present data; thus, the null hypothesis for equal variance was rejected. This would mean that there were significantly divergent assemblage variations. To derive diversity indices such as Shannon-Wiener and Simpson, PAST software (version 3.17c) was used. Additionally, nonmetric multidimensional scaling (NMDS) further developed a relationship between the sampled lakes. It applied these relationships using Bray-Curtis similarity based on the occurrence data of each species to model dissimilarities in low-dimensional space. Further, maps of the sampled sites were derived from QGIS software (version 3.16.10) providing spatial data of the study sites.

2.2. Viss oxbow lake's comparative analysis of Contemporary and Subfossil Cladocera assemblages concerning lake utilization and environmental factors

2.2.1. Viss Oxbow lake

During this experiment, we investigated the Viss oxbow lake – as a multi-utilized lake located in the Northern-Eastern part of Hungary. The lake is under mixed utilization, divided into three main parts (connected to each other) which are utilized differently, as follows: First part, represents nature protected area (dashed line), where all anthropogenic input or activity was prohibited. Only those activities are allowed, that enhance and increase the diversity and focuses on nature conservation purposes. Second part is heavily influenced by agricultural loads (dotted line), where we can find inlet channel from arable lands and water outlet for irrigation purposes. The third part is under recreation use where mostly fishing is the main activity, while other recreational activities e.g. sightseeing, tourism, kayaking can happen as well (solid line) seen in Figure 3.

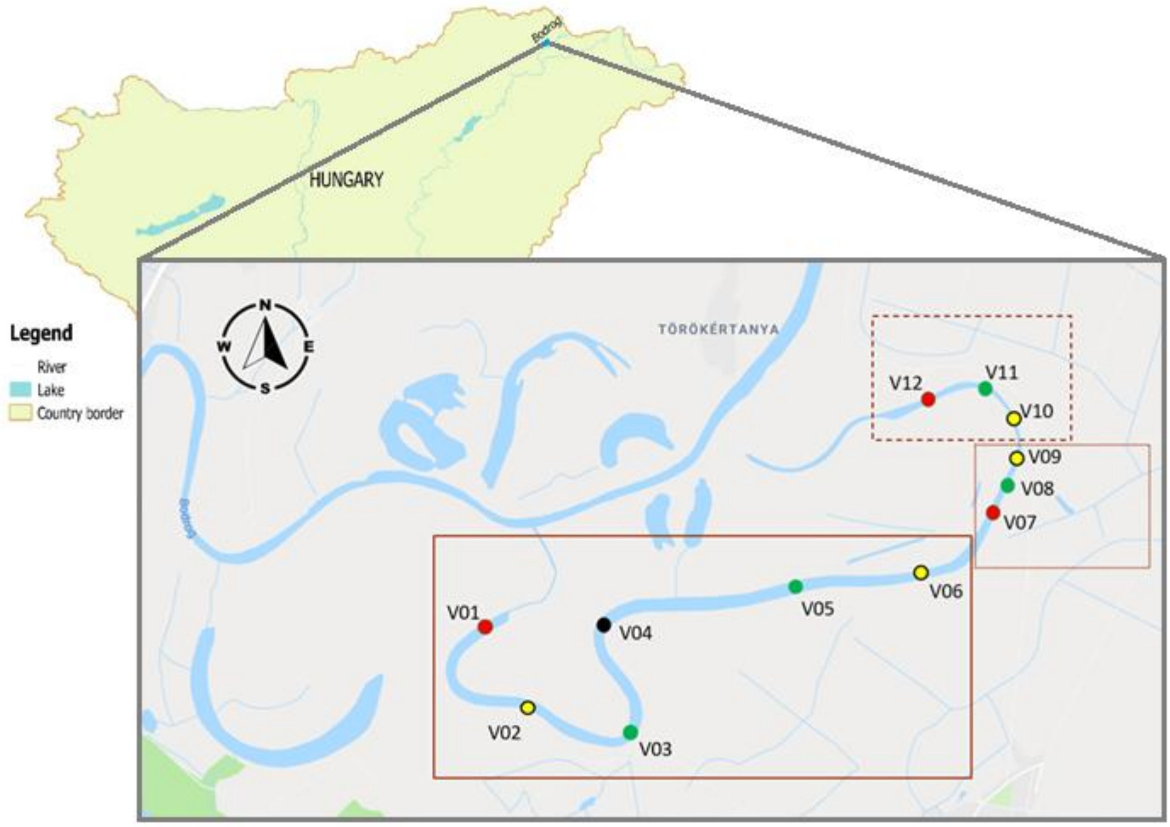

Figure 2: The experimental lake with indication of the utilizations and sampling sites with the main type of vegetation coverage. Coding: red dot – submerged vegetation, black dot – emergent vegetation, yellow dot – floating-leaved vegetation, green dot – open water area. (Source: Author, 2024)

2.2.2. Field work

This research's venue is the Viss Oxbow Lake which encompasses varied zones that face different intensities of pressure from anthropogenic activity. In the summer vegetation period of 2019, 12 soft sediment samples and 12 filtered water samples were collected. Figure 1 represents the sampling sites with their types of utilization and vegetation covering. All sites were georeferenced by using GPS device (Garmin eTrex).

On-site environmental measurements were performed with YSI EXO2 multiparameter sonde (Xylem, 599502-1). Water temperature, dissolved oxygen content, conductivity, suspended solids, as well as chlorophyll-a and pH were among the parameters recorded.

Soft sediment samples were collected with an 8 cm-diameter gravity corer (WaterMark, USA). From each core, sampled was only the first surface layer which enabled collection of 1 cm sediment and storage in plastic containers in cool conditions during transfer and storage in the laboratory. Filtered water was collected using a Schindler-Patalas plankton trap with a 30 µm mesh attachment with a total of 30 l of water processed per site, stored in plastic containers and preserved in the field with 96% Patosolv alcohol for further analysis.

2.2.3. Laboratory work

Filtered samples were stained with Safranin-glycerine for easier analysis, while sediment samples were prepared according to the standard method outlined by Korhola and Rautio (2001). Such prepared samples were examined through Alpha BIO-2T LED microscope. Subfossil and modern Cladocera species identification has been carried out using guides by Szeroczyńska and Sarmaja-Korjonen, 2007. At least 200 individuals were counted from the filtered samples, whereas for sediment samples, at least 200 individuals or 350–400 remains were quantified.

The organic matter and calcium carbonate content of the sediment were assessed using the sequential loss-on-ignition method described by Berglund and Ralska-Jasiewiczowa, (1991), also water samples were analyzed for ortho-phosphate, nitrate-nitrogen, nitrite-nitrogen, ammonium-nitrogen, sulfate, and chloride ion concentrations. Total alkalinity and chemical oxygen demand were also measured.

2.2.3.1. Microscopic identification and counting

The inverted microscope of Olympus-IX73 was used for phytoplankton counting (ind. L-1) at a magnification of 1000 (100X) and 400 (40X) and the light microscope of Olympus-BX53 was used for identifying the phytoplankton species.

2.3. Data analysis

In the statistical analysis, PAST v. 2.17 statistical program was used for conducting PCA (Principal component analysis) for both physical-chemical and phytoplankton data abundance (Ind. L) after normalizing the data (Log^{+1}). R-studio was used for conducting CCA (Canonical correspondence analysis) after normalizing the data (Log^{+1}), phytoplankton species abundance (Ind. L) with greater than 2% relative abundance was chosen in CCA. PAST v. 2.17 statistical program was used for Pearson's correlation after normalizing the data (Log^{+1}) for both physical-chemical and phytoplankton data abundance (Ind. L^{-1}).

3. RESULTS AND EVALUATION

The results are presented as follows: in the sub-chapters, we discuss topics formulated in the objectives, which contain the specific objectives in italics for each water type.

3.1. Mediation of Cladocera species by researcher's chest wader

	TI	SZO	KMT	SZ1	KBM	R	KTP	VE	L	KE	SZ2	S
Taxa	17	17	6	14	9	16	21	22	11	22	3	3
Individuals	310	590	90	660	140	520	760	1220	150	1060	40	40
Dominance	0.0801	0.1106	0.2099	0.1405	0.1327	0.0880	0.0883	0.1037	0.1111	0.0943	0.3750	0.3750
Simpson	0.9199	0.8894	0.7901	0.8595	0.8673	0.9120	0.9117	0.8963	0.8889	0.9057	0.6250	0.6250
Shannon	2.6740	2.4750	1.6770	2.2520	2.1070	2.5710	2.6620	2.5400	2.3030	2.6290	1.0400	1.0400

Table 1. Presents the number of taxa and individuals of Cladocera recorded in each studied lake, along with measures of dominance, Simpson, and Shannon diversity indices. The table uses colour coding to represent lake types: red – oxbow lakes, green -abandoned fishing lakes and with blue – intensively fishded lakes. (Author's data, 2024)

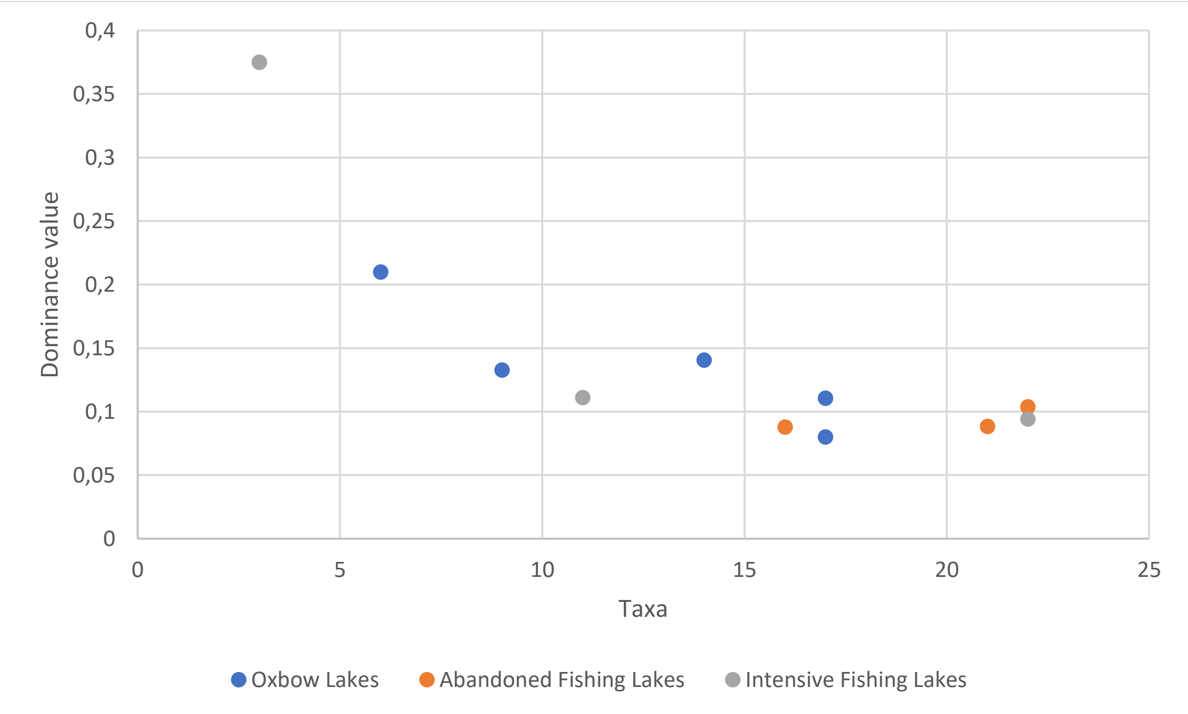

Figure 3. Comparison of Taxa from three lake groups with dominance. (Author's data, 2024)

This scatter plot illustrates the relationship between taxa (x-axis) and dominance value (y-axis) for three types of lakes: Oxbow Lakes, Abandoned Fishing Lakes, and Intensive Fishing Lakes

The NMDS analysis illustrates the spatial orientation of the sampled lakes based on the number of Cladocera individuals collected from each lake using chest waders after exiting the lakes (Figure 4).

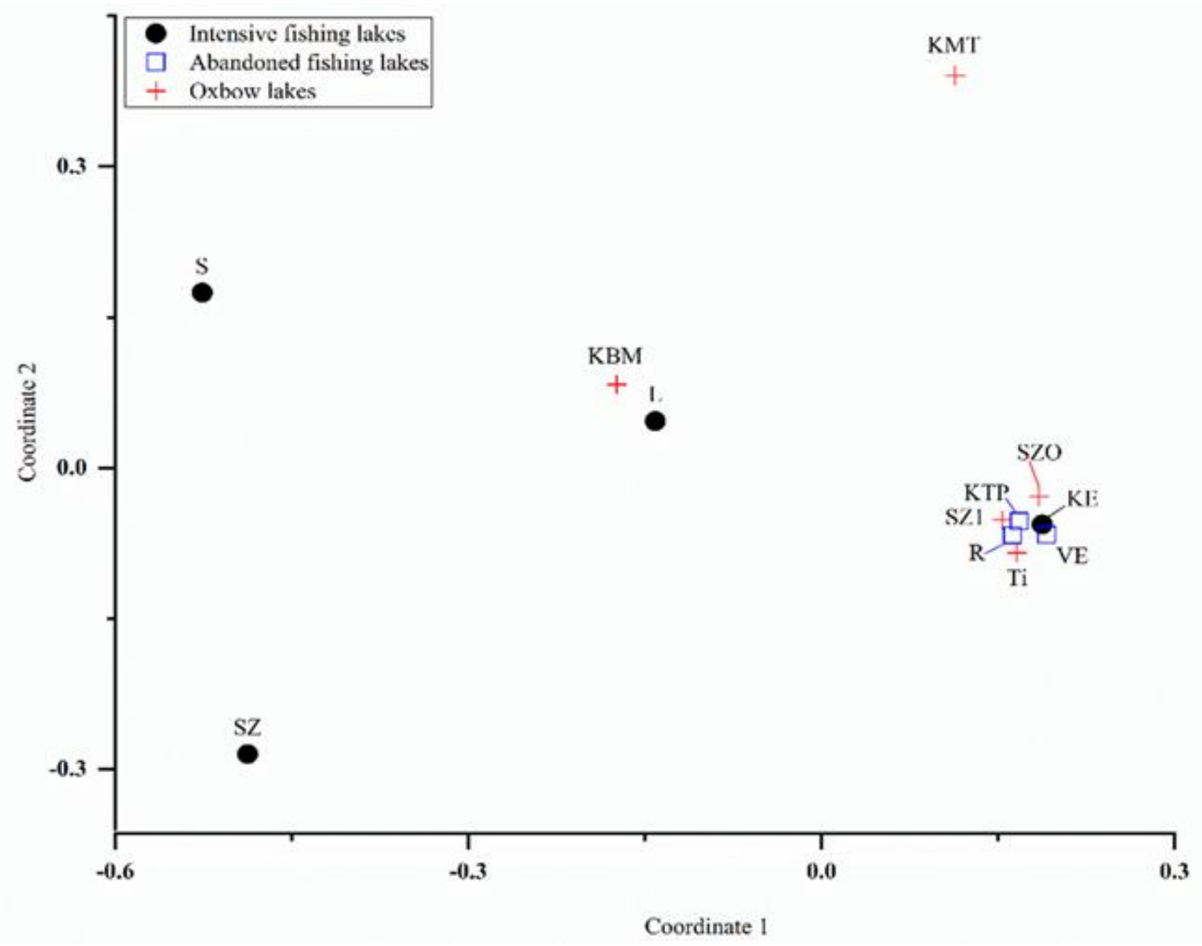

Figure 43. Non-metric multidimensional scaling (NMDS) with Bray-Curtis dissimilarity index. Analysis made on the Cladocera individuals grouped by the utilization types. Stress value is 0.09356. Red plus – oxbow lakes, blue square – abandoned fishing lakes, black dot – intensive fishing lakes. (Author's data, 2023)

a) *What is the potential for Cladocera species to be dispersed through scientists' chest waders during sampling procedures?*

Species of Cladocera have dispersal potential through the researchers' chest waders when sampling. As scientists practically go into water body with waders, these waders species such as Cladocera, will attach to the surface and remain there for a certain period. Long-distance dispersal of aquatic organisms by sediments transported with scientists' equipment has been documented in studies such as those of (Valls et al., 2016).

Our findings also revealed a considerable number of Cladocera sticking to chest waders during sampling further substantiating the probabilities of unintentional transfer of species between waterbodies. It is worth mentioning that also utilization and water body type affect the ability and the number of species of Cladocera that can and will be dispersed.

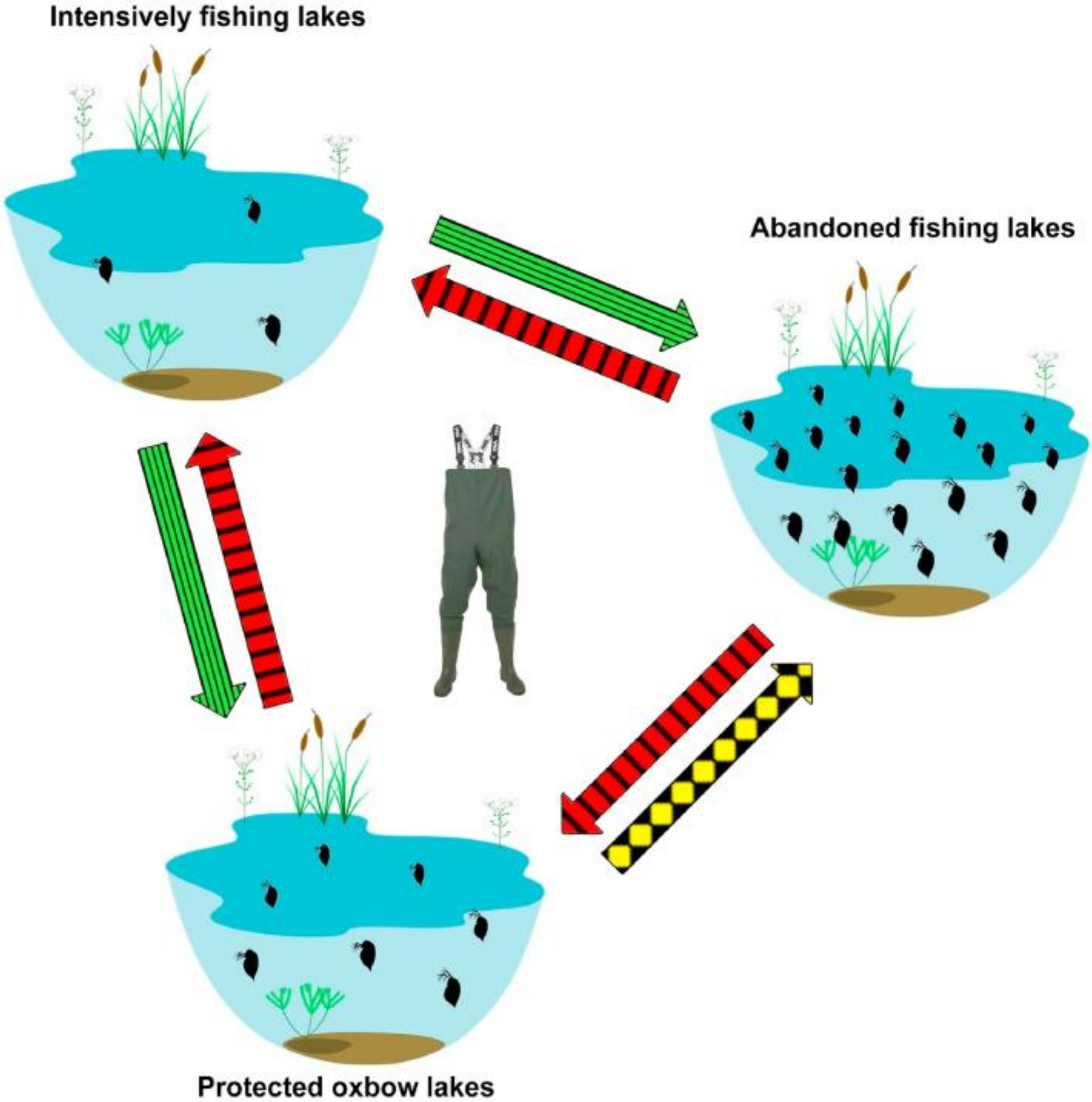

Figure 5. Schematic graph of the investigated differently utilized lakes with indication of the possible mediations' routes. Arrows – possibility of species mediation. The red arrow - major. The green arrow - minor. The yellow arrow – moderate. (Created by the author, 2023)

b) *How do different types of lake utilization affect the extent of Cladocera dispersal facilitated by chest waders?*

The type of lake utilization lowers or increases the chest waders Cladocera dispersal ability. Heavily fished lakes, with intense anthropogenic pressure, would probably not have many Cladocera attach due to their number being lower from fish predation effects and environmental disturbances. Conversely, abandoned fishing lakes and oxbow lakes with less human impact and more stable environmental conditions have high abundance and diversity of Cladocera making it more probable to pick species up and disperse them by means of chest waders. Hence, lakes with higher diversity and abundance of Cladocera would be more susceptible to unintentional dispersal of these species through sampling activities.

c) What impact does inadequate cleaning of chest waders prior to sampling have on the accuracy and integrity of collected data?

Failure to clean chest waders before sampling may compromise data accuracy and integrity. If these are not well cleaned between use at two different types of lakes, the Cladocera or some other aquatic organism can be transferred to another site, which would introduce it into the area. For example, this would false - overestimate the species richness and modified community composition in lakes sampled.

For example, the transfer of *Monospilus dispar* from a protected lake accidentally might end up in completely false data regarding the species in one locality as opposed to another. Hence, thorough cleaning before sampling proves necessary for the validity and reliability of ecological studies. Waterkeyn et al., (2010) and Valls et al., (2016) present evidence regarding the roles that poor cleaning practices play in the inadvertent dispersal of aquatic invertebrates.

3.2.Comparative analysis of contemporary and subfossil Cladocera assemblages with respect to lake utilization and environmental factors

Table 2. Presents a comprehensive overview of the sampling sites utilized in the analysis of contemporary Cladocera populations. This table shows the attributes of each sampling site: Taxa, Individuals, Dominance, Simpson and Shannon diversity indices. Written with blue colour V01 – V06 are sampling points from recreational area, with red colour – agriculturally influenced area sampling points and with green colour – protected area sampling points. (Author's data, 2024)

	CONTEMPORARY				
SAMPLES	Taxa_S	Individuals	Dominance	Simpson	Shannon
V01	5	22	0.3595	0.6405	1.271
V02	7	38	0.295	0.705	1.57
V03	4	24	0.5104	0.4896	0.8817
V04	8	42	0.2007	0.7993	1.802
V05	2	14	0.8673	0.1327	0.2573
V06	6	33	0.3811	0.6189	1.292
V07	7	63	0.3384	0.6616	1.413
V08	3	3	0.333	0.6667	1.099
V09	1	1	1	0	0
V10	5	18	0.5432	0.4568	0.9609
V11	7	53.5	0.224	0.776	1.655
V12	5	20	0.65	0.35	0.7777

Table 3. Presents a comprehensive overview of the sampling sites utilized in the analysis of subfossil Cladocera

populations. This table shows the attributes of each sampling site: Taxa, Individuals, Dominance, Simpson and Shannon diversity indices. Underlined with blue colour V01 – V06 are sampling points from recreational area, with red underline – agriculturally influenced area sampling points and with green underlined – protected area sampling points. (Author's data, 2024).

	SUBFOSSIL				
SAMPLES	Taxa	Individuals	Dominance	Simpson	Shannon
V01	15	1360	0.3409	0.6591	1.497
V02	16	683	0.2997	0.7003	1.847
V03	10	2617	0.4722	0.5278	1.023
V04	24	1244	0.1488	0.8512	2.41
V05	11	4574	0.5035	0.4965	0.9779
V06	14	5980	0.5442	0.4558	1.097
V07	11	4709	0.6421	0.3579	0.841
V08	20	2317	0.313	0.687	1.782
V09	15	5825	0.4266	0.5734	1.341
V10	16	3483	0.3352	0.6648	1.629
V11	21	2200	0.2534	0.7466	2.012
V12	14	2867	0.3337	0.6663	1.545

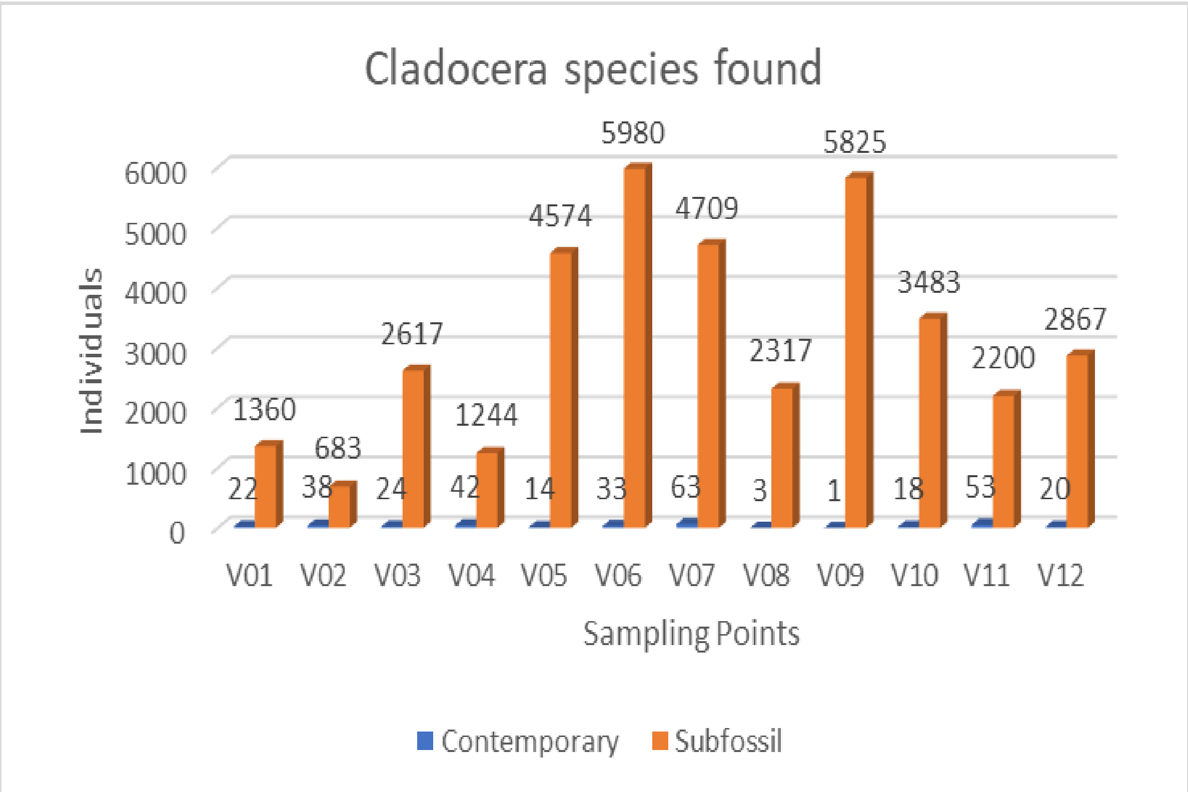

Figure 64. Comparison of individuals in subfossil and contemporary samples. (Author's data, 2024)

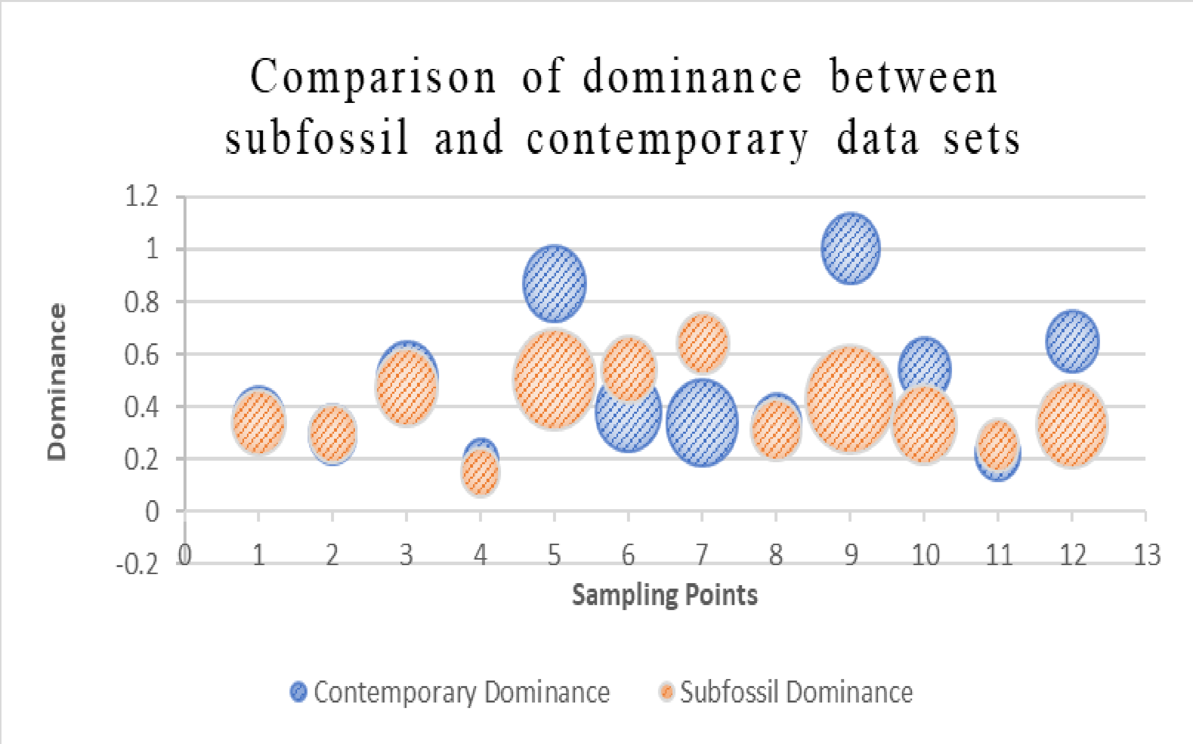

Figure 7. Comparison of dominance between contemporary and subfossil Cladocera samples. (Author's data, 2024).

a) *How do contemporary and subfossil Cladocera assemblages differ in composition across distinct utilization zones within a multi-utilized lake?*

Cladocera composition of contemporary vs subfossil assemblages in Viss Oxbow Lake varied considerably within distinct utilized zones. Subfossil samples always displayed higher species richness compared to contemporary samples. For example, subfossil assemblages manifested a species count nearly 100 times more than contemporary samples having a diversity around three times higher. Such differences represent the distribution of species remains over a very long time in the sediments, preserving all the historical biodiversity since the contemporary samples do not show it due to environmental pressures and other anthropogenic stressors.

Small-sized species such as *Bosmina spp.* and *Chydorus sphaericus* dominated both contemporary and subfossil assemblages, especially in those zones experiencing increased anthropogenic activities. Fewer larger Daphnids could be found, possibly due to fish predation as the cause explored by studies such as (Boersma et al., 1991). These differences between contemporary and subfossil Cladocera are informative about ecological dynamics and impacts of lake utilization during history on community structure.

b) *To what extent do different types of lake utilization influence the composition of Cladocera assemblages?*

The use of Viss Oxbow Lake significantly alters the diversity of Cladocera assemblages to the extent that, among its three different utilization areas, the area with little human activities is reported to be the highest in species diversity owing to stable environmental conditions and low predation pressure. However, decreasing species richness was observed from the moderate to the high-utilization zones, with the highly utilized area being greatly impacted by heavy fishing, habitat alterations, and fish predation. Such a gradient sufficiently substantiates the far-reaching impact of lake use on Cladocera assemblages and underscores the necessity for balanced management preservation to ensure the biodiversity and integrity of ecosystems.

Overall, the different types of utilization by humans for lakes will ultimately determine the way the assemblages will be composed in Cladocera-influence factors concerning the degree of anthropogenic disturbance and exposure to predation by fishes.

4. NEW SCIENTIFIC FINDINGS

- ### Dispersal Potential of Cladocera via Chest-Waders

Scientists' chest waders can act as vectors for Cladocera dispersal, especially to very biodiverse lakes with a strong call for strict cleaning protocols concerning the use of chest waders to avert cross-lake dispersal.

- ### Lake Utilization and Cladocera Composition

These lakes tenants are very much so intensely affected by the activities of man and the presence of fish stocking, where abandoned fishing lakes hold a greater treasure of Cladocera than over-fished lakes.

- ### Contemporary vs. Subfossil Cladocera Discrepancy

In contrast to contemporary samples, subfossil Cladocera assemblages were reported to be exceedingly species rich offering insight into the biodiversity that once existed in the past and the change in ecosystems over time.

- ### Predation as a Key Driver of Cladocera Distribution

Small species of Cladocera tend to dominate in highly fished lakes due to predation pressure, while large Daphnids seem to predominate in the more undisturbed environments like abandoned fishing lakes and oxbows.

5. REFERENCES

Berglund, B.E., Ralska-Jasiewiczowa, M., 1991. Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley and sons., Chichester New York Brisbane.

Bhattarai, U., 2017. Impacts of Climate Change on Biodiversity and Ecosystem Services: Direction for Future Research. Hydro Nepal J. Water Energy Environ. 20, 41–48. https://doi.org/10.3126/hn.v20i0.16488

Boersma, M., Van Densen, W.L.T., Vijverberg, J., 1991. The effect of predation by smelt (*Osmerus eperlanus*) on *Daphnia hyalina* in a shallow eutrophic lake. SIL Proc. 1922-2010 24, 2438–2442. https://doi.org/10.1080/03680770.1989.11899983

De Meester, L., Gómez, A., Okamura, B., Schwenk, K., 2002. The Monopolization Hypothesis and the dispersal–gene flow paradox in aquatic organisms. Acta Oecologica 23, 121–135. https://doi.org/10.1016/S1146-609X(02)01145-1

Dodson, S.I., 2005. Introduction to Limnology. McGraw-Hill, Boston.

Dodson, S.I., Ryan, S., Tollrian, R., Lampert, W., 1997. Individual swimming behavior of *Daphnia* : effects of food, light and container size in four clones. J. Plankton Res. 19, 1537–1552. https://doi.org/10.1093/plankt/19.10.1537

Downing, J.A., Prairie, Y.T., Cole, J.J., Duarte, C.M., Tranvik, L.J., Striegl, R.G., McDowell, W.H., Kortelainen, P., Caraco, N.F., Melack, J.M., Middelburg, J.J., 2006. The global abundance and size distribution of lakes, ponds, and impoundments. Limnol. Oceanogr. 51, 2388–2397. https://doi.org/10.4319/lo.2006.51.5.2388

Frey, D.G., 1982. Contrasting strategies of gamogenesis in northern and southern populations of Cladocera. Ecology 1, 223–241.

Jeppesen, E., Kronvang, B., Meerhoff, M., Søndergaard, M., Hansen, K.M., Andersen, H.E., Lauridsen, T.L., Liboriussen, L., Beklioglu, M., Özen, A., Olesen, J.E., 2009. Climate Change Effects on Runoff, Catchment Phosphorus Loading and Lake Ecological State, and Potential Adaptations. J. Environ. Qual. 38, 1930–1941. https://doi.org/10.2134/jeq2008.0113

Jorgensen, S.E., Lofler, H., Rast, W., Straskraba, M., 2005. LAKE AND RESERVOIR MANAGEMENT. Elsevir.

Korhola, A., Rautio, M., 2001. Cladocera and Other Branchiopod Crustaceans, in: Smol, J.P., Birks, H.J.B., Last, W.M. (Eds.), Tracking Environmental Change Using Lake Sediments, Developments in Paleoenvironmental Research. Springer Netherlands, Dordrecht, pp. 5–41. https://doi.org/10.1007/0-306-47671-1_2

Likens, G.E., 2009. Encyclopedia of inland waters, 1st ed. ed. Academic Press, London Boston.

Maltby, E., Acreman, M.C., 2011. Ecosystem services of wetlands: pathfinder for a new paradigm. Hydrol. Sci. J. 56, 1341–1359. https://doi.org/10.1080/02626667.2011.631014

Szeroczyńska, K., Sarmaja-Korjonen, K., 2007. Atlas of Subfossil Cladocera from Central and Northern Europe.

Threlkeld, S.T., 1988. Planktivory and planktivore biomass effects on zooplankton, phytoplankton, and the trophic cascade1. Limnol. Oceanogr. 33, 1362–1375. https://doi.org/10.4319/lo.1988.33.6.1362

Valls, L., Castillo-Escrivà, A., Mesquita-Joanes, F., Armengol, X., 2016. Human-mediated dispersal of aquatic invertebrates with waterproof footwear. Ambio 45, 99–109. https://doi.org/10.1007/s13280-015-0689-x

Vanni, M.J., 1986. Competition in zooplankton communities: Suppression of small species by *Daphnia pulex* 1. Limnol. Oceanogr. 31, 1039–1056. https://doi.org/10.4319/lo.1986.31.5.1039

Waterkeyn, A., Vanschoenwinkel, B., Elsen, S., Anton-Pardo, M., Grillas, P., Brendonck, L., 2010. Unintentional dispersal of aquatic invertebrates via footwear and motor vehicles in a Mediterranean wetland area. Aquat. Conserv. Mar. Freshw. Ecosyst. 20, 580–587. https://doi.org/10.1002/aqc.1122

Weiskopf, S.R., Rubenstein, M.A., Crozier, L.G., Gaichas, S., Griffis, R., Halofsky, J.E., Hyde, K.J.W., Morelli, T.L., Morisette, J.T., Muñoz, R.C., Pershing, A.J., Peterson, D.L., Poudel, R., Staudinger, M.D., Sutton-Grier, A.E., Thompson, L., Vose, J., Weltzin, J.F., Whyte, K.P., 2020. Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. Sci. Total Environ. 733, 137782. https://doi.org/10.1016/j.scitotenv.2020.137782

Zawisza, E., Filbrandt-Czaja, A., Correa-Metrio, A., 2016. Subfossil Cladocera and pollen as indicators of natural and anthropogenic trophic changes of Lake Jelonek (Tuchola Forest, N Poland) during the Holocene. Adv. Oceanogr. Limnol. 1. https://doi.org/10.4081/aiol.2016.6234

6. PUBLICATIONS

DEBRECENI EGYETEM
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Jelölt: Hajredini, Arber
Doktori Iskola: Juhász-Nagy Pál Doktori Iskola
MTMT azonosító: 10098533

A PhD értekezés alapjául szolgáló közlemények

Idegen nyelvű tudományos közlemények külföldi folyóiratban (2)

1. Gyulai, I., **Hajredini, A.**, Varga, K., Jakab, J., Vallejo-Cuzco, G., Somlyai, I., Grigorszky, I., Berta, C.: Comparative analysis of contemporary and subfossil Cladocera assemblages with respect to lake utilisation and environmental factors.
   Aquat. Sci. 87 (1), 1-14, 2025. ISSN: 1015-1621.
   DOI: http://dx.doi.org/10.1007/s00027-024-01146-y
   IF: 2 (2023)

2. **Hajredini, A.**, Demelezi, F., Somlyai, I., Grigorszky, I., Berta, C.: Possible mediation of Cladocera species by a researcher's chest wader.
   Heliyon. 9 (6), 1-10, 2023. ISSN: 2405-8440.
   DOI: http://dx.doi.org/10.1016/j.heliyon.2023.e16725
   IF: 3.4

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További közlemények

Idegen nyelvű tudományos közlemények külföldi folyóiratban (1)

3. Grigorszky, I., Kiss, K. T., Szabó, L. J., Dévai, G., Nagy, S. A., Somlyai, I., Berta, C., Gligora-Udovič, M., Borics, G., Pór, G., Yaqoob, M. M., **Hajredini, A.**, Tumurtogoo, U., Ács, É.: Drivers of the Ceratium hirundinella and Microcystis aeruginosa coexistence in a drinking water reservoir.
   Limnetica. 38 (1), 41-53, 2019. ISSN: 0213-8409.
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