DYNAMICS OF ZOOPLANKTON COMMUNITY DEVELOPMENT IN THE DUBĂSARI RESERVOIR

LEBEDENCO Liubovi

Abstract. This paper presents the results of a study conducted between 2020 and 2024 on the development and dynamics of zooplankton communities in the Dubăsari reservoir (Dniester river, Republic of Moldova), in the context of hydrological changes and anthropogenic impact. Seasonal sampling was carried out in the upper, middle, and lower sectors of the reservoir, analyzing the density and biomass of the main taxonomic groups (Rotatoria, Copepoda, Cladocera). An increase in zooplankton density and biomass was observed over the analysed period, with maximum values recorded in 2024, associated with intensified eutrophication. The middle sector stood out as the most productive, while seasonal patterns revealed development peaks in summer, with rotifers dominating numerically and crustaceans contributing mostly to the biomass. The results of the study reflect the influence of local physico-chemical factors and anthropogenic pressure on the structure and functioning of the Dubăsari reservoir ecosystem, highlighting the need for sustainable ecological management of water resources.

Keywords: aquatic ecosystems**,** zooplankton communities, Dubăsari reservoir, density.

Rezumat. Dinamica dezvoltării comunității de zooplankton în lacul de acumulare Dubăsari. Lucrarea prezintă rezultatele studiilor effectuate din perioada anilor 2020-2024, privind dezvoltarea și dinamica comunităților zooplanctonice din lacul de acumulare Dubăsari (fluviul Nistru, Republica Moldova), în contextual schimbărilor hidrologice și impactului antropic. Eșantionările au fost efectuate sezonier în sectorul superior, mijlociu și inferior ale lacului, fiind analizate densitatea și biomasa principalelor grupuri taxonomice (Rotatoria, Copepoda, Cladocera). S-a observat o creștere a densității și biomasei zooplanctonului în perioada analizată, cu valori maxime înregistrate în anul 2024, asociate cu intensificarea eutrofizării. Sectorul mijlociu s-a remarcat ca fiind cel mai productiv, în timp ce structura sezonieră a evidențiat vârfuri de dezvoltare vara, când numeric predomină rotiferele , iar crustaceele contribuie în special la formarea biomasei. Rezultatele reflectă influența factorilor fizico-chimici locali și a presiunii antropice asupra structurii și funcționării ecosistemului lacului de acumulare Dubăsari, subliniind necesitatea unui management ecologic sustenabil al resurselor de apă.

Cuvinte cheie: ecosistem acvatic, comunitățile zooplanctonice, lacul de acumulare Dubăsari, efectivul.

INTRODUCTION

In the lower part of the middle sector of Dniester River, on the territory of the Republic of Moldova, in 1954 the Dubăsari reservoir was built (Fig. 1), which stretches from the town of Camenca to the town of Dubăsari. The width of the lake varies between 200 and 1800 m, with an average width of approximately 528 m. The surface area of the lake is 6570 ha, the average depth reaches 7.19 m and the total volume of water is 485.5 thousand m^3.

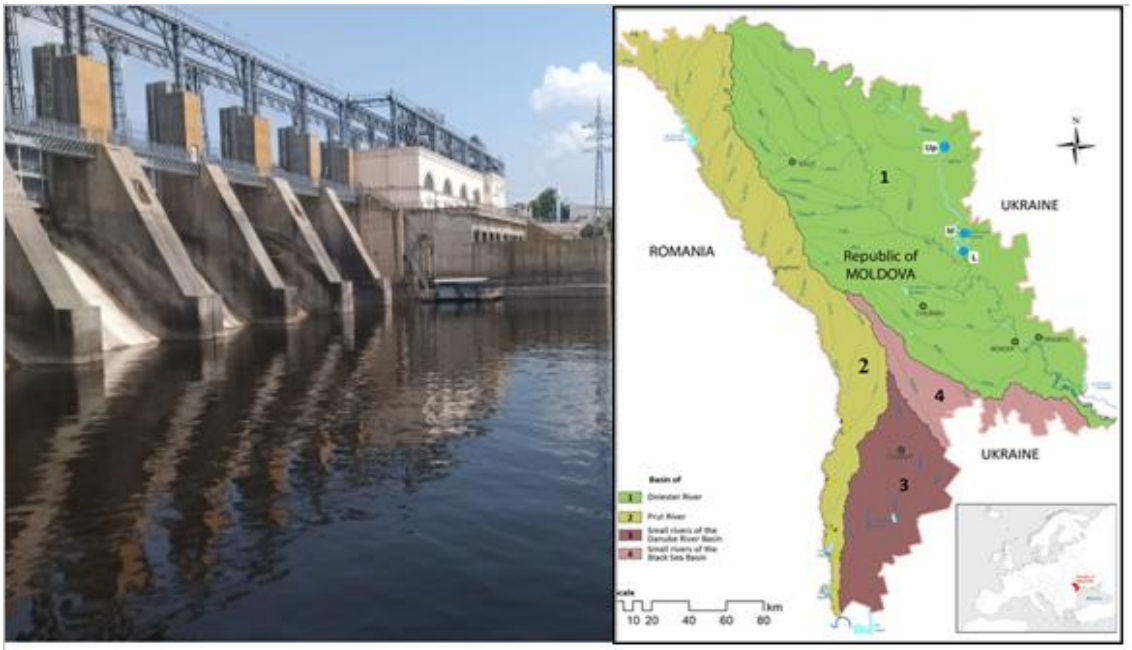

Figure 1. Dubăsari reservoir - location of sampling stations: Up - upper, M - middle, L – lower (original).

The assessment of the current status of the aquatic ecosystems, species diversity and the evolution of water quality is a major issue in the context of the protection and sustainable management of water resources, the anthropogenic impact and, in particular, the exploitation of the cascade of reservoirs built in the last two decades on the Dniester river which have caused significant changes in the hydrological and hydrochemical regime, an increase in the degree of eutrophication, as well as the level of organic pollution, considerably influencing the status of biodiversity and the quantitative structure of the main aquatic communities (CLIMENCO, 2005; ZUBCOV et al., 2021). Zooplankton community plays an essential role in functioning of aquatic ecosystems, forming an intermediate link between phytoplankton and higher-order organisms, such as fish and invertebrates in the trophic network. Zooplankton, through its increased sensitivity, nutrition via filtration, and short life cycle, reacts quickly to changes in environmental conditions. In recent years, fluctuations in the hydrological regime have been also reflected on the dynamics of zooplankton communities by restructuring the species composition and varying the quantitative parameters of its development in aquatic ecosystems, including in the Dubăsari reservoir (LEBEDENCO, 2020).

The construction of the Dubăsari reservoir had as its main purpose the regulation of flood flows, the production of electricity, the supply of drinking water, the provision of water for industrial needs and the irrigation of agricultural lands. In regard to its morphology, the reservoir is divided into three main sectors: upper, middle and lower. The impact of hydropower constructions was manifested by significant changes in the hydrological regime of the middle and lower sectors of the Dniester. Some risks also exist of irreversible changes in the hydrographic basin of this portion of the river. It should be noted that the flow rate and speed of water flow in the Dniester River are closely dependent on the operation of hydroelectric power plants. Currently, in the middle and lower sectors of the Dniester, alluvium and mountain suspensions are almost completely absent, and approximately 80% of the riverbed is covered with higher aquatic vegetation, which favors the development of limnephilic organisms (ZUBCOV et al., 2021).

The purpose of this work was to analyze the dynamics of zooplankton development in the Dubăsari reservoir, in a multiannual, spatial and seasonal context, by evaluating the density and biomass variations of the main zooplankton groups, as well as identifying the factors that influence these variations and the impact on the structure of the zooplankton community.

MATERIALS AND METHODS

This paper presents the results of investigations of zooplankton communities in the Dubăsari reservoir, located in the Republic of Moldova. Zooplankton samples were collected from Dubăsari reservoir during the years 2020 - 2024, as part of the research of the Laboratory of Hydrobiology and Ecotoxicology of the Institute of Zoology in a series of complex expeditions carried out in all seasons across the sectors of the Dubăsari reservoir ecosystem: upper, middle, and lower. Sample collection was carried out in accordance to unified methods for hydrobiological sample collection and processing (JURMINSKAIA et al., 2015; DEREVENSKAIA, 2015; LEBEDENCO et al., 2021). Zooplankton samples were collected using the Apstein net (№ 55) by filtering a quantity of 100 liters of water. The collected material was immediately fixed in the field with Lugol's solution. The quantitative counting of zooplankton was carried out using Bogorov counting chamber and a Discovery V8 ZEISS stereo zoom binocular microscope, with three replicates per sample. The density (N – ind/m^3) of the organisms was calculated per cubic meter. Identification of the main zooplankton groups (Rotatoria, Copepoda, Cladocera) was carried out up to the lowest possible taxonomic level, with the use of the microscope Axio Imager A.2 (Zeiss). The identification of the taxonomic structure of the zooplankton groups was carried out with the use of identification guides (KUTIKOVA, 1970; DUMONT & NEGREA, 2002; NABEREJNII, 1984; FORRO et al., 2008; ALEXEEV & TALOLICHIN, 2010).

REZULTS AND DISCUSSION

Previous studies have shown that the damming of the Dniester River and the creation of the Dubăsari reservoir have caused a considerable restructuring of zooplankton communities, both qualitatively and quantitatively. This change was mainly caused by modifications in the hydrological regime of the ecosystem, as a result of the influence of anthropogenic factors (CLIMENCO & NABEREJNÂI, 2006; LEBEDENCO, 2020).

The zooplankton community of Dubăsari reservoir is composed of three main taxonomic groups: Rotatoria, Copepoda and Cladocera. The diversity of zooplankton communities shows a tendency of increasing from the upper sector of the lake to the area near the dam, with a maximum diversity observed in the middle sector. Research results (LEBEDENCO, 2024) revealed that the maximum diversity of zooplankton in the middle sector of the Dubăsari reservoir during 2008-2024 was represented by 143 species, which accounted for approximately 72% of the total species diversity (199). During the different stages of research, the zooplankton was mostly dominated by rotifers, which constituted over 60% of the total identified species. At the same time, a clear trend of decreasing was observed in rotifers from the upper to the lower sector of the lake, while, at the same time, there was an increasing contribution of lower crustaceans, especially cladocerans. This variability in species composition reflects different ecological conditions between the sectors of the lake associated with local physico-chemical factors, the structure of the trophic web, as well as with the complex interactions between the different groups of zooplankton organisms.

The multiannual analysis of zooplankton structure, highlighting the contribution of the main zooplankton groups in the formation of density and biomass is presented in Fig. 2. This analysis demonstrates the dynamics and variability of these groups of organisms in relation to the annual and seasonal evolution of density and biomass, providing essential information on the interaction between these groups in the Dubăsari reservoir ecosystem. Regarding the contribution to the formation of zooplankton density, rotifers showed a relative constant predominance throughout the entire period with values ranging between 62% in 2021 and 71% in 2022. Copepods recorded a significant variation in regard to their contribution, from a minimum of 11% in 2022 to a maximum of 35% in 2020. Cladocera had a marginal contribution in 2020, of only 1%, but recorded a significant increase in 2021, reaching 22%. In 2022, its contribution decreased slightly to 18%, and in 2023 it continued to decrease up to 10%. In 2024, the ecological conditions of the Dubăsari reservoir were less favorable for the development of cladocerans, as they showed low density values of only 2%, indicating a considerable reduction in the density of this group.

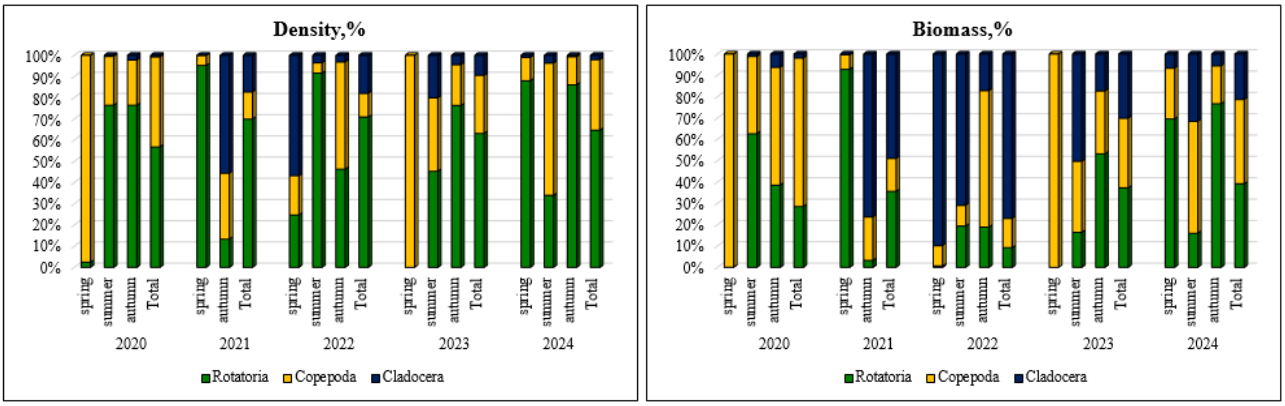

Figure 2. Share (%) of the main groups in the formation of zooplankton density and biomass in the Dubăsari reservoir, during study period 2020-2024.

Over the 5 years of study, various proportions of different zooplankton groups contributed to the formation of zooplankton biomass. Therefore, rotifers had significant fluctuations in biomass formation, with a greater increase in 2023 and 2024, reaching 38% and 39% respectively. An essential role in the formation of zooplankton biomass especially in the lentic ecosystems such as the Dubăsari reservoir was played by lower crustaceans (copepods and cladocerans) owing to their size. Copepods recorded a maximum contribution in 2020, accounting for 65%. In 2021 and 2022, the contribution of copepods decreased, reaching 17% and 14% respectively due to competition with the cladoceran group, and in 2023 and 2024 their contribution increased again to 32% and 40% respectively.

The contribution of cladocerans to biomass formation was reduced in 2020, registering only 3%. In 2021, on the opposite, a sharp increase was observed, their contribution reaching 55%, and in 2022 a peak of 77% was reached, indicating a dominance of this group in the formation of zooplankton biomass. In 2023 and 2024, the contribution of cladocerans constituted 30% and 21%, respectively.

During 2020-2024, the quantitative parameters of zooplankton in the Dubăsari reservoir ecosystem showed significant variations in spatial and multiannual dynamics (Table 1). The analysis of the multiannual evolution of the development of zooplankton communities highlighted the highest values of density and biomass in 2024, in all sectors of the lake, with a preponderance in the middle sector (density - 313.4 thousand ind./m^3 and biomass - 1182.72 mg/m^3) and the lower sector (density - 298.2 thousand ind./m^3 and biomass - 1404.78 mg/m^3). This trend could be explained by the intensified eutrophication processes and a complex ecological response of zooplankton community to environmental changes, including climate change and anthropogenic pressure. According to the literature, the increase in zooplankton density and biomass represents a relevant ecological indicator of structural changes at the trophic level and the degree of primary productivity (LAMPERT & SOMMER, 2007).

The upper sector recorded the lowest density values over the entire study period, with a minimum in 2020 (3.08 thousand ind./m^3) and a significant increase in 2024 (70.5 thousand ind./m^3). Zooplankton biomass in this sector followed a generally ascendent trend, starting from a very low value in 2020 (19.95 mg/m^3), increasing considerably in 2021 (148.78 mg/m^3), and reaching a peak in 2024 (161.63 mg/m^3). This evolution is explained by the fact that not only a numerical increase of zooplankton occurred, but also the number of large zooplankton species, such as copepods and cladocerans increased.

The middle sector was highlighted as the most productive in terms of zooplankton density, recording the highest values in 2024 (313.4 thousand ind./m^3) and 2022 (195.7 thousand ind./m^3). This high productivity is influenced by the presence of Goieni Bay, characterized by stagnant waters, rich biological diversity and high abundance of hydrobiont communities, as well as by the proximity of the Iagorlyc nature reserve, which offers stable and favorable ecological conditions for the development of zooplankton. In this sector of the reservoir, the highest values of zooplankton density were recorded, which suggests an optimal balance between the availability of trophic resources (phytoplankton) and favorable physico-chemical conditions to the development of zooplankton. These results are consistent with the previous

studies (CLIMENCO & NABEREJNÂI, 2006), which argue that the middle areas of accumulation reservoirs ecosystems tend to support the most stable planktonic communities.

At the level of the entire ecosystem of the Dubasari reservoir, the zooplankton density showed a generally increasing trend during the period 2020-2024, with values varying from 55.8 thousand ind/m^3 in 2020 to 227.4 thousand ind./m^3. This dynamics highlights an overall increase in the zooplankton productivity of the Dubăsari reservoir ecosystem.

Table 1. Multiannual dynamics of the density and biomass of the zooplankton communities of the Dubăsari reservoir (2020-2024).

sector	**upper**		**middle**		**lower**		**Average on lake**	
year	N, ind./m^3	B, mg/m^3	N, ind./m^3	B, mg/m^3	N, ind./m^3	B, mg/m^3	N, ind./m^3	B, mg/m^3
2020	3075	19.95	112100	407.46	52335	458.73	55837	295.38
2021	39181	148.78	19125	130.69	22333	343.68	26880	207.72
2022	7493	111.70	195710	278.65	103497	1335.64	102233	575.33
2023	7068	58.70	102600	462.25	14660	156.34	41442	225.76
2024	70503	161.63	313440	1182.72	298184	1404.78	227376	916.38

The zooplankton biomass in the middle sector ranged between 130.69 mg/m^3 in 2021 and 1182.72 mg/m^3 in 2024. The maximum value reached in 2024, reflected a high level of productivity can be associated with an intense development of zooplankton species, especially of the large forms, such as cladocerans (351.05 mg/m^3) and copepods (162.80 mg/m^3). At the same time, rotifers also recorded a significant value of 668.88 mg/m^3 during 2024, contributing substantially to the biomass. This composition highlights the existence of a well-developed trophic base in the middle sector of the lake in 2024.

There was a significant increase in zooplankton density in the lower sector during 2024, reaching a value of 298.2 thousand ind./m^3, which was almost three times higher than in 2022 (103.5 thousand ind./m^3). This increase can be associated with the stagnant nature of the waters in this sector, as well as with the intensification of trophicity.

The zooplankton biomass in the lower sector recorded the highest values in the entire research period and in all sectors of the lake, reaching an absolute maximum in 2024 - 1404.78 mg/m^3. Even in the previous years, the biomass remained at high levels: with 458.73 mg/m^3 in 2020, 343.68 mg/m^3 in 2021, 1335.64 mg/m^3 in 2022, and 156.34 mg/m^3 in 2023. The increased values of zooplankton biomass in this sector are mainly due to the constant presence of copepods and cladocerans, whose biomass values ranged between 22.13 - 877.47 mg/m^3, respectively 3.63-1138.40 mg/m^3.

The seasonal dynamics zooplankton development is reflected in Fig. 3, with the highest values ranging between 3.54-213.6 thousand ind./m^3 for density and 61.04-1293.02 mg/m^3 for biomass of numerical density and biomass were recorded in the summer season. The spring and autumn seasons presented lower values, but it was observed that, in spring, biomass values were higher compared to autumn, especially due to the development of cladocerans. Autumn, on the other hand, is characterized by a larger population, associated with the increase in organic substances and the development of rotifers.

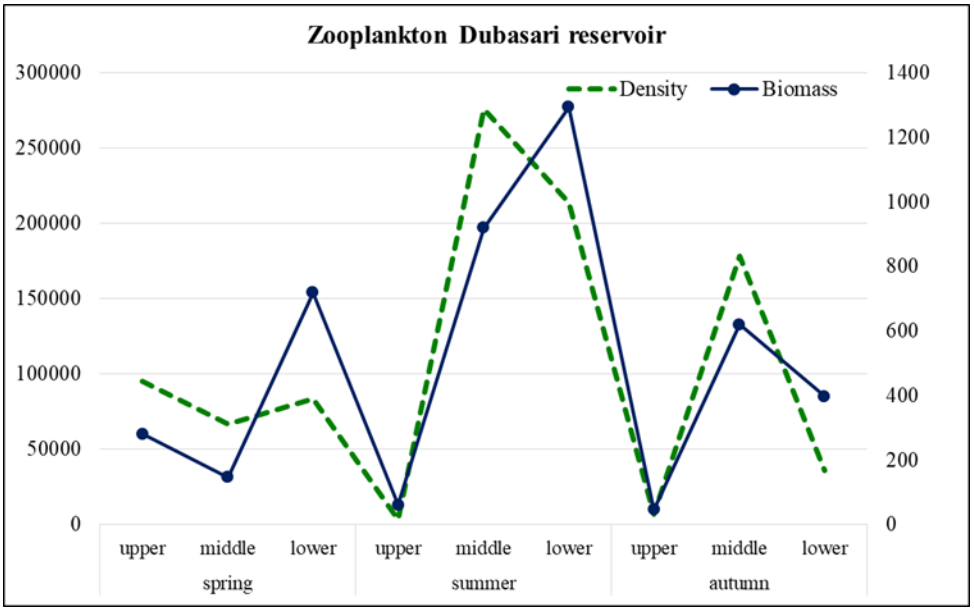

Figure 3. Dynamics of the population (thousands of ind./m^3)
and biomass (mg/m^3) of zooplankton in Dubăsari reservoir, (average 2020-2024).

Zooplankton density showed significant seasonal and spatial variations across the sectors of Dubăsari reservoir (Table 2). In the spring season, the highest vaues of zooplankton density were recorded in the upper sector (95.2 thousand ind./m^3), followed by the lower sector (83.5 thousand ind./m^3), while the middle sector presented a lower value (66.7 thousand ind./m^3). The zooplankton community was dominated by rotifers, which constituted 86% of the total density in the upper sector, 85% in the middle sector and 43% in the lower sector.

In the summer season, zooplankton density increased significantly, reaching maximum values in the middle sector (275.8 thousand ind./m^3) and in the lower sector (213.6 thousand ind./m^3). In contrast, a considerably lower density (3.5 thousand ind./m^3) was observed in the upper sector recorded. The taxonomic structure of the zooplankton community varied depending on the sector: Rotatoria dominated in the middle sector (81% of density), Copepoda was predominant in the lower sector (59%), and Cladocera was the least predominant with values between 4% and 27% of the total density, depending on the sector.

In the autumn season, the zooplankton density showed considerable variations between sectors of the Dubăsari reservoir. The maximum value was recorded in the middle sector (178.2 thousand ind./m^3), followed by the lower sector (35.7 thousand ind./m^3) and the upper sector, with the lowest density (6.6 thousand ind./m^3). Regarding the zooplankton community structure, Rotatoria dominated the middle sector with a share of 90%, while Copepoda - in the lower sector, with a share of 57%.

Table 2. Seasonal dynamics of zooplankton density and biomass in Dubăsari reservoir (2020-2024).

season	taxon	Density, thousand ind./m3						Biomass, mg/m3					
		upper	%	middle	%	lower	%	upper	%	middle	%	lower	%
spring	Rotatoria	81.4	*86*	56.8	*85*	35.9	*43*	174.22	*62*	127.29	*65*	114.17	*10*
	Copepoda	12.5	*13*	8.6	*13*	19.8	*24*	76.99	*27*	31.71	*22*	165.86	*23*
	Cladocera	1.3	*1*	1.3	*2*	27.8	*33*	44.31	*11*	38.24	*13*	807.52	*67*
	Total	**95.2**		**66.7**		**83.5**		**280.75**		**146.30**		**718.87**	
summer	Rotatoria	1.8	*50*	222.4	*81*	77.7	*36*	3.25	*5*	220.50	*24*	217.01	*17*
	Copepoda	0.8	*23*	40.8	*15*	126.3	*59*	9.57	*16*	169.70	*18*	662.01	*51*
	Cladocera	0.9	*27*	12.6	*5*	9.6	*4*	48.22	*79*	528.94	*58*	414.00	*32*
	Total	**3.5**		**275.8**		**213.6**		**61.04**		**919.14**		**1293.02**	
autumn	Rotatoria	1.7	*26*	159.7	*90*	8.0	*22*	1.76	*4*	482.71	*78*	32.10	*8*
	Copepoda	3.1	*47*	16.9	*9*	20.4	*57*	13.70	*30*	88.82	*14*	220.26	*55*
	Cladocera	1.8	*27*	1.6	*1*	7.3	*20*	30.44	*66*	47.88	*8*	181.41	*37*
	Total	**6.6**		**178.2**		**35.7**		**45.90**		**619.42**		**397.48**	

In the summer season, when high temperatures are an essential factor in stimulating the development of zooplankton, biomass values were considerably higher compared to the other seasons. The highest values were recorded in the lower sector (1293.02 mg/m^3), followed by the middle sector (919.14 mg/m^3), while the upper sector presented a much lower value (61.04 mg/m^3). This biomass formation was mainly determined by the massive development of cladocerans and copepods, which accounted for 76% of the biomass in the middle sector and 83% in the lower sector.

In the autumn season, biomass reached maximum values in the middle sector (619.42 mg/m^3), followed by the lower sector (397.48 mg/m^3) and the upper sector (45.90 mg/m^3). The contribution to the formation of autumn biomass in the middle sector belongs to rotifers (78%), in the upper sector - to cladocerans (66%) and in the lower sector - to copepods with 55% share.

CONCLUSIONS

During the period 2020-2024, a general ascendent trend in zooplankton density and biomass was observed in the Dubasari reservoir, with maximum values reached in 2024, which could be explained by an intensification of eutrophication processes and the impact from climate change. The highest values were recorded in the middle and lower sectors. The seasonal dynamics of zooplankton highlights a maximum density and biomass in the summer season, which are the result of high temperatures and an increase in the availability of trophic resources. In spring, the development of cladocerans predominates (by biomass), and in autumn an increase in density of rotifers was observed. The analysis by taxonomic groups highlighted a dominance of rotifers density, however a major importance in the formation of biomass was given by copepods and cladocerans, owing to their large size. These variations reflect local differences in the physicochemical conditions and trophic interactions in the Dubăsari reservoir ecosystem.

The middle sector of the Dubăsari reservoir stands out as the most productive area in terms of both density and biomass of zooplankton, being influenced by factors such as the presence of the Goieni Gulf and the proximity of the Iagorlyc nature reserve, which contribute to the stability and complexity of local food webs.

The damming of the Dniester River and the creation of the Dubăsari reservoir generated significant changes in the structure of zooplankton communities, both qualitatively and quantitatively, which was influenced mainly by changes in the hydrological regime and anthropogenic pressure. The taxonomic structure of zooplankton presented variations in spatial and seasonal distribution, with rotifers dominating in most sectors in regards to the density and an essential contribution of crustaceans (especially cladocerans), owing to the contribution of these groups to the formation of biomass.

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