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Diversity of phytoplankton of the Rivers Ciulucul Mare, Ciulucul de Mijloc, and Ciulucul Mic in the sub-basin of the Răut river

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Abstract. The article presents the results of investigations on the taxonomic composition of phytoplankton in the rivers Ciulucul Mare, Ciulucul de Mijloc and Ciulucul Mic from the River Răut sub-basin. The phytoplankton composition was represented by a total of 80 species and varieties of planktonic algae belonging to 6 taxonomic groups: *Cyanophyta* (*Cyanobacteria*), *Bacillariophyta*, *Heterokontophyta*, *Dinoflagellata*, *Euglenophyta*, and *Chlorophyta*. The richest diversity of phytoplankton was attested in the River Ciulucul Mare (55 species). The values of saprobic indices, estimated on the basis of indicator species (48 species from the total number of 80), of which 56% are typically beta-mesosaprobic, confirm the following: the water quality was satisfactory for the development of phytoplankton and was mainly assigned to quality classes II-III (good-moderately polluted).
Keywords: phytoplankton, diversity, indicator species, water quality.

Diversitatea fitoplanctonului râurilor Ciulucul Mare, Ciulucul de Mijloc și Ciulucul Mic din subbazinul hidrografic al râului Răut

Rezumat. Articolul prezintă rezultatele investigațiilor privind structura taxonomică a fitoplanctonului din trei râuri (Ciulucul Mare, Ciulucul de Mijloc și Ciulucul Mic) din subbazinul hidrografic al râului Răut. Componența fitoplanctonului a fost reprezentată în total de 80 specii şi varietăţi de alge planctonice care se referă la 6 grupe taxonomice: *Cyanophyta (Cyanobacteria)*, *Bacillariophyta*, *Heterokontophyta*, *Dinoflagellata*, *Euglenophyta*, *Chlorophyta*. Diversitatea mai bogată a fitoplanctonului a fost atestată în râul Ciulucul Mare (55 specii). Valorile indicilor saprobici, estimați în baza speciilor indicatoare din compoziția fitoplanctonului (48 de specii din numărul total de 80), care în proporție de 56% sunt tipic beta-mezosaprobe, confirmă următoarele: calitatea apei a fost satisfăcătoare pentru dezvoltarea fitoplanctonului și a fost atribuită în principal claselor de calitate II-III (bună-poluată moderat).
Cuvinte-cheie: fitoplancton, diversitatea, specii indicatoare, calitatea apei.

1. Introduction

The rivers Ciulucul Mare (*Great Ciulucul*), Ciulucul de Mijloc (*Middle Ciulucul*), and Ciulucul Mic (*Little Ciulucul*) are some of the key tributaries of the River Răut. The rivers Ciulucul Mare and Ciulucul de Mijloc are the left tributaries of the River Ciulucul Mic, while the River Ciulucul Mic is a right tributary of the River Răut. The river originates near the village of Pietrosu from the district of Fălești. In its upper course, the valley is narrow, but it widens considerably downstream of Coșcodeni [1, 8, 9, 10]. The small rivers in the region are mainly impacted by anthropogenic eutrophication, along with sedimentation processes and pollutant accumulation. Most of the anthropogenic load is caused by runoff from the drainage basin surface, agricultural lands and livestock farms [9, 10]. In many places, rivers are dammed to form lakes used for fishing [6].

Phytoplankton, as a component of the ecosystem, plays a special role in the cycles of oxygen, phosphorus, and nitrogen, as well as in the synthesis of organic substances; and serves as food for zooplankton species and phytophagous fish. At the same time, planktonic algae are among the organisms that serve as water quality indicators and are used to determine the ecological status and ecological potential of ecosystems. The assessment of diversity, the analysis of seasonal and multiannual dynamics of the quantitative parameters of phytoplankton, and the water quality of tributaries are essential for understanding their impact on the formation of water quality in the River Răut [6, 7].

2. Materials and Methods

The phytoplankton samples were collected from three rivers: Ciulucul Mare, Ciulucul de Mijloc, and Ciulucul Mic, located in the hydrological sub-basin of the River Răut. The samples were collected in the vicinity of the localities situated along the studied rivers: village (v.) Bănesti, city Sîngerei, and v. Bilicenii Vechi (Ciulucul Mare); v. Ciulucul, v. Glinjeni, v. Chișcareni, and v. Ciuciuleni (Ciulucul de Mijloc); v. Mândrești and v. Verejeni (Ciulucul Mic). The processing of the samples was carried out as part of the research at the Hydrobiology and Ecotoxicology Laboratory of the Institute of Zoology from Moldova State University. Sample collecting and processing was carried out according to the unified methods for collecting and processing hydrobiological samples [2, 3, 4, 5]. Algae species identification was performed using the microscope MIKMED-2 (LOMO), equipped with a digital camera and identifying keys [4, 5, 11].

3. Results and Discussions

The phytoplankton composition of the River Ciulucul Mare was represented by 55 species and varieties of planktonic algae, belonging to 6 taxonomic groups: *Cyanophyta (Cyanobacteria)* – 9, *Bacillariophyta* – 18, *Heterokontophyta* – 1, *Dinoflagellata* – 1, *Euglenophyta* – 18, and *Chlorophyta* – 8 (Table 1).

Table 1. Taxonomic composition of the phytoplankton of the small rivers: Ciulucul Mare, Ciulucul de Mijloc and Ciulucul Mic.

Name of the taxa	**Ciulucul Mare**	**Ciulucul de Mijloc**	**Ciulucul Mic**
Cyanophyta (Cyanobacteria)	9	9	10
Bacillariophyta	18	12	7
Heterokontophyta	1		
Dinoflagellata	1		1
Euglenophyta	18	12	11
Chlorophyta	8	16	12
Total	**55**	**49**	**41**

The most widespread species were *Anabaena spiroides* Kleb., *Oscillatoria lacustris* Kleb., *Synechocystis aquatilis* (Sanv.) from *Cyanophyta (Cyanobacteria)* group; *Nitzschia sigmoidea* (Ehr.) W. Sm., *Surirella ovata* Kütz., *Surirella robusta* Ehr. from *Bacillariophyta* group; *Ophiocytium lagerheimii* Lemm. from *Heterokontophyta* algae group; *Glenodinium gymnodinium* Penard from *Dinoflagellata* algae group; *Euglena caudata* E.F.W. Hübner, *Euglena fenestrata* Elenk., *Monomorphina nordstedtii* (Lemm.) Popova, *Strombomonas fluviatilis* Lemm. from *Euglenophyta* group; and *Monoraphidium contortum* (Thur.) Komárk.-Legn., *Pandorina morum* (O.F. Müll.) Bory, *Cosmarium undulatum* Corda from *Chlorophyta* group. No species from the *Chrysophyta* group were recorded, but a more intense development of *Euglenophyta* algae and diatoms was observed (Table 2).

The phytoplankton of the River Ciulucul de Mijloc was represented by 49 species and varieties of planktonic algae that refer to 4 taxonomic groups: *Cyanophyta (Cyanobacteria)* – 9, *Bacillariophyta* – 12, *Euglenophyta* – 12, and *Chlorophyta* – 16 (Table 1). Among the species most commonly found in the River Ciulucul de Mijloc, we mention: *Aphanizomenon flos-aquae* Ral. ex Bor. & Fl., *Oscillatoria amphibia* Ag., *Oscillatoria planctonica* Wolosz. from cyanophyta algae group; *Amphiprora paludosa* W. Smith,

Campylodiscus clypeus Ehr., *Cyclotella kuetzingiana* Thw. from the diatom group; *Euglena deses* Ehr., *Euglena hemichromata* Skuja, *Monomorphina pyrum* Ehr., *Trachelomonas hispida* (Perty) F. Stein. from euglena algae group; *Ankyra ankora* (G.M. Sm.) Fott., *Crucigenia tetrapedia* (Kirchner) Kuntze, *Chlorella vulgaris* Beij., *Scenedesmus quadricauda* (Turpin) Bréb., *Tetrastrum triangulare* (Chodat) Komárek from green algae group. The species from the *Heterokontophyta*, *Dinoflagellata*, and *Chrysophyta* groups have not been observed.

In the River Ciulucul Mic, a total of 41 phytoplankton species, classified into five taxonomic groups, were recorded: *Cyanophyta (Cyanobacteria)* – 10, *Bacillariophyta* – 7, *Dinoflagellata* – 1, *Euglenophyta* – 11, and *Chlorophyta* – 12 (Table 1). More common were the species from the group *Cyanophyta – Anabaena flos-aquae* (Breb.) and *Merismopedia tenuissima* Lemm.; from group *Bacillariophyta – Cocconeis placentula* Ehr., *Navicula cryptocephala* Kütz., and *Synedra acus* Kütz.; from *Euglenophyta – Euglena acus* (O.F. Müll.) Ehr., *Euglena oxyuris* Schm., *Euglena polymorpha* P.A. Dang.; and from group *Chlorophyta – Dictyosphaerium pulchellum* H.C. Wood, *Monoraphidium komarkovae* Nyg., *Scenedesmus falcatus* Chodat, and *Schroederia setigera* (Schr.) Lemm. (Table 2).

Table 2. List of taxa of algae identified in the small rivers Ciulucul Mare, Ciulucul de Mijloc, and Ciulucul Mic.

Taxon	**Saprobity indicator species**	**Ciulucul Mare**	**Ciulucul de Mijloc**	**Ciulucul Mic**
Phylum *Cyanophyta* (*Cyanobacteria*)				
Order *Nostocales*				
Aphanizomenon flos-aquae (L.) Ralfs	β	+	+	+
Anabaena flos-aquae (Lyngb.) Breb.	β		+	+
Anabaena spiroides Kleb.	$o-\beta$	+	+	+
Anabaena sigmoidea Nyg.				+
Anabaena sphaerica Born. et Flah.				+
Anabaena variabilis Kutz.		+		
Order *Chroococcidiopsidales*				
Gloeocapsa turgida (Kutz.) Hollerb.	o	+	+	+
Order *Chroococcales*				
Merismopedia tenuissima Lemm.	$\beta-\alpha$	+	+	+

Microcystis aeruginosa Kutz.	β	+		+
Synechocystis aquatilis Sanv.		+	+	+
Order *Oscillatoriales*				
Oscillatoria amphibia Ag.	β		+	
Oscillatoria lacustris (Kleb.) Geitl.		+		
Oscillatoria planctonica Wolosz.		+	+	+
Order *Nodosilineales*				
Romeria leopoliensis (Racib.) Koczw	$o-\beta$		+	
Phylum *Bacillariophyta*				
Order *Achnanthales*				
Cocconeis placentula Ehr.	β	+	+	+
Order *Stephanodiscales*				
Cyclotella Kuetzingiana Thw.	β	+	+	+
Cyclotella meneghiniana Kutz	$\alpha-\beta$		+	
Order *Cymbellales*				
Gomphonema olivaceum (Lyngb.) Kutz.	β	+	+	
Gomphonema parvulum Kutz.	β	+		
Order *Melosirales*				
Melosira italica (Ehr.) Kutz.	$o-\beta$	+		
Order *Naviculales*				
Amphiprora paludosa W.Smith.		+	+	
Gyrosigma acuminatum (Kutz.) Rabenh.	β	+		
Navicula gracilis Ehr.	$\beta-o$		+	+
Navicula cincta (Ehr.) Kutz.	$\beta-\alpha$	+		
Navicula cryptocephala Kutz.	α	+	+	+
Navicula cryptocephala var.intermedia Grun.	β	+		
Order *Bacillariales*				
Nitzschia acicularis W.Sm.	α	+	+	+
Nitzschia Kuetzingiana Hilse		+		
Nitzschia longissima var.reversa (Breb.)		+	+	+
Nitzschia sigmoidea (Ehr.) W.Sm.	β	+		
Nitzschia palea (Kutz.) W.Sm.	α	+		
Hantzschia amphioxys Grun.	α		+	
Order *Surirellales*				

Campylodiscus clypeus Ehr.			+	
Surirella ovata Kutz.	β	+		
Surirella robusta Ehr.		+		
Order *Fragilariales*				
Synedra acus Kutz.	β	+	+	+
Phylum *Heterokontophyta*				
Class: *Xanthophyceae*				
Ophiocytium lagerheimii Lemm.		+		
Phylum *Dinoflagellata*				
Peridinium cinctum (O.F.M.) Ehr				+
Glenodinium gymnodinium Penard.		+		
Phylum *Euglenophyta*				
Order *Euglenales*				
Euglena acus Ehr.	β	+	+	+
Euglena caudata E.F.W. Hubn.	$\rho - \alpha$	+	+	+
Euglena caudata v. minor Defl.		+		
Euglena deses (O.F.Mül.) Ehr.			+	
Euglena oxyuris Schmarda	$\beta - \alpha$	+	+	+
Euglena polymorpha Dang.	α	+	+	+
Euglena hemichromata Skuja	$\beta - o$		+	
Euglena texta Dujardin	β	+		+
Euglena granulata (G.A.Klebs) F.Schmitz	$\beta - o$	+	+	+
Euglena gracilis G.A. Klebs.	o	+		+
Euglena variabilis G.A. Klebs.	β	+		
Euglena viridis Ehr	$\rho - \alpha$	+	+	+
Euglena vermicularis Proškina-Lavrenko		+		
Euglena fenestrata Elenk.		+		
Lepocinclis fusiformis (Carter) Lemm.	β	+	+	+
Monomorphina pyrum Ehr.	β	+	+	
Monomorphina Nordstedtii (Lemm.) Popova		+		
Phacus pleuronectes Dujardin.	β	+	+	
Trachelomonas hispida (Perty) Stein	β	+	+	+
Strombomonas fluviatilis (Lemm.) Defl.	β	+		+
Phylum *Chlorophyta*				

Order *Chlamydomonadales*				
Carteria pallida Korsch			+	
Pandorina morum (Mull.)Bory	β	+		
Chlorococcum infusionum (Sch.) Meneg			+	
Order *Chlorellales*				
Actinastrum hantzschii Lagerh.	β		+	
Chlorella vulgaris Beier.	$\rho - \alpha$		+	+
Dictyosphaerium pulchellum Wood.	β	+	+	+
Order *Sphaeropleales*				
Ankyra ancora(G.M.Smith) Fott			+	
Crucigenia tetrapedia W.et G.S.West	$o - \beta$	+	+	
Monoraphidium contortum Thur.		+	+	+
Monoraphidium minutum (Nag.)			+	+
Monoraphidium komarkovae Nygaard			+	+
Scenedesmus acutiformis Schroed.				+
Scenedesmus quadricauda Turp	β	+	+	+
Scenedesmus intermedius Chodat			+	
Scenedesmus falcatus Chodat.		+	+	+
Schroederia setigera (Schroed.) Lemm			+	+
Tetraedron minimum (A.Br.) Hansg.	β		+	
Tetraedron caudatum (Corda) Hansg.	β			+
Tetraedron triangulare Korsch.		+	+	+
Tetrastrum triacanthum Korschik.				+
Order *Desmidiales*				
Cosmarium undulatum Corda		+		
Total 80	**48**	**55**	**49**	**41**
β, α, $\beta - \alpha$ - mesosaprobe species; o-oligosaprobe and ρ-polisaprobe				

The planktonic algae indicators of the water saprobity of the River Ciulucul Mare were represented by 37 species. Of these, the majority (59%) are beta-mesosaprobic species, the most frequently encountered of them being *Aphanizomenon flos-aquae* Ral. ex Bor. & Fl., *Microcystis aeruginosa* Kutz., *Cocconeis placentula* Ehr., *Cyclotella kuetzingiana* Thw., and *Euglena acus* (O.F. Müll.) Ehr. In contrast, alfa-mesosaprobic species accounted for about 4%, which refers to: *Navicula cryptocephala* Kütz. Speaking about the oligosaprobic and polysaprobic species, they made up 10%, among which

being *Gloeocapsa turgida* (Kützing), *Euglena gracilis* G.A. Klebs., and *Euglena viridis* (O.F. Müll.). Accounting for 8%, Ehr. oligo-beta-mesosaprobic species were represented by the species: *Anabaena spiroides* Woronic., and *Melosira italica* Ehr. Finally, beta-oligosaprobic species, accounting for 3%, were represented by the species *Euglena granulata* (G.A. Klebs) F. Schmitz (Figure 1).

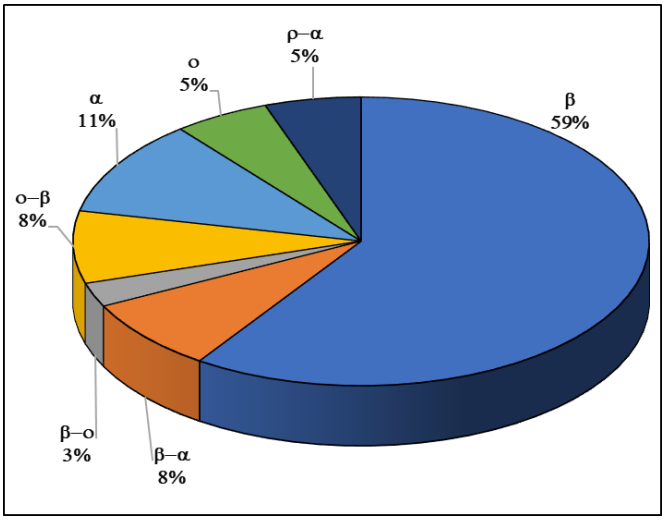

Figure 1. Distribution of indicator species in the phytoplankton composition of the River Ciulucul Mare in saprobity zones.

The River Ciulucul de Mijloc was represented by 33 indicator species of water saprobity, most of which belong to beta-mesosaprobic species (48%): *Anabaena flos-aquae* (Brébiss.), *Gomphonema olivaceum* Ehr., *Synedra acus* Kützing, *Lepocinclis fusiformis* Lemmerm., *Phacus pleuronectes* (O.F. Müller) Dujardin, and *Aktinastrum hantzschii* Lagerh. In addition, alfa-mesosaprobic algae species (12%) are represented by *Hantzschia amphioxys* (Ehr.) Grun., and *Euglena polymorpha* Dang. Alpha-beta-mesosaprobic species (about 9%) were represented by: *Cyclotella meneghiniana* Kützing, *Merismopedia tenuissima* Lemm., *Euglena oxyuris* Schmarda. The species with preferences for the oligo-beta and beta-oligosaprobic zones accounted for about 18%, being represented by *Romeria leopoliensis* (Raciborski) Kocz., *Navicula gracilis* Ehr., *Euglena hemichromata* Skuja. Among the poly-alpha-mesosaprobic species, the following were identified: *Euglena caudata* E.F.W. Hübner, *Chlorella vulgaris* Beijerinck. The smallest group, representing only 3%, consisted of oligosaprobic species (Figure 2).

In the phytoplankton composition of the River Ciulucul Mic, 27 indicator species of saprobity were identified. Of these, 52% are represented by beta-mesosaprobic

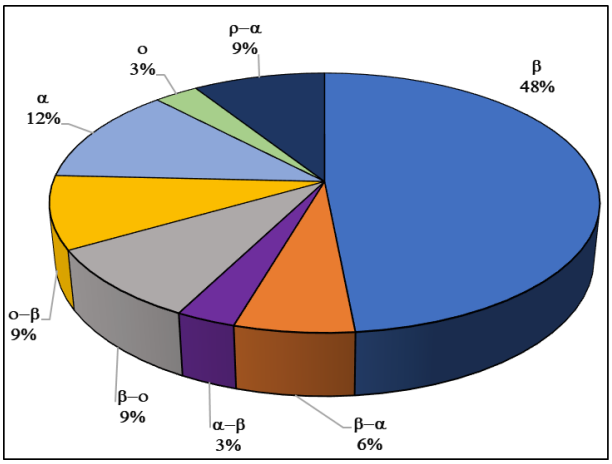

Figure 2. Distribution of indicator species in the phytoplankton composition of the Ciulucul de Mijloc river in saprobity zones.

species: *Euglena texta* Dujardin, *Trachelomonas hispida* (Perty) F. Stein, *Strombomonas fluviatilis* Lemm., *Dictyosphaerium pulchellum* H.C. Wood, *Scenedesmus quadricauda* (Turpin) Brébisson, and *Tetraedron caudatum* (Corda) Hansgirg. Alpha-mesosaprobic species made up 11%: *Nitzschia acicularis* W. Smith and *Euglena polymorpha* Dang. Beta-alpha- and beta-oligosaprobic species together accounted for 14%, while the poly-alpha-mesosaprobic algae species constituted 11%, the majority of which belong to the *Euglenophyta* group. The species with preferences for oligosaprobic zone developed in rather small numbers (Figure 3).

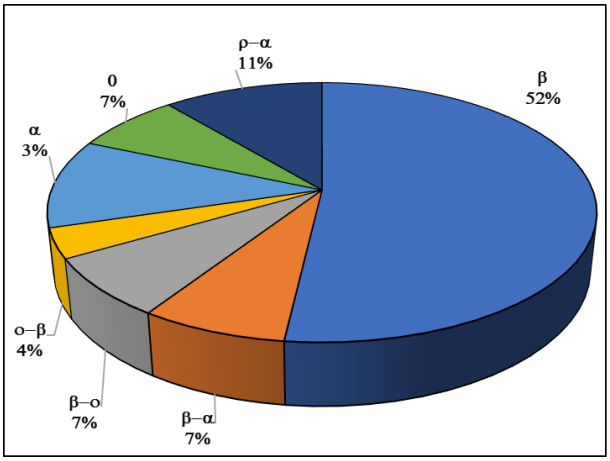

Figure 3. Distribution of indicator species in the phytoplankton composition of the River Ciulucul Mic in saprobity zones.

The values of the saprobic index, estimated on the basis of the quantitative parameters of the indicator species from the River Ciulucul Mare, varied within the limits of the beta- and alpha-mesosaprobic zones, ranging from 1.97 to 2.67, which falls within the limits of water quality class III (moderately polluted). The estimated saprobic index values for the River Ciulucul de Mijloc ranged from 1.8 to 2.82, which correspond to the beta- and alpha-mesosaprobic zones and water quality class III (moderately polluted). For the River Ciulucul Mic, the saprobic index values ranged from 1.84 to 2.58, fitting within the beta-mesosaprobic zones and corresponding to water quality classes II - III (good - moderately polluted).

4. Conclusions

The floristic basis of the phytoplankton of the rivers Ciulucul Mare, Ciulucul de Mijloc, and Ciulucul Mic, located in the Răut river sub-basin, was made up of representatives of the phylums *Euglenophyta*, *Bacillariophyta* and *Chlorophyta*. The highest diversity of phytoplankton was recorded in the River Ciulucul Mare. As a result of damming the rivers, a higher proportion of limnophilic algae was observed in their ecosystems.

In the ecosystems of the investigated rivers, beta-mesosaprobic planktonic algae species predominated, many of which belong to the *Bacillariophyta* and *Euglenophyta* groups. There have not been recorded species that prefer the xenosaprobic zone.

According to the values of the saprobic index of the phytoplankton, the water quality of the rivers Ciulucul Mare, Ciulucul de Mijloc, and Ciulucul Mic falls within the limits of classes II-III (good - moderately polluted).

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