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Density and Diversity Differences of Contemporary and Subfossil Cladocera Assemblages: A Case Study in an Oxbow Lake

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Abstract: Cladocerans are biological indicators of environmental changes. Their remains provide information on past changes in lake environments. We studied the correspondence between contemporary Cladocera assemblages and their subfossil remains from an oxbow lake. We sought to demonstrate that there were differences among the various sites of an oxbow lake with different utilization based on contemporary and subfossil Cladocera assemblages and physical–chemical variables. The oxbow lake's two sides are used as fishing sites, where angling is the main activity. The middle site of the lake is under nature protection with high macrovegetation coverage. Contemporary and subfossil Cladocera assemblages were sampled from 21 sampling sites along the oxbow lake. Our research showed that the subfossil Cladocera assemblages had higher species richness and densities (36 taxa) than the contemporary species (29 taxa). We found one species of the Polyphemidae family only in the contemporary assemblage. Among the sites, Cladocera assemblages differed in their species composition and density. The highest densities were found in the second fishing site due to the appearance of the small-sized Bosmids. The relationship between Cladocerans and the physical–chemical variables showed that some variables, such as chlorophyll-a, biological oxygen demand, dissolved oxygen, copper, phosphide, and organic matter content, significantly affected Cladocera composition. We found that the subfossil Cladocera assemblage was significantly more diverse and abundant than the contemporary one, indicating that an integrated sampling may be sufficient to provide better results on the total species composition of the water body.

Keywords: physical–chemical variables; contemporary; subfossil; Cladocera; fishing and natural site

1. Introduction

Most of the oxbow lakes are the remains of river activity, unlike other standing water bodies. They feature a variety of aquatic plants, freshwater organisms, and they are characterized by a wide range of environmental parameters [1,2]. Oxbow lakes are a susceptible water body (which directly affects the biodiversity and ecology of the surrounding area) that offers a wide variety of habitats for aquatic organisms, macrophytes, and invertebrates [3]. The majority of oxbow lakes are mainly used for agriculture (irrigation, water

reservoir), fishing (fish farming and angling), and as a reservoir (for human use), which has increased human activity and pollution in the freshwater ecosystem [4]. Therefore, more nutrition and pollution can create the eutrophic condition that favors phytoplankton growth [5,6]. Researchers recorded that the influx of nutrients from non-point sources (agriculture, run-off, chemical fertilizer) affected the lake ecosystem and significantly enhanced eutrophication [7].

Any freshwater body can contain one or more species of aquatic invertebrates that mainly belong to Cladocera. Cladocera are one of the main small-sized components of the zooplankton that are widely distributed in open water, littoral, and benthic zones [8]. Moreover, they can be planktonic, photophilic, and benthic. The majority of species consume bacteria, detritus, or algae (filtrates), but some are predators. Algae can affect their spread and diversity [9,10]. Generally, Cladocera species are incredibly abundant in eutrophic, phytoplankton-rich water bodies [11] during spring and in the rainy seasons, but growth is limited in cold conditions [12,13]. Cladocera assemblages play an essential role in aquatic ecosystems, as they provide food source for higher taxonomic levels (fish and invertebrates) and contribute to the structure of aquatic food webs [14,15]. As a size-selective predator, omnivorous fishes play an important role in regulating Cladoceran assemblage structure. Lakes with zooplanktivorous fish species mainly contain small-sized zooplankton species [16–18], while in fishless lakes, zooplankton assemblages are dominated by large species [19,20]. This is also confirmed by Liu et al. [21], who reported that when planktivorous fish assemblage reached a relatively large population size, Bosmids morphology (the length of the carapace, antennule, and mucro) decreased. Accordingly, Cladocerans are protecting themselves from fish predation by taking refuge in macrophytes beds during the daytime, which allows a high grazing pressure on the phytoplankton to be maintained [20,22,23]. Also some littoral-benthic species occur connected to macrophytes and feed on them [24]. Additionally, submerged vegetation can absorb nutrients from algae and from the water body that can support a balanced aquatic ecosystem (many fish, crab, and aquatic macroinvertebrate species require submerged vegetation to survive) [25].

Compared to other aquatic microorganisms, Cladocera are unique in that they are usually preserved as fossils due to their strong chitinous exoskeleton (shell, head shield, postabdomen, and antennule segments) [26,27]. Hence, Cladocera remains are often found in lake sediment and can be used to determine the environmental conditions during the organism's lifetime. In addition, paleoclimate, food web analysis, and changes in nutrition status over the past few years can be determined by using Cladocera remains [28,29]. Some researchers have related contemporary and subfossil Cladocera distribution to different environmental pressures [3,30].

Biodiversity conservation is very important. Species conservation and management depend on a complete understanding of habitat requirements. The habitat of a species refers to where that species lives, and the ecosystem resources (abiotic and biotic) required for survival and reproduction. Wetlands were selected as part of the international convention for the conservation of species, with a particular emphasis on the ecological needs of water birds. [31]. Additionally, oxbow lakes are natural habitats that provide breeding areas for endangered water bird species and spawning grounds for many fish species. Consequently, some oxbow lakes are Ramsar Convention Sites (e.g., Mártélyi-floodplain and oxbow lake) [32].

For the aforementioned reasons, the distribution and structure of Cladocera fauna ultimately reflect the environmental conditions of the region they inhabit. Therefore, today's priority task is understanding the physical–chemical and biological interactions in ecosystems. Consequently, it is crucial to know about environmental factors or human activity (e.g., fish management, angling) affecting the contemporary and subfossil Cladocera assemblages. Thus, our research aims to investigate the differences between utilization type (active fishing and angling) and nature protection based on physical–chemical variables and species density, and diversity of contemporary and subfossil Cladocera species. The main objectives were to (i) examine the difference between the contemporary and subfossil

Cladocera assemblages; and (ii) find out which of the physical–chemical variables are the most effective in shaping the structure of Cladocera assemblages of the oxbow lake.

2. Materials and Methods

2.1. Study Area

The Nagy–Morotva oxbow lake is located between Rakamaz and Tiszanagyfalu cities in N–E Hungary (Figure 1). It is a naturally created oxbow lake in the floodplain of the river Tisza. The length of the oxbow lake is 4.5 km, its width ranges between 100–130 m. The surface area is 9 ha and the average depth is 80–150 cm, depending on the water level [33]. The oxbow lake is located on a Nature 2000 territory. The oxbow lake was divided into three different parts, two of which are used as intensive fishing areas (FS-1: fishing site-1 and FS-2: fishing site-2), and both were dredged during the last decades (eliminating the top sediment layer). The middle part is under nature protection; thus, fishing is prohibited (NS: natural site).
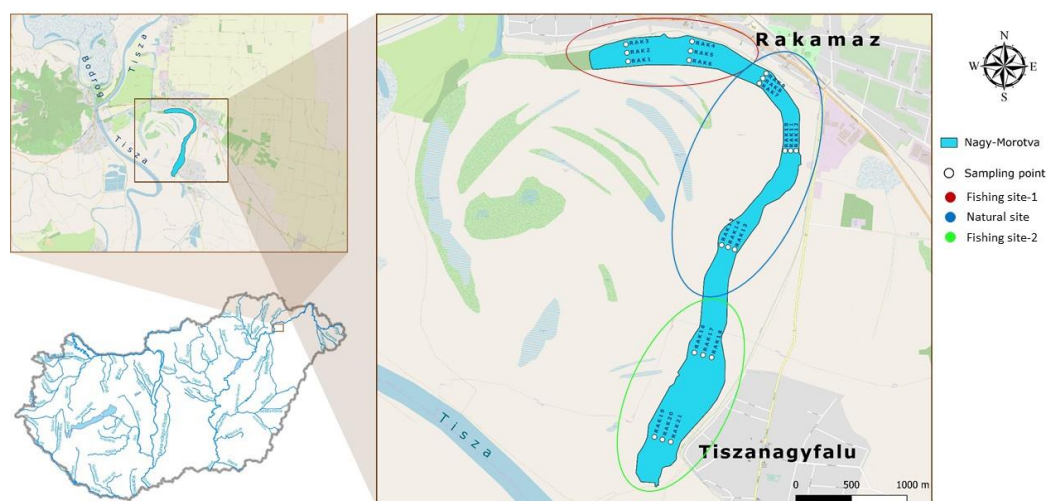
Figure 1. Area of research and sampling points in Nagy–Morotva oxbow lake.

In terms of fish stock, most of the natural fish species of Hungary can be found in the oxbow lake. The fish fauna can be characterized by many common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), crucian carp (*Carassius carassius*), pike perch (*Sander lucioperca*), and bream (*Abramis brama*) species.

The summer period is characterized by an 80–90% macrovegetation coverage. However, outside the summer period and in the fishing sites, the macrovegetation coverage was lower and did not cover the middle part of the oxbow lake. In the fishing sites, macrophytes are only found in the littoral zone. By contrast, the natural site was 80–90% covered throughout the entire vegetation period. The most dominant macrophytes in the fishing sites were the white water lily (*Nymphaea alba*) and water pumpkin (*Nuphar lutea*). The natural site was covered with more diverse macrophytes species, like water soldier (*Stratoites alloides*), white water lily (*Nymphaea alba*), and hornwort (*Ceratophyllum demersum*). Common reed (*Phragmites australis*), lesser bulrush (*Typha angustifolia*), and reed sweetgrass (*Glyceria maxima*) were only on the shoreline of the oxbow lake.

2.2. Sampling Method

Samples were taken at 21 selected locations at the Nagy–Morotva oxbow lake in October 2018 and 2019. The three differently utilized parts of the lake were sampled in transects (from one side to the other side). We collected 6 samples from both fishing sites (1 and 2), while 9 samples were collected from the natural site. Data collection included field and laboratory methods for estimating the physical and chemical variables, and the Cladocera assemblages.

2.2.1. Field and Laboratory Methods

For analyzing the contemporary Cladoceran assemblage, we collected filtered samples with a 30 L volume Schindler–Patalas plankton trap [34], with a mesh size of 35 μm. These samples were preserved with 70% ethanol in field, to avoid fungal and bacterial growth. For analyzing the subfossil Cladoceran assemblage, sediment samples were collected with a gravity-corer [35], and only the top 1 cm of fresh sediment was used for further analyses. For analyzing the physical and chemical variables, non-filtered water samples were collected from the top (50 cm) surface of the water in a 1.5 L plastic bottle and stored at cold temperature until arriving at the laboratory.

In laboratory, the non-filtered water samples were analyzed for chemical variables, including: total suspended solids (TSS) which was measured according to the Hungarian Standard MSZ 260-3:1973; chloride-ions (Cl^-) which was determined by using Németh [36] method; total hardness; orthophosphate-ions (PO_4^{3-}) and total-phosphorus were measured according to the Hungarian Standard MSZ 12750-17:1974; nitrate-nitrogen (NO_3^--N), nitrite-nitrogen (NO_2^--N), ammonium-ions (NH_4^+), and Kjeldahl-nitrogen (KJN) were measured according to the Hungarian Standards MSZ (12750-16:1974, 1484-13:2009, 7150-1:1992, and 260-12:1987); sulphate-ions (SO_4^{2-}) were measured according to the International Standard ISO 15923-1:2013; total alkalinity was determined by using the Hungarian Standard MSZ 448-11:1986; humic acid was measured using the method of Tisza River Regional Waterworks Ltd. HKE-3: 2002; biochemical oxygen demand (BOD_5) was measured according to the International Standard MSZ EN 1899-2:2000; chemical oxygen demand (COD_{sMn} and COD_{Cr}) were measured according to the Hungarian Standards MSZ (448-20:1990, and ISO 6060: 1991); hydrogen carbonate (HCO_3^-) and carbonate (CO_3^{2-}) content measurement were based on the Hungarian Standard MSZ 448-11:1986.

In addition to the non-filtered water samples, macro-elements (Ca^{2+}, K^+, Mg^{2+}, and Na^+), and micro-elements (Al^{3+}, Ba^{2+}, Cd^{2+}, Cr^{2+}, Cu^{2+}, Mn^{2+}, Fe^{2+}, Li^+, Ni^{2+}, Pb^{2+}, Sr^{2+}, and Zn^{2+}) were also measured by MP-AES (Microwave Plasma Atomic Emission Spectrometry).

From the sediment samples, we determined the calcium-carbonate ($CaCO_3$) and the organic matter contents based on the standard method of Dean [37].

2.2.2. Cladocera Analyses

Filtered Cladocera samples were treated on field with 70% ethanol, as previously mentioned. In laboratory, they only needed dyeing (few drops of Safranin–glycerin solution) for easier identification.

Analyzes of the subfossil Cladocera assemblage and treatment of the sediment were based on the standard method of Korhola and Rautio [26]. A total of 1 cm^3 of soft sediments from every 21 samples were placed in a plastic beaker and added 100 mL of 10% KOH (potassium-hydroxide) solution. The prepared samples were heated up in a water bath at 100 °C for 30 min (stirring it regularly) and then sieved through a mesh (35-μm). All the particles were transferred with distilled water into a plastic tube. Same dyeing (Safranin–glycerin) was used for the sediment samples and 70% ethanol was also added to the prepared samples.

Identification of the Cladocera species was done at the species level. A total of 10% of the total samples were used under an Olympus BX53 light microscope (Olympus Europe Holding GMBH, Hamburg, Germany) (at 100× magnification). Whenever less than 100 specimens were encountered from a sample, the total volume of the sample was assessed. Frey [38], Gulyás and Forró [39], Szeroczyńska, and Sarmaja-Korjonen [40], and Błedzki and Rybak [41] identification keys were used to identify the contemporary and subfossil Cladocera species.

2.3. Statistical Analysis

PAST (Paleontological Statistics) [42] and R [43] program were used for the statistical analyses in this research. The PAST software calculated the species diversity and dominance for contemporary and subfossil Cladocera assemblages.

Principal components analysis (PCA) with Bray–Curtis similarity was used to the patterns of variation within the physical–chemical variables. Principal coordinates analysis (PCoA) with Jaccard similarity (capscale() function in vegan package [44]) was used to reveal patterns of contemporary and subfossil Cladoceran assemblages. Group dispersions were tested using permutational multivariate analysis (adonis) based on Jaccard distances. Pairwise comparison was done using the function of Martinez [45] with Benjamini & Hochberg ("fdr") adjusted p-values. Distance-based redundancy analysis (dbRDA, capscale() function in vegan package) was used with the same similarity matrices to find the variables that most strongly relate to patterns of Cladoceran assemblages.

3. Results

3.1. Cladocera Assemblage

A total of 37 Cladocera taxa were found in the surface water and sediment of the oxbow lake (Table 1). A total of 75% of these species were found in both filtered and surface sediment samples. High variance was observed between sampling points, in Shannon-diversity, dominance, and density for contemporary and subfossil assemblages (Table 2). The subfossil Cladocera assemblage markedly showed a higher species richness (97%) and density than contemporary assemblage in the oxbow lake. Our results revealed that the natural site of the oxbow lake had 31 species in the subfossil assemblage, while its contemporary assemblage showed about 19 species. Similarly, the angling activity sites were characterized by higher subfossil Cladocera species assemblage in fishing site-1 and fishing site-2 areas (29 and 33 species, respectively) than contemporary species assemblages (23 and 18 species respectively, for fishing site-1 and fishing site-2).

The dominant species in both Cladoceran assemblages were *Eubosmina coregoni*, *Bosmina longirostris*, and *Chydorus sphaericus*. Some of the littoral species, including *Alona rustica*, *Alonella nana*, *Alonopsis elongata*, *Camptocercus fennicus*, *Camptocercus lilljeborgi*, *Daphnia longispina*, and *Sida crystallina*, were only found in the sediment samples. Only one family of *Polyphemidae* sp. was found in the filtered sample. In general, the highest density of *B. longirostris* was observed in the filtered (38–55%) and sediment (69–73%) samples from the three sites. The contemporary Cladocera assemblages in fishing site-2 were characterized by some species (*B. longirostris*, *E. coregoni*) that are more abundant than subfossil Cladocera assemblages.

Species diversity and density of Cladocera showed high variations from site to site (Table 2). It is a known fact that the species richness of the subfossil Cladocerans increased from fishing site-1 to fishing site-2 (fishing site-1:29, natural site:31, and fishing site-2:33). However, the contemporary Cladocerans declined from fishing site-1 to fishing site-2 (fishing site-1:23, natural site:19, and fishing site-2:18).

A total of 49% of the variance in contemporary Cladoceran assemblages were explained in the first two principal co-ordinates axes (PCoA). The PCoA ordination revealed that the species composition of contemporary Cladocerans of the fishing site-2 lower section of the oxbow lake significantly differs from the others (adonis: $R^2 = 0.142$, $p < 0.05$), but fishing site-1 and natural site of the oxbow lake had very similar Cladoceran assemblages (Table 1, Figure 2A).

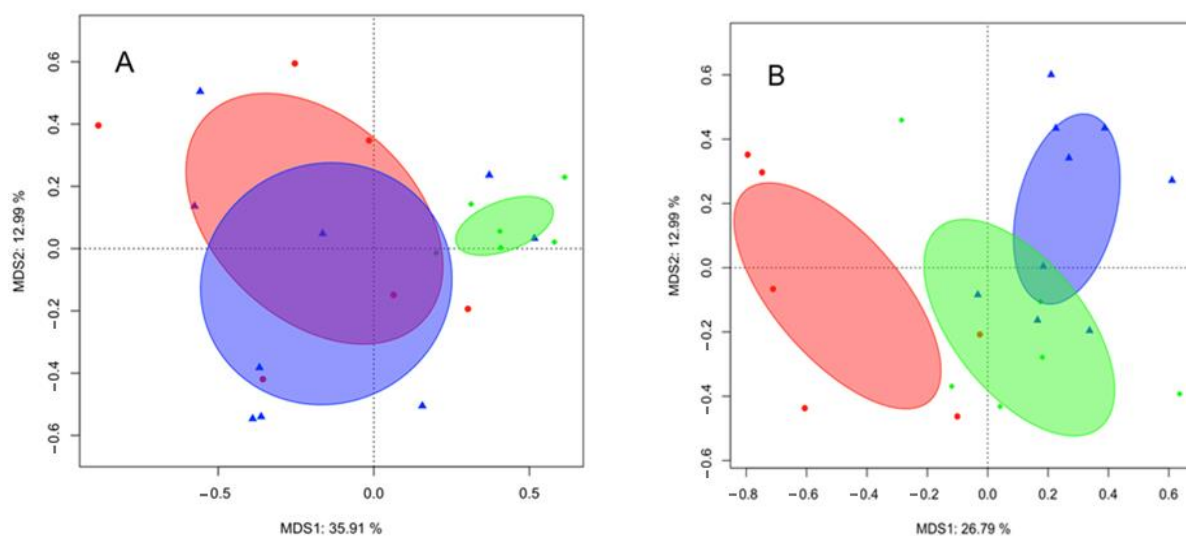**Table 1.** Result of pairwise multilevel comparison of contemporary Cladoceran assemblages in the three sites of the oxbow lake using adonis.

Pairs	F.Model	R^2	*p*-Value	$p_{adjusted}$	Sig
FS-1 vs. NS	0.7835624	0.0568476	0.607	0.6070	n.s.
FS-1 vs. FS-2	3.6415464	0.2669453	0.007	0.0105	
NS vs. FS-2	3.7957823	0.2259962	0.007	0.0105	

Table 2. Diversity indices of subfossil and contemporary Cladoceran assemblages in the oxbow lake (C: contemporary assemblage and S: subfossil assemblage).

Sites	Sampling Points	Taxa	Individuals		Dominance	Shannon
			Ind. L^{-1}	Ind. cm^{-3}		
Fishing site-1	C_RAK1	16	610		0.1973	2.07
	S_RAK1	19		8417	0.2077	2.13
	C_RAK2	11	2975		0.4691	1.22
	S_RAK2	18		11,000	0.3627	1.63
	C_RAK3	8	2825		0.5990	0.89
	S_RAK3	10		13,500	0.4489	1.22
	C_RAK4	12	2950		0.5402	1.09
	S_RAK4	15		8333	0.3498	1.57
	C_RAK5	9	6201		0.6578	0.67
	S_RAK5	16		19,750	0.3878	1.46
	C_RAK6	10	4800		0.5352	1.02
	S_RAK6	19		10,833	0.2419	2.05
Natural site	C_RAK7	12	2525		0.4061	1.41
	S_RAK7	20		15,375	0.1866	2.22
	C_RAK8	7	3450		0.5806	0.86
	S_RAK8	11		4950	0.2374	1.75
	C_RAK9	6	3400		0.6620	0.63
	S_RAK9	20		9750	0.1936	2.14
	C_RAK10	11	3125		0.5668	1.05
	S_RAK10	19		4950	0.1709	2.27
	C_RAK11	13	3500		0.4184	1.45
	S_RAK11	20		8700	0.1711	2.25
	C_RAK12	9	3000		0.4678	1.23
	S_RAK12	17		7275	0.1923	2.07
	C_RAK13	9	2450		0.4511	1.27
	S_RAK13	14		5200	0.1916	1.98
	C_RAK14	8	1125		0.4084	1.29
	S_RAK14	20		8475	0.3039	1.85
	C_RAK15	4	1300		0.5806	0.76
	S_RAK15	16		4850	0.2186	2.00
Fishing site-2	C_RAK16	8	8800		0.6408	0.74
	S_RAK16	24		6750	0.1101	2.63
	C_RAK17	7	15,450		0.5411	0.75
	S_RAK17	16		4500	0.3277	1.71
	C_RAK18	11	14,950		0.5566	0.83
	S_RAK18	27		6250	0.2026	2.33
	C_RAK19	9	21,500		0.5512	0.74
	S_RAK19	22		4750	0.1745	2.30
	C_RAK20	8	11,950		0.5407	0.80
	S_RAK20	18		5750	0.2599	1.99
	C_RAK21	8	14,900		0.5607	0.78
	S_RAK21	23		7425	0.2456	2.19

There is little variance: 40% of the total variance in subfossil Cladoceran assemblages explained in the first two principal co-ordinates axes (PCoA). The three sites of the oxbow lake were characterized by different subfossil Cladocera assemblages (adonis: $R^2 = 0.201$, $p < 0.05$) (Table 3), but the subfossil Cladocera assemblages of the two fishing sites were closer together, and natural site had quite a different assemblage (Figure 2B).

Figure 2. Results of Principal Co-ordinate Analysis (PCoA) of the contemporary and subfossil Clado-cera assemblages of the three sampling sites of the Nagy–Morotva oxbow lake. (**A**) Contemporary Cladocera assemblage, (**B**) Subfossil Cladocera assemblage. The group centroids of the sites are marked with coloured ellipses (Red: Fishing site-1, Blue: Natural site, Green: Fishing site-2).

Table 3. Result of pairwise multilevel comparison of subfossil Cladoceran assemblages in the three sites of the oxbow lake using adonis (* represents significance if $p_{adjusted} < 0.005$).

Pairs	F.Model	R^2	*p*-Value	$p_{adjusted}$	Sig
FS-1 vs. NS	4.671560	0.2643547	0.003	0.009	*
FS-1 vs. FS-2	2.978583	0.2294999	0.012	0.015	
NS vs. FS-2	1.750745	0.1186886	0.015	0.015	

### 3.2. Cladocera Assemblage Correlation with Physical and Chemical Variables

Principal component analysis (PCA) determined on the physicochemical variables showed the three sites (Figure 3). The first axis (PC1) explained 31.15% of the total variance in the water samples, while the second axis (PC2) explained 18.17%. (Figure 3A). The first two axes of PCA on physicochemical variables show a clear separation of the three sites. Natural site was positively correlated with the Chl_a, DO.P, and Ca^{2+}. Fishing site-2 was characterized by SO_4^{2-}, TDS, Cl^-, Na^{2+}, and NH_4^+. Most of the cations (K^+, Mg^{2+}, Al^{3+}, Ba^{2+}, Cr^{2+}, Pb^{2+}, Sr^{2+}), ODO, and HCO_3 were the main factors in fishing site-1.

The first axis (PC1) explained 32.25% of the total variance in the sediment samples, and the second axis (PC2) explained 25.73% (Figure 3B). Fishing site-1 was affected by LOI550, NH_4^+. Natural site was significantly correlated with conductivity, LOI550, NO_2^-, NH_4^+, PO_3, ORP but negatively with LOI950, O_2, and pH. Fishing site-2 was affected by NO_2^- and PO_3.

Based on dbRDA of the Cladoceran densities, the three sites could be divided into three plots. The first (dbRDA1) explained 36.42% of the total variance, but the second axis (dbRDA2) explained 6.96% (Figure 4A). Out of the four explanatory physicochemical variables, fishing site-1 and natural site overlapped with BOD_5, Chl_a, Cu^{2+}, and DO.P, which were highly significant for the contemporary assemblage. *Alona intermedia*, *Bosmina. sp*, *C. sphaericus*, *Monospilus dispar*, and *Pseudochydorus globosus* show high density in fishing site-1 and the natural site. *M. dispar*, and *A.intermedia* have a significant positive correlation with DO.P. BOD_5, Chl_a, and Cu^{2+} have a significant negative correlation with DO.P. *C. sphaericus* and *P. globosus* have a significant negative correlation with BOD_5, Chl_a, and Cu^{2+}. While Chl_a, BOD_5, DO.P, and Cu^{2+} did not significantly correlate with fishing site-2 and *Bosmina* sp. has a significant negative correlation with physicochemical variables. Fishing site-2 was separated from other sites.
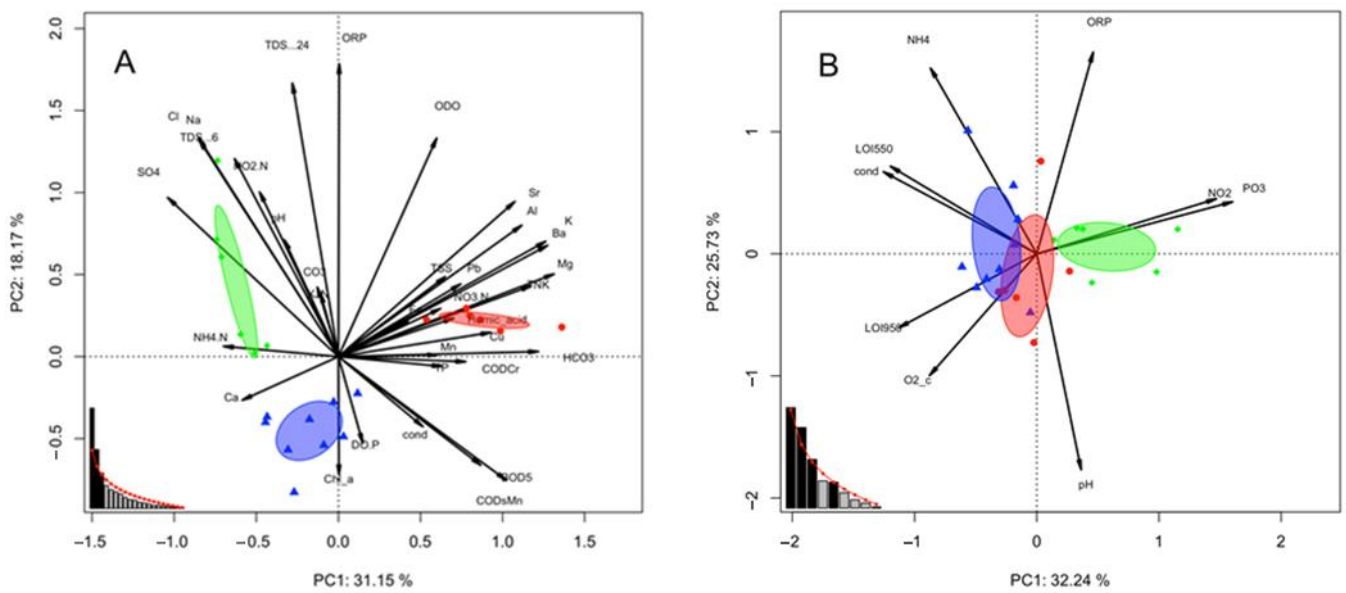
Figure 3. Principal components analysis (PCA) of all measured physical–chemical variables from (**A**) water and (**B**) surface sediment in the oxbow lake. (Red: Fishing site-1, blue: Natural site, and green: Fishing site-2).
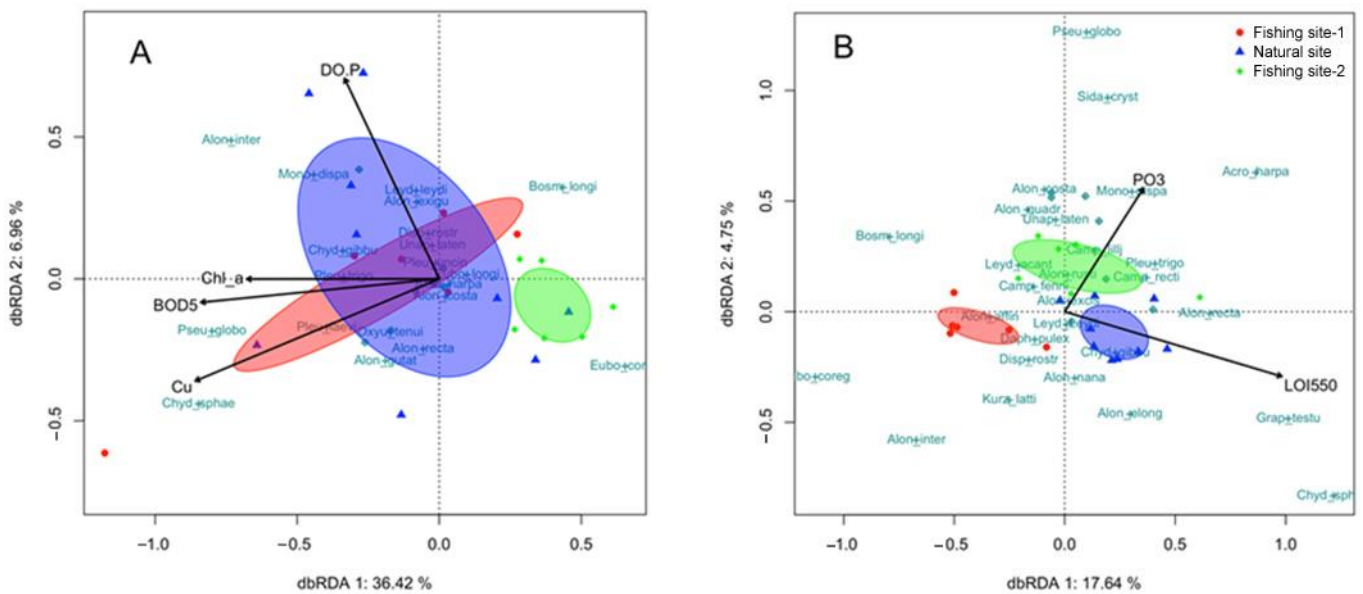
Figure 4. Distance-based redundancy analysis (dbRDA) ordination plot showing (**A**) contemporary and (**B**) subfossil Cladocera assemblages among the three sites concerning forward measured physical–chemical variables; Color of sites represented samples taken from the three different sites (Red color-Fishing site-1, Blue color-Natural site, and Green color-Fishing site-2).

Considering the sediment samples, the three sites were separated based on the dbRDA (Figure 4B). The first axis (dbRDA1) explained 17.64% of the total variance, while the second axis (PC2) explained 4.75%. Generally, *A. intermedia*, *Coronatella rectangula*, *Bosmina.* sp., *C. sphaericus*, and *P. globosus* were highly abundant in the three sites. *Acroperus harpae*, *Alona gutatta*, *Graptoleberis testudinaria*, and *Pleuroxus trigonellus* had a high density in the natural site and fishing site-2. Additionally, *A. elongala* and *Disparalona rostrata* only were highly abundant in the natural site. PO_3 had a significant positive correlation with fishing site-2, while LOI550 had a significant negative correlation with the natural site. Furthermore, PO_3 and LOI550 did not have a significant correlation with fishing site-1.

3.3. Beta-Diversity

In the contemporary assemblages, the Shannon value varied between the following ranges: fishing site-1 (0.89–2.07), natural site (0.63–1.45), and fishing site-2 (0.74–0.83). In contrast, the Shannon values of the subfossil assemblages were higher (fishing site-1: 067–2.13; natural site: 1.75–2.27; fishing site-2: 1.71–2.33) than the contemporary assemblages (Table 1).

Both the contemporary and subfossil Cladocera assemblages in the oxbow lake are characterized by a high degree of similarity in all three areas. Between 43% and 51.5% of the species stock is common among the three sites. The subfossil assemblage of the oxbow lake shows more similarity to the contemporary assemblage, so its beta diversity is lower (48.5%). The species structure of the three areas shows a very similar pattern (Figure 5). The beta diversity of the fishing site-1 was the highest (47.2%) and it decreases in the other two (46.4 and 45.5%). In fishing site-1, 20% of the species were found in only one location, while the Cladocera assemblage in the natural site was the most diverse: approximately 30% of the species were responsible for the variety received.
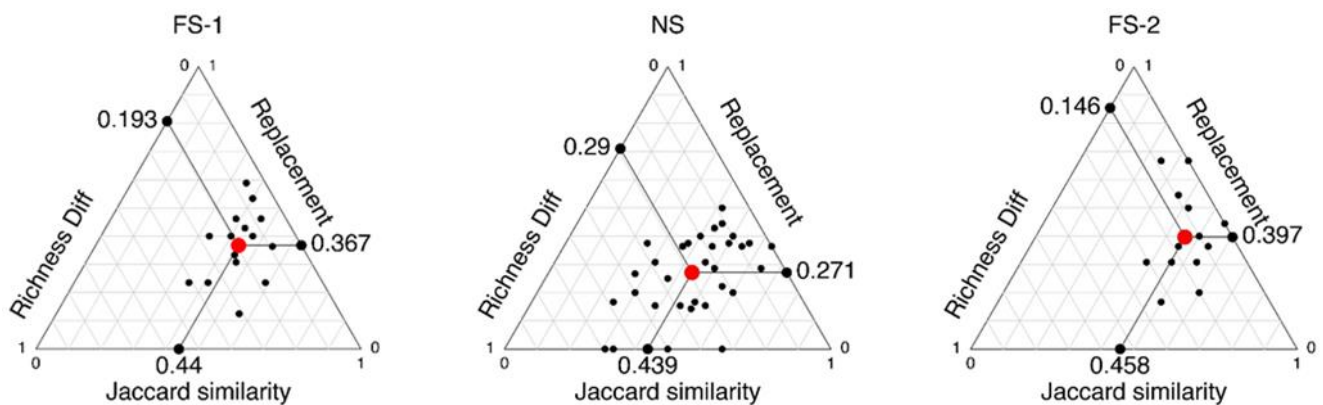
Figure 5. Simplex plots based on similarity, richness differences, and species replacement for all the pairwise comparisons of the subfossil Cladocera assemblage of the three sites of the oxbow lake. Three sites: fishing site-1 (FS-1), natural site (N.S.), fishing site-2 (FS-2).

The contemporary Cladocera assemblage is characterized by greater diversity and greater beta diversity, giving 56.8% of the variation in the contemporary assemblage (Figure 6). The highest beta diversity (the lowest similarity) was obtained in the natural site. Some 30% of the species are characteristic of only one habitat, while in the fishing site-1 and fishing site-2, the proportion of individual species occurring only in a given place is 15–20%.
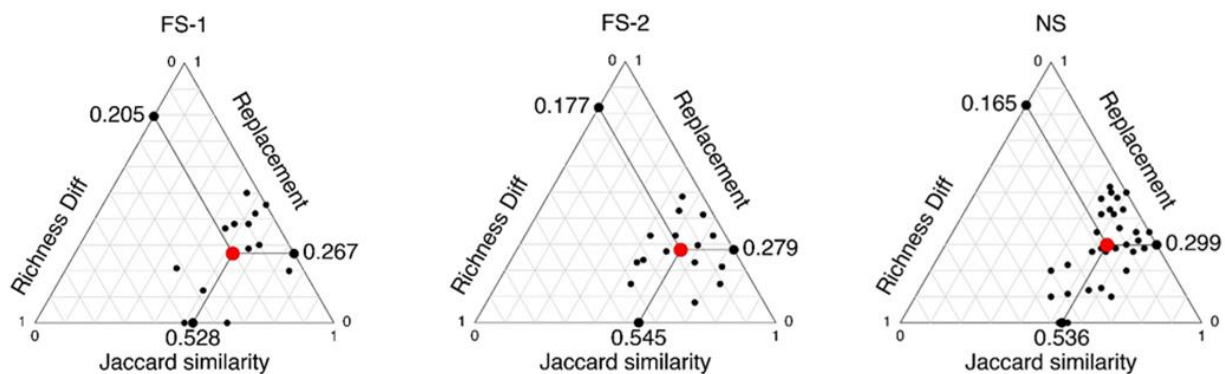
Figure 6. Simplex plots based on similarity, richness differences, and species replacement for all the pairwise comparisons of the contemporary Cladocera assemblage of the three sites of the oxbow lake. Three sites: fishing site-1 (FS-1), natural site (N.S.), fishing site-2 (FS-2).

4. Discussion

Distinct Cladocera assemblages can be observed in water and surface sediment samples [46,47]. Studies of subfossil Cladocera assemblages provide essential information about benthic and littoral ecology. Therefore, we studied both the contemporary and subfossil Cladocera assemblages in a shallow oxbow lake (Nagy–Morotva). Our research hypotheses were confirmed. When species are determined in the oxbow lake, the filtered samples had a lower diversity but a higher density of Cladoceran species (taxa: 29, individual: 176,783 Ind. L^{-1}) in comparison to the sediment samples (taxa: 36, individual: 131,711 Ind. cm^{-3}). Other published studies [30,46] have mentioned that comparing filtered and sediment samples produce different results. A subfossil assemblage's diversity and density come from several years' deposition in the surface sediment as well as its connection with environmental variables [17,48]. Korponai et al. [49] reported that 27 taxa for contemporary and 18 taxa for subfossil Cladocera species were determined in the same region. These differences are probably due to differences in the sampling points; indeed, Korponai et al. used one sampling point from each oxbow lake while we collected samples from 21 different points. Nonetheless, the high density of *E. longirostris* and *C. sphaericus* showed similarities for both types of research work. In case of a shallow oxbow lake, one sample from the deepest point is not enough to analyze the subfossil Cladocera assemblages.

According to Davidson et al. [30], the density of size-selective predators and macrophytes affect the population of zooplankton community of shallow lakes. Also, fish pressure has been shown to increase predation on bigger-sized Cladocera species, which causes a decrease in species richness, and smaller Cladocera species may dominate in the water body [3,18]. In contrast, the results showed that fishing site-1 (contemporary) and fishing site-2 (subfossil) had a high number of Cladocera species, but some results showed similarity; fishing sites showed a high density of *Bomina* sp. Respectively, the density of contemporary and subfossil *B. longirostris* were higher in fishing sites 1 and 2 than in the N.S. However, the contemporary and remains of *C. sphaericus* had high numbers in the natural site. These two species became dominant in the Cladocera assemblage under high-pressure fish predation [3].

In addition, previous studies reported that *A. guttata* remains are observed in a high organic matter pool [50]. Our result showed a high number of *A. guttata* remains preserved in the fishing site-1. However, some researchers have found [50–55] that a high extension of microvegetation coverage cause a smaller fish stock which contributes to a lower predation pressure in the shallow lake.

We found other correspondence between subfossil and contemporary assemblages. Some species (*A. rustica*, *A. nana*, *A. elongata*, *C. fennicus*, *C. lilljeborgi*, *D. longispina*, and *D. crystalline*) were found in the sediment, but did not occur in the contemporary assemblages as also reported in another study [56]. Researchers reported [17,57] that the family of *Polyphemidae* sp. has a soft-shelled chitinous body part, probably preserved only in the contemporary assemblage in the present research.

Sedimentary remains show a shift in Cladocera diversity, as reported in other research conducted in shallow lakes [17,58]. The result of the beta-diversity analysis of contemporary and subfossil Cladocera showed no significant differences in the patterns of Cladocera assemblage. The replacement of species between sites was low, and the richness differences in sampling sites were low in both assemblages. Therefore, we observed lower and higher Shannon values of Cladocera assemblage in the natural site (contemporary) and fishing site-1 (subfossil), respectively. Fishing sites had a lower density of contemporary Cladocera assemblages than natural sites. Indeed, Berta et al. [3] already demonstrated the impact of introducing fish.

PCA and dbRDA showed how differences in physical–chemical variables may influence Cladoceran densities in the oxbow lake. We found six measured variables (DO.P, Cu^{2+}, BOD_5, Chl_a, PO_3, and LOI_{550}) which could explain the significant variation in the density of Cladoceran assemblages among the three sites of the oxbow lake. These four

measured variables (DO.P, Cu^{2+}, BOD$_5$, and Chl_a) are strongly associated with fishing site-1 and natural site. Phosphorus and Chl_a were also important measured variables in explaining the distribution of contemporary Cladoceran assemblages in the other published studies [48,53,59]. These studies suggest that nutrient enrichment affects the habitat conditions of Cladocera, including food quantity and quality, predation pressure, and macroinvertebrates. Tavşanoğlu et al. [59] highlighted that increasing phosphorous content may be related to enhanced fish predation in large-sized Cladocerans. We observed decreases in Cladoceran species richness from fishing site-1 to fishing site-2 with increased phosphorous from fishing site-2 to fishing site-1. However, Jeppesen et al. [58] recorded the opposite trend: species richness decrease with an increase in phosphorous. Our contemporary datasets of fishing site-1 had a high correlation with Cu^{2+}, especially *C. sphaericus*. Sadeq et al. [60] reported Cu^{2+} influences the survival, density, size, and growth rate of Cladocera species.

Both the contemporary and subfossil Cladocera assemblages in the oxbow lake are characterized by a high degree of similarity in all three areas, with 43% and 51.5% of the species stock in common. However, the contemporary Cladocera assemblage is characterized by greater diversity and greater beta diversity, with 56.8% providing diversity to the contemporary Cladocera assemblage. The highest beta diversity (the lowest similarity) was obtained in the N.S. Approximately 30% of the species stock are characteristic of only one habitat, while in the fishing sites, the proportion of species occurring only in the given place is 15%–20%. The oxbow lake subfossil assemblage shows greater similarity to the contemporary assemblage, so its beta diversity is lower (48.5%). The species structure of the three areas shows a very similar picture. The beta diversity was the highest at FS-1 (47.2%), while the other two were lower and lower (46.4% and 45.5%). In the fishing site-1 area, 20% of the species were found only in one location, while the Cladocera assemblage in the natural-site was the most diverse, with 30% of the species were responsible for the variety obtained.

In summary, the Cladocera assemblage of the Nagy–Morotva oxbow lake does not form a meta-community due to significant similarities between different habitats. However, habitat diversity during near-natural management of the middle oxbow lake section results in a more diverse Cladocera assemblage. This habitat diversity is reflected in the high rate of species exchange in subfossil species. Berta et al. [3] found that in the case of long oxbow lakes, the beta-diversity of the contemporary and subfossil Cladocera assemblages was driven by similarities between the sampled sites. Vad et al. [61] and Tóth et al. [62] found in the case of separate ponds that the beta-diversity of the ponds was driven by species replacement. It means that if the investigated assemblages were found in the same lake, the dispersion capabilities of Cladoceran species would indicate a higher species replacement.

We observed higher diversity, species density, and low density in the sediment than in water samples. In this sense, present Cladocera information can be obtained from the filtered sample, while the subfossil contains Cladocera assemblage providing data for more than one year [63]. Also, because of this previously mentioned phenomenon, Cladocera species have been commonly used as a bio-indicator of eutrophic conditions researches [64]. The higher diversity of subfossil assemblage indicates that an integrated sediment sample from three different sites may supply enough information for assessing Cladoceran assemblage composition and environmental conditions.

5. Conclusions

In the research, we showed differences in Cladoceran assemblages from the water and the surface sediment of three different oxbow lake sites, also comparing the use of different sampling methods (i.e., filtered water samples and sediments). The subfossil Cladocera assemblage presented a high number of species, and density differed from contemporary assemblages in the three sites (fishing site-1, natural site, and fishing site-2). It showed that the fishing sites of oxbow lake could increase the density of some species. Also, our research showed that analysis of contemporary Cladocera only proved informative about

species diversity and density at the sampling time. However, the subfossil Cladocera community can provide information about the Cladocera for over a year and determine changes in environmental variables (fish, large plants, and environmental conditions). Research pointed out that comparing subfossil and contemporary Cladocera assemblages is particularly useful in characterizing water body conditions.

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References

1. Meerhoff, M.; Mazzeo, N.; Moss, B.; Rodríguez-Gallego, L. The Structuring Role of Free-Floating versus Submerged Plants in a Subtropical Shallow Lake. *Aquat. Ecol.* **2003**, *37*, 377–391. [CrossRef]
2. Kuczyńska-Kippen, N.M.; Nagengast, B. The Influence of the Spatial Structure of Hydromacrophytes and Differentiating Habitat on the Structure of Rotifer and Cladoceran Communities. *Hydrobiologia* **2006**, *559*, 203–212. [CrossRef]
3. Berta, C.; Tóthmérész, B.; Wojewódka, M.; Augustyniuk, O.; Korponai, J.; Bertalan-Balázs, B.; Nagy, A.S.; Grigorszky, I.; Gyulai, I. Community Response of Cladocera to Trophic Stress by Biomanipulation in a Shallow Oxbow Lake. *Water* **2019**, *11*, 929. [CrossRef]
4. Wetzel, R.G. Clean Water: A Fading Resource. In *The Dynamics and Use of Lacustrine Ecosystems*; Ilmavirta, V., Jones, R.I., Eds.; Springer: Dordrecht, The Netherlands, 1992; pp. 21–30. ISBN 978-94-010-5218-4.
5. Carpenter, S.R.; Ludwig, D.; Brock, W.A. Management of eutrophication for lakes subject to potentially irreversible change. *Ecol. Appl.* **1999**, *9*, 751–771. [CrossRef]
6. Heisler, J.; Glibert, P.M.; Burkholder, J.M.; Anderson, D.M.; Cochlan, W.; Dennison, W.C.; Dortch, Q.; Gobler, C.J.; Heil, C.A.; Humphries, E.; et al. Eutrophication and Harmful Algal Blooms: A Scientific Consensus. *Harmful Algae* **2008**, *8*, 3–13. [CrossRef] [PubMed]
7. Havens, K.E. Secondary Nitrogen Limitation in a Subtropical Lake Impacted by Non-Point Source Agricultural Pollution. *Environ. Pollut.* **1995**, *89*, 241–246. [CrossRef]
8. Kurek, J.; Korosi, J.B.; Jeziorski, A.; Smol, J.P. Establishing Reliable Minimum Count Sizes for Cladoceran Subfossils Sampled from Lake Sediments. *J. Paleolimnol.* **2010**, *44*, 603–612. [CrossRef]
9. Krztoń, W.; Pudaś, K.; Pociecha, A.; Strzesak, M.; Kosiba, J.; Walusiak, E.; Szarek-Gwiazda, E.; Wilk-Woźniak, E. Microcystins Affect Zooplankton Biodiversity in Oxbow Lakes: Microcystins Affect Zooplankton. *Environ. Toxicol. Chem.* **2017**, *36*, 165–174. [CrossRef]
10. Krztoń, W.; Kosiba, J.; Pociecha, A.; Wilk-Woźniak, E. The Effect of Cyanobacterial Blooms on Bio- and Functional Diversity of Zooplankton Communities. *Biodivers. Conserv.* **2019**, *28*, 1815–1835. [CrossRef]
11. de Bernardi, R.; Giussani, G.; Manca, M. Cladocera: Predators and Prey. *Hydrobiologia* **1987**, *145*, 225–243. [CrossRef]
12. Abrantes, N.; Antunes, S.C.; Pereira, M.J.; Gonçalves, F. Seasonal Succession of Cladocerans and Phytoplankton and Their Interactions in a Shallow Eutrophic Lake (Lake Vela, Portugal). *Acta Oecologica* **2006**, *29*, 54–64. [CrossRef]

13. Dodson, S.L.; Cáceres, C.E.; Rogers, D.C. Cladocera and Other Branchiopoda. In *Ecology and Classification of North American Freshwater Invertebrates*; Elsevier: Amsterdam, The Netherlands, 2010; pp. 773–827. ISBN 978-0-12-374855-3.

14. Krause, A.E.; Frank, K.A.; Mason, D.M.; Ulanowicz, R.E.; Taylor, W.W. Compartments Revealed in Food-Web Structure. *Nature* **2003**, *426*, 282–285. [CrossRef] [PubMed]

15. Shurin, J.B.; Clasen, J.L.; Greig, H.S.; Kratina, P.; Thompson, P.L. Warming Shifts Top-down and Bottom-up Control of Pond Food Web Structure and Function. *Phil. Trans. R. Soc. B* **2012**, *367*, 3008–3017. [CrossRef] [PubMed]

16. Hrbáčke, J.; Dvořakova, M.; Kořínek, V.; Procházkóva, L. Demonstration of the effect of the fish stock on the species composition of zooplankton and the intensity of metabolism of the whole plankton association: With 22 figures on 2 folders. *SIL Proc. 1922–2010* **1961**, *14*, 192–195. [CrossRef]

17. Brooks, J.L.; Dodson, S.I. Predation, Body Size, and Composition of Plankton: The Effect of a Marine Planktivore on Lake Plankton Illustrates Theory of Size, Competition, and Predation. *Science* **1965**, *150*, 28–35. [CrossRef]

18. Confer, J.L.; Applegate, G. Size-Selective Predation by Zooplankton. *Am. Midl. Nat.* **1979**, *102*, 378. [CrossRef]

19. Hall, D.J.; Zaret, T.M. Predation and Freshwater Communities. Yale Univ. Press, New Haven, Connecticut. 187 p. *Limnol. Oceanogr.* **1982**, *27*, 391–393. [CrossRef]

20. Pociecha, A.; Bielańska-Grajner, I.; Kuciel, H.; Wojtal, A.Z. Is Zooplankton an Indicator of the Water Trophic Level in Dam Reservoirs? *Oceanol. Hydrobiol. Stud.* **2018**, *47*, 288–295. [CrossRef]

21. Liu, B.; Wu, J.; Hu, Y.; Wang, G.; Chen, Y. Seven Years Study of the Seasonal Dynamics of Zooplankton Communities in a Large Subtropical Floodplain Ecosystem: A Test of the PEG Model. *IJERPH* **2022**, *19*, 956. [CrossRef]

22. Lauridsen, T.; Pedersen, L.J.; Jeppesen, E.; Sønergaard, M. The Importance of Macrophyte Bed Size for Cladoceran Composition and Horizontal Migration in a Shallow Lake. *J. Plankton Res.* **1996**, *18*, 2283–2294. [CrossRef]

23. Wilk-Woźniak, E.; Walusiak, E.; Burchardt, L.; Cerbin, S.; Chmura, D.; Gąbka, M.; Glińska-Lewczuk, K.; Gołdyn, R.; Grabowska, M.; Karpowicz, M.; et al. Effects of the Environs of Waterbodies on Aquatic Plants in Oxbow Lakes (Habitat 3150). *Ecol. Indic.* **2019**, *98*, 736–742. [CrossRef]

24. Barker, T.; Irfanullah, H.M.; Moss, B. Micro-Scale Structure in the Chemistry and Biology of a Shallow Lake: Micro-Scale Patchiness. *Freshw. Biol.* **2010**, *55*, 1145–1163. [CrossRef]

25. Grigorszky, I.; Nagy, S.; Krienitz, L.; Kiss, K.T.; Hamvas, M.M.; Tóth, A.; Borics, G.; Máthé, C.; Kiss, B.; Borbély, G.; et al. Seasonal Succession of Phytoplankton in a Small Oligotrophic Oxbow and Some Consideration to the PEG Model. *SIL Proc. 1922–2010* **2000**, *27*, 152–156. [CrossRef]

26. Korhola, A.; Rautio, M. Cladocera and Other Branchiopod Crustaceans. In *Tracking Environmental Change Using Lake Sediments*; Smol, J.P., Birks, H.J.B., Last, W.M., Eds.; Developments in Paleoenvironmental Research; Springer: Dordrecht, The Netherlands, 2001; Volume 4, pp. 5–41. ISBN 978-90-481-6034-1.

27. Frey, D.G. Cladocera Analysis. In *Handbook of Holocene Palaeoecology and Palaeohydrology*; Wiley: Chuchester, UK, 1986; pp. 667–692. ISBN 0-471-90691-3.

28. Korhola, A.; Olander, H.; Blom, T. Cladoceran and Chironomid Assemblages as Qualitive Indicators of Water Depth in Subarctic Fennoscandian Lakes. *J. Paleolimnol.* **2000**, *24*, 43–54. [CrossRef]

29. Kienast, F.; Wetterich, S.; Kuzmina, S.; Schirrmeister, L.; Andreev, A.A.; Tarasov, P.; Nazarova, L.; Kossler, A.; Frolova, L.; Kunitsky, V.V. Paleontological Records Indicate the Occurrence of Open Woodlands in a Dry Inland Climate at the Present-Day Arctic Coast in Western Beringia during the Last Interglacial. *Quat. Sci. Rev.* **2011**, *30*, 2134–2159. [CrossRef]

30. Davidson, T.A.; Sayer, C.D.; Perrow, M.R.; Bramm, M.; Jeppesen, E. Are the Controls of Species Composition Similar for Contemporary and Sub-Fossil Cladoceran Assemblages? A Study of 39 Shallow Lakes of Contrasting Trophic Status. *J. Paleolimnol.* **2007**, *38*, 117–134. [CrossRef]

31. Liordos, V.; Kontsiotis, V.J. Identifying Important Habitats for Waterbird Conservation at a Greek Regional Nature Park. *Avian. Res.* **2020**, *11*, 39. [CrossRef]

32. Babcsányi, I.; Tamás, M.; Szatmári, J.; Hambek-Oláh, B.; Farsang, A. Assessing the Impacts of the Main River and Anthropogenic Use on the Degree of Metal Contamination of Oxbow Lake Sediments (Tisza River Valley, Hungary). *J. Soils Sediments* **2020**, *20*, 1662–1675. [CrossRef]

33. Dévai, G.; Miskolci, M.; Jakab, T. Habitat Diversity of the Nagy-Morotva Based on Dragonfly Fauna. In Proceedings of the Presented at the Hungarian Hydrological Society, XXXIV. National Wandering Assembly, Section 8: Protection of Wetlands, Debrecen, Hungary, 6–8 July 2016.

34. Schindler, D.W. Two Useful Devices for Vertical Plankton and Water Sampling. *J. Fish. Res. Board Can.* **1969**, *26*, 1948–1955. [CrossRef]

35. Glew, J.R. Miniature Gravity Corer for Recovering Short Sediment Cores. *J. Paleolimnol.* **1991**, *5*, 285–287. [CrossRef]

36. Német, J. *Methods of Biological Water Qualification*; Institute of Environmental Management, Environmental Protection Information Service: Budapest, Hungary, 1998.

37. Dean, W.E., Jr. Determination of Carbonate and Organic Matter in Calcareous Sediments and Sedimentary Rocks by Loss on Ignition: Comparison with Other Methods. *SEPM JSR* **1974**, *44*, 242–248. [CrossRef]

38. Frey, D.G. The Taxonomy and Biogeography of the Cladocera. *Hydrobiologia* **1987**, *145*, 5–17. [CrossRef]

39. Gulyás, P.; Forró, L. *Az Ágascsápú Rákok (Cladocera) Kishatározója*; Környezetgazdálkodási Intézet: Budapest, Hungary, 1999; ISBN 978-963-602-743-8.

40. Szeroczyńska, K.; Sarmaja-Korjonen, K. *Atlas of Subfossil Cladocera from Central and Northern Europe*; Friends of the Lower Vistula Society: Świecie, Poland, 2007; ISBN 978-83-924919-6-5.

41. Błedzki, L.A.; Rybak, J.I. *Freshwater Crustacean Zooplankton of Europe: Cladocera & Copepoda (Calanoida, Cyclopoida) Key to Species Identification, with Notes on Ecology, Distribution, Methods and Introduction to Data Analysis*, 1st ed.; Springer International Publishing: Cham, Switzerland, 2016; ISBN 978-3-319-29871-9.

42. Hammer, Ø.; Harper, A.T.D.; Ryan, D.P. PAST: Paleontological Statistic Software Package for Education and Data Analysis. *Palaeontol. Electron.* **2001**, *4*, 9.

43. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2018.

44. Oksanen, J.; Blanchet, M.; Friendly, R.; Legendre, P.; McGlinn, D.; Minchín, P.R.; O'Hara, R.B.; Simpson, G.L.; Solymos, P.; Stevens, M.H.H.; et al. *Community Ecology Package: "Vegan" Package*; R Development Core Team: Vienna, Austria, 2017.

45. Rodriguez-Martinez, A.; Posma, J.M.; Ayala, R.; Neves, A.L.; Anwar, M.; Petretto, E.; Emanueli, C.; Gauguier, D.; Nicholson, J.K.; Dumas, M.-E. MWASTools: An R/Bioconductor Package for Metabolome-Wide Association Studies. *Bioinformatics* **2018**, *34*, 890–892. [CrossRef] [PubMed]

46. Frey, D.G. The Ecological Significance of Cladoceran Remains in Lake Sediments. *Ecology* **1960**, *41*, 684–699. [CrossRef]

47. Amoros, C.; Jacquet, C. The Dead-Arm Evolution of River Systems: A Comparison between the Information Provided by Living Copepoda and Cladocera Populations and by Bosminidae and Chydroidae Remains. *Hydrobiologia* **1987**, *145*, 333–341. [CrossRef]

48. Brodersen, K.P.; Whiteside, M.C.; Lindegaard, C. Reconstruction of Trophic State in Danish Lakes Using Subfossil Chydorid (Cladocera) Assemblages. *Can. J. Fish. Aquat. Sci.* **1998**, *55*, 1093–1103. [CrossRef]

49. Korponai, J.; Braun, M.; Forró, L.; Gyulai, I.; Kövér, C.; Nédli, J.; Urák, I.; Buczkó, K. Taxonomic, Functional and Phylogenetic Diversity: How Subfossil Cladocerans Mirror Contemporary Community for Ecosystem Functioning: A Comparative Study in Two Oxbows. *Limnetica* **2019**, *38*, 431–456. [CrossRef]

50. Sayer, C.D.; Burgess, A.; Kari, K.; Davidson, T.A.; Peglar, S.; Yang, H.; Rose, N. Long-Term Dynamics of Submerged Macrophytes and Algae in a Small and Shallow, Eutrophic Lake: Implications for the Stability of Macrophyte-Dominance. *Freshw. Biol.* **2010**, *55*, 565–583. [CrossRef]

51. Jeppesen, E.; Jensen, J.P.; Søndergaard, M.; Lauridsen, T.; Pedersen, L.J.; Jensen, L. Top-down Control in Freshwater Lakes: The Role of Nutrient State, Submerged Macrophytes and Water Depth. *Hydrobiologia* **1997**, *342*, 151–164. [CrossRef]

52. Gannon, J.E.; Stemberger, R.S. Zooplankton (Especially Crustaceans and Rotifers) as Indicators of Water Quality. *Trans. Am. Microsc. Soc.* **1978**, *97*, 16. [CrossRef]

53. Kattel, G.R.; Battarbee, R.W.; Mackay, A.; Birks, H.J.B. Are Cladoceran Fossils in Lake Sediment Samples a Biased Reflection of the Communities from Which They Are Derived? *J. Paleolimnol.* **2007**, *38*, 157–181. [CrossRef]

54. Davidson, T.A.; Sayer, C.D.; Perrow, M.; Bramm, M.; Jeppesen, E. The Simultaneous Inference of Zooplanktivorous Fish and Macrophyte Density from Sub-Fossil Cladoceran Assemblages: A Multivariate Regression Tree Approach. *Freshw. Biol.* **2010**, *55*, 546–564. [CrossRef]

55. Scheffer, M. Alternative Attractors of Shallow Lakes. *Sci. World, J.* **2001**, *1*, 254–263. [CrossRef] [PubMed]

56. Nevalainen, L. Evaluation of Microcrustacean (Cladocera, Chydoridae) Biodiversity Based on Sweep Net and Surface Sediment Samples. *Écoscience* **2010**, *17*, 356–364. [CrossRef]

57. Çakıroğlu, A.İ.; Tavşanoğlu, Ü.N.; Levi, E.E.; Davidson, T.A.; Bucak, T.; Özen, A.; Akyıldız, G.K.; Jeppesen, E.; Beklioğlu, M. Relatedness between Contemporary and Subfossil Cladoceran Assemblages in Turkish Lakes. *J. Paleolimnol.* **2014**, *52*, 367–383. [CrossRef]

58. Jeppesen, E.; Peder Jensen, J.; SØndergaard, M.; Lauridsen, T.; Landkildehus, F. Trophic Structure, Species Richness and Biodiversity in Danish Lakes: Changes along a Phosphorus Gradient: A Detailed Study of Danish Lakes along a Phosphorus Gradient. *Freshw. Biol.* **2000**, *45*, 201–218. [CrossRef]

59. Tavşanoğlu, Ü.N.; Šorf, M.; Stefanidis, K.; Brucet, S.; Türkan, S.; Agasild, H.; Baho, D.L.; Scharfenberger, U.; Hejzlar, J.; Papastergiadou, E.; et al. Effects of Nutrient and Water Level Changes on the Composition and Size Structure of Zooplankton Communities in Shallow Lakes under Different Climatic Conditions: A Pan-European Mesocosm Experiment. *Aquat. Ecol.* **2017**, *51*, 257–273. [CrossRef]

60. Sadeq, S.A.; Beckerman, A.P. The Chronic Effects of Copper and Cadmium on Life History Traits Across Cladocera Species: A Meta-Analysis. *Arch. Environ. Contam. Toxicol.* **2019**, *76*, 1–16. [CrossRef]

61. Vad, C.F.; Horváth, Z.; Kiss, K.T.; Ács, É. Microcrustacean (Cladocera, Copepoda) Communities in Artificial Lakes in the Region of the North Hungarian Mountains, with Special Reference to the Advantive Species. *Acta. Zool. Hung.* **2012**, *58*, 47–61.

62. Tóth, A.; Horváth, Z.; Vad, C.F.; Zsuga, K.; Nagy, S.A.; Boros, E. Zooplankton of the European Soda Pans: Fauna and Conservation of a Unique Habitat Type: Zooplankton of Soda Pans. *Int. Rev. Hydrobiol.* **2014**, *99*, 255–276. [CrossRef]

63. Davidson, T.A.; Reid, M.A.; Sayer, C.D.; Chilcott, S. Palaeolimnological Records of Shallow Lake Biodiversity Change: Exploring the Merits of Single versus Multi-Proxy Approaches. *J. Paleolimnol.* **2013**, *49*, 431–446. [CrossRef]

64. Christoffersen, K.; Riemann, B.; Klysner, A.; Søndergaard, M. Potential Role of Fish Predation and Natural Populations of Zooplankton in Structuring a Plankton Community in Eutrophic Lake Water. *Limnol. Oceanogr.* **1993**, *38*, 561–573. [CrossRef]