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WATER QUALITY ASSESSMENT OF PONDS OF THE CENTRAL POLISSIA BY THE STRUCTURAL AND FUNCTIONAL INDICATORS OF PHYTOPLANKTON

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Reservoirs formed in the process of human activity are a new type of reservoir and an integral element of landscapes. Studies of these water bodies make it possible to establish the mechanisms of formation and functioning of phytoplankton in artificially created ecosystems. Studies were conducted in 2018-2020 on phytoplankton assemblages in ponds of the Central Polissia area in Ukraine. The work aimed to evaluate the water quality of the Central Polissia ponds according to structural and functional indicators of phytoplankton development. Differences in phytoplankton abundance, biomass, and structure, dominant complexes of species were assessed in the studied ponds. 103 species of algae, represented by 105 intraspecific taxa, including those containing the nomenclature type species, from 7 divisions, 11 classes, 20 orders, 31 families, and 60 genera were found in the studied ponds. The occurrence of 9 types of algae, which were not previously found in the territory of Ukrainian Polyassia. Chlorophyta, Euglenozoa, and Miozoa were the structure-forming divisions in the phytoplankton biomass in the studied ponds. The dominant species complex of the ponds' phytoplankton (according to abundance and biomass) was formed by 5–18 species, which accounted for 33–62% of the species richness of the water bodies. Shannon's diversity index indicated the predominance of the polydominant structure of phytoplankton in most ponds. Phytoplankton assemblages of the studied ponds in central Polissia were characterized by high biodiversity, differentiated structure, and differences in dominant species, which highlight the critical role of artificial water bodies in biodiversity. This study provides necessary information for understanding the changes in the phytoplankton community caused by anthropogenic impacts on artificial water bodies.

***Keywords**: algae, phytoplankton, ponds, Polissia.*

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ОЦІНКА ЯКОСТІ ВОДИ СТАВКІВ ЦЕНТРАЛЬНОГО ПОЛІССЯ ЗА СТРУКТУРНО-ФУНКЦІОНАЛЬНИМИ ПОКАЗНИКАМИ ФІТОПЛАНКТОНУ

О. В. Кравцова, Ю. С. Шелюк

Водойми, що утворилися в процесі діяльності людини, є новим типом водойм і невід'ємним елементом ландшафтів. Дослідження цих водних об'єктів дають змогу встановити механізми формування та функціонування фітопланктону в штучно створених екосистемах. У 2018-2020 роках проводились дослідження фітопланктону у ставках Центрального Полісся в Україні. Метою роботи було оцінити якість води ставків Центрального Полісся за структурно-функціональними показниками розвитку фітопланктону. З'ясовано особливості складу, чисельності, біомаси фітопланктону, домінуючих комплексів видів у досліджуваних ставках. У ставках виявлено 103 види водоростей, представлених 105 внутрішньовидовими таксонами з номенклатурним типом виду включно, із 7 відділів, 11 класів, 20 порядків, 31 родини та 60 родів. Виявлено 9 видів водоростей, які раніше не зустрічалися на території Українського Полісся. Структуроутворюючими відділами у формуванні біомаси фітопланктону досліджуваних водойм були Chlorophyta, Euglenozoa та Miozoa. Домінуючий видовий комплекс фітопланктону ставків (за чисельністю та біомасою) включав по 5–18 видів, що становило 33–62 % видового багатства водойм. Індекс різноманіття Шеннона вказував на переважання полідомінантної структури фітопланктону в більшості ставків. Фітопланктон досліджуваних водойм центрального Полісся характеризуються високим видовим багатством, полідомінантною структурою угруповань, складністю структури домінантних комплексів, що підкреслює вагому роль штучних водойм у біорізноманітті. Це дослідження дає необхідну інформацію для розуміння змін у планктонних угрупованнях, зумовлених антропогенним впливом на штучні водойми.

***Ключові слова**: водорості, фітопланктон, водойми, Полісся.*

Introduction

Using the different components of hydrobiota, especially phytoplankton, is the priority of modern methods for assessing the ecological status of aquatic ecosystems. Phytoplankton is the first trophic level in the water's chain of complex food relationships. It is the first to react to anthropogenic pollution of water bodies and therefore is a representative indicator of their quality and self-purification ability. The diversity and development of hydrobionts acquire particular importance as bioindicators in ecological monitoring and biotesting in the conditions of increased anthropogenic influence on the environment. Various phytoplankton classification systems were designed based on the environmental characteristics of algae species (Reynolds, 1980; Reynolds, 1984; Salmaso & Padisák, 2007; Padisak et al., 2009). Similarly, the phytoplankton diversity index (Spellerberg and peter, 2003), dominance index (Ignatiades, 2020), biological pollution index (Chen et al., 2021), and biological integrity index (Zhu et al., 2021) are commonly used for the water quality and ecological status of lakes, rivers and reservoirs in water monitoring and evaluation.

Today, the research on reservoirs of different typologies and genesis, especially those formed due to significant anthropogenic environmental impacts, is quite relevant. In this regard, artificial reservoirs are specific little-studied aquatic ecosystems that attract special attention.

Ukrainian Polissia is unique region located in the northern part of the country. Polissia is one of the most powerful natural reservoirs of fresh water in Ukraine, which is used by almost half of the country's entire population. Artificial reservoirs are an integral element of the landscapes of Ukrainian Polissia. Current information on planktonic algae of reservoirs of anthropogenic origin in the Polissia region mainly concerns flooded quarries from the extraction of minerals (Shelyuk et al., 2018; Shelyuk, Astahova, 2020; Shelyuk, 2022). The researchers noted that in artificial reservoirs that were formed at the site of mineral extraction pits, regardless of their type, successions of the autotrophic link occur intensively. One of its mechanisms is the formation of phytoplankton dominated by green, diatom, blue-green and euglena algae. In general, in the literature, information on artificial reservoirs mainly concerns their further restoration and use as a source of water resources in industry and agriculture, energy, and recreation (Markovič et al., 2014; Pujades et al., 2016; Bodeux et al., 2017; Poulain et al., 2021). There are few works related to the autotrophic link of the ponds of the Polis region. Moreover, they were carried out more than ten years ago, so comparing them with the current is relevant.

Knowledge of the regularities of the structural and functional organization of the autotrophic link of the ponds of the Polis region forms the prerequisites for an objective assessment of their condition, forecast of changes, rational use of water resources and is existential the development of methods of monitoring and management of artificially created water ecosystems at various levels of anthropogenic transformation.

The work aimed to evaluate the water quality of the Central Polissia ponds according to structural and functional indicators of phytoplankton development.

Materials and methods

Study area. This study concentrated on ponds located in Central Polissia (Novohrad-Volynskyi town, Soniachne village, Kodnia village, Ivanivka village in Zhytomyr district) in Ukraine. Material for the study included the samples of phytoplankton taken during 2018–2020. The study area has seven ponds with different morphometric characteristics shown in Table 1.

Table 1

Morphometric characteristics of studied water bodies

Ponds	Depth, м	Area of the water mirror, м^2	Location	Purpose of the pond
Novohrad-Volynskyi No. 1	1,5	50	Novohrad-Volynskyi town	Aquaculture, recreation
Novohrad-Volynskyi No. 2	1,5	55	Novohrad-Volynskyi town	Aquaculture, recreation
Soniachne No. 1	2,0	500	Soniachne village surroundings, Zhytomyr district	Aquaculture, recreation
Soniachne No. 2	2,5	1400	Soniachne village surroundings, Zhytomyr district	Aquaculture, recreation
Kodnia	2,0	45	Kodnia village, Zhytomyr district	Aquaculture, recreation
Ivanivka	1,5	40	Ivanivka village, Zhytomyr district	Aquaculture, recreation
Nalyvnyii	2,5	300	Kodnia village, Zhytomyr district	Aquaculture, recreation

Samples were taken monthly during three growing seasons (March - November) and processed following standard hydrobiological procedures (Methods ..., 2006). The taxonomic nomenclature of algae is given according to the international electronic catalog AlgaeBase (Guiry & Guiry, 2020, www.algaebase.org). Saprobiological assessment of water quality is given according to the Pantle-Buck method (Pantle & Buck, 1955) in Sladeček's modification (Sladeček, 1986). Bioindicative analysis was done considering the indicator properties of algae given in the relevant monographs and articles (Barynova, 74–76). Shannon-Weaver's diversity index (Odum, 1986) was assessed based on taxa biomass. The trophic status of water bodies was assessed based on the phytoplankton biomass (Methods ..., 2006).

During the research period (vegetation season 2018–2020), 168 algal samples were collected and processed to determine the phytoplankton's qualitative and quantitative diversity.

Results

Algae plankton communities of the ponds. 35 species (37 infraspecific taxa) of algae were found in the plankton of the pond Novohrad-Volynskyi No. 1 for the period under the study. They were related to 6 divisions: Euglenozoa – 13 species (15 infraspecific taxa)– 40,6% of the total number of species and varieties, Chlorophyta – 7 (7) - 18,9%, Bacillariophyta, Miozoa –5 (5) each one– 13,5%, Ochrophyta – 3 (3) – 8,1%, Cyanoprocaryota – 2 (2) – 5,4%.Overall, the phytoplankton of No. 1 pond in Novograd-Volynskyi town was formed by the algae related to 10 classes, 12 orders, 17 families, and 22 genera.

The highest species richness had the following classes: Euglenophyceae - 40% of the total number of taxa ranked below the genus, Chlorophyceae - 16%, Dinophyceae - 14%, Chrysophyceae - 8 Euglenales (40%) and Sphaeropleales (11%) are at the level of orders1%). Euglenaceae (44%), Peridiniaceae (11%), and Gomphonemataceae (5%) were the leading families.

According to the taxonomic categories "species" and "genus" ratio, euglena prevailed. The generic coefficient of which reached 3.3. As a result of the rank assessment of the generic composition of planktonic algae communities, 4 leading taxonomically important genera were identified: *Trachelomonas* Ehrenb. – 16% of the total number of species and H.V.T., *Euglena* Ehrenb. – 14%, *Peridinium* Ehrenb., *Phacus* Dujard. - 8% each. They made up almost 46% of the species composition of the pond's phytoplankton. Most genera are monotypic (82% are 1–2 species). The proportion of flora is 1:1.24:2.06:2.18.

Among the species, the highest frequency of occurrence was: *Chlamydomonas globosa* J. Snow, *Peridinium cinctum* (O. F. Müll.) Ehrenb. (75% проб), *Peridinium bipes* F. Stein (63%), *Crucigeniella rectangularis* (Nägeli) Komárek, *Trachelomonas volvocina var. volvocina* Ehrenb., *T. volvocina var. derephora* M.A. Conrad (50% each).

The phytoplankton of pond Novograd-Volynskyi No. 2 had the most prosperous species composition among the investigated water bodies. It was made up of 51 species of algae (53 in total) from 6 divisions: Chlorophyta – 23 species, represented by 23 intraspecific taxa - 43.4% of their total number, Euglenophyta – 11 (13) – 24.5%, Bacillariophyta – 10 (10) – 18.9%, Cyanoprokaryota – 3 (3) – 5.6%, Dinophyta, and Chrysophyta – 2 (2) – 3.8% each, respectively. Unlike pond No. 1, green algae dominated in pond No. 2. The following classes had tremendous significance: Chlorophyceae – 36% of the total species and intraspecific composition of algae, Euglenophyceae – 25%. At the level of orders, as in pond No. 1, Euglenales dominated - 25%, Sphaeropleales - 23%, and, in addition, Fragilariales - 9% and Chlorellales - 8%. The leading families were Euglenaceae (25%), Scenedesmaceae – 17%, and Fragilariaceae – 9%.

The highest frequency of occurrence was: *Chlamydomonas globosa* (88% проб), *Monoraphidium contortum* (Thur.) Komark.-Legn., *Raphidocelis subcapitata* (Korschikov) Nygaard et al., *Trachelomonas volvocina var. derephora*, *T. volvocina var. volvocina* (75%), *Fragilarioforma virescens (Ralfs)* D. M. Williams et Round, *Pseudodidymocystis planctonica* (Korschikov) E. Hegew. et Deason (63%). In general, algae from 9 classes, 15 orders, 19 families, and 34 genera formed the phytoplankton of Pond No. 2 in Novohrad-Volynskyi. Three leading genera should be noted in taxonomic significance: *Trachelomonas* – 11.3% of the total number of species and t.v.t., *Euglena* – 7.5%, *Acutodesmus* (E. Hegew.) P. Tsarenko – 5.7%. They made up 25% of all the species and intraspecies richness of the pond's phytoplankton. Most of the algae genera of the pond had low species saturation. 91% of genera included only 1–2 species. The genus coefficient calculated for the phytoplankton of Pond No. 2 reaches 1.5. Euglenozoa, Cyanoprokaryota, Bacillariophyta, and Chlorophyta had the most significant importance. Genera with few species characterized other departments. The proportion of flora is 1:1.79:2.68:2.79.

Phytoplankton of the pond in the Kodnya village of the Zhytomyr district was formed by 27 species (27 intraspecies taxa) from 5 divisions: Chlorophyta – 15 species, represented by 15 intraspecific taxa - 55.6% of their total number, Euglenozoa – 5 (5) – 18.5%, Ochrophyta – 4 (4) – 14.8%, Cyanoprocaryota – 2 (2) – 7.4%, Dinophyta – 1 (1) – 3.7%, respectively. A specific feature of the phytoplankton of the pond was the absence of representatives of diatoms in its composition.

At the class level, Chlorophyceae – 35%, Euglenophyceae – 19%, and Chrysophyceae – 15% were the leading ones. At the level of orders, Sphaeropleales (27%), Euglenales, and Chlorellales (19% each) dominated. The same dominant orders were present in the ponds of the Novograd-Volynskyi town. The leading families were Euglenaceae – 19%, Scenedesmaceae and Chlorellaceae – 12% each. The 2 leading taxonomically important genera were singled out: *Trachelomonas* (11.5% of the total number of species and the total number of species) and *Crucigeniella* Lemmerm. (7.7%). Only one algae species represents most algae genera (92%). The average number of genera is 1.1; the Euglenophyta division had the highest number of genera with species and intraspecific taxa. The species with the highest frequency of occurrence were: *Chrysococcus rufescens* G.A.Klebs, *Chlamydomonas globosa*, *Schroederia setigera* (Schroder) Lemmerm., *Pseudodidymocystis planktonica* (100% of samples). In general, the phytoplankton of the Kodnya pond was formed by 7 classes, 9 orders, 14 families, and 23 genera. The proportion of flora is 1:1.64:1.86:1.86.

22 species of algae, represented by 23 intraspecific taxa, were identified in pond Soniachne No. 1 for the observation period. 5 divisions formed the phytoplankton: Euglenozoa - 9 species, represented by 10 intraspecific taxa - 43.5% of their total number, Chlorophyta - 6 (6) – 26.1%, Bacillariophyta – 3 (3) – 13.0% and Cyanoprocaryota – 2 (2) – 8.7% each. In pond No. 1 in the Soniachne village some of the classes were dominated as in the mentioned above water bodies. The most important floristic classes were: Euglenophyceae - 44% of the total species and intraspecific diversity of algae, Chlorophyceae - 22%, and at the level of orders Euglenales - 44% and Sphaeropleales - 17%. The leading families were Euglenaceae (44%), Scenedesmaceae, Fragilariaceae, Peridiniaceae - 8.7% each. The species with the highest frequency of occurrence were: *Chlamydomonas globosa* (90% of samples), *Synedra acus* Kütz. (80%), *Microcystis pulverea* (Wood) Forti emend Elenkin, *Trachelomonas volvocina var. volvocina*, *Pseudodidymocystis planktonica*, *Peridinium cinctum* (70%). Algae from 8 classes, 9 orders, 11 families, and 16 genera formed the phytoplankton of this pond. According to the taxonomic importance, two leading genera are distinguished: Trachelomonas - 30.4% of the total species and in. t. and Euglena – 8.7%. They accounted for 39% of all species and intraspecies diversity of phytoplankton in the pond. A low representation characterized most of the algae genera of the pond; 88% of the genera had only 1–2 species. The genus coefficient calculated for the

phytoplankton of Pond No. 1 in the Soniachne village reached 1.4. Therefore, the Euglezoa division had the greatest saturation of genera with species and intraspecific taxa. The proportion of flora was: 1:1.45:2.00:2.09.

Phytoplankton of pond Soniachne No. 1 was formed by 29 species (30 of the total number of species) from 6 divisions: Chlorophyta – 9 species, represented by 9 intraspecific taxa - 30.0% of their total number, Euglenozoa – 8 (9) – 30.0%, Bacillariophyta – 8 (8) – 26.7%, Charophyta – 2 (2) – 6.7%, Cyanoprocaryota – 1 (1) – 3.3%, respectively. Euglenophyceae, Chlorophyceae – 30% each, Fragilariophyceae – 13% were leading at the class level. At the level of orders, Sphaeropleales – 20%, Euglenales – 19%, Fragilariales – 13%, Thalassiosirales, and Chlamydomonadales – 10% each dominated, as in the ponds mentioned above. The leading families were: Euglenaceae – 39%, Fragilariaceae – 13%, Scenedesmaceae, Stephanodiscaceae, and Chlamydomonadaceae – 10% each. The genus Trachelomonas had the highest species richness (23.3% of the total number of species and the total number of species). At the same time, most genera (95%) were represented by only 1–2 types of algae. The average number of genera with species is 1.4, which is the largest, as in the ponds mentioned above, in the department Euglenozoa. The species with the highest frequency of occurrence were: *Synedra acus, Peridinium cinctum* (90% of samples), *Trachelomonas volvocina var. volvocina, Tabularia fasciculata* (C. Agardh) D.M. Williams et Round, *Chlamydomonas globosa* (80%), *Trachelomonas volvocina var. derephora* (70%). In general, the phytoplankton of pond No. 2 in the Soniachne village was formed by algae from 8 classes, 9 orders, 12 families, and 21 genera. The proportion of flora was: 1:1.75:2.42:2.50.

Phytoplankton of the Ivanivka pond was formed by 20 species of algae (21 species) from 5 divisions: Euglenozoa – 9 species, represented by 10 intraspecific taxa - 47.6% of their total number, Chlorophyta – 6 (6) – 28.5%, Bacillariophyta – 3 (3) – 14.3%, Miozoa, Ochrophyta – 1 (1) – 4.8% each, respectively. Unlike all other studied ponds, representatives of the Cyanoprokaryota division were not found in this reservoir. The following classes had the most significant importance: Euglenophyceae - 48% of the total species and intraspecific diversity of algae; Chlorophyceae - 29%. Euglenales and Sphaeropleales dominated (48% and 14%respectivetely) at the level of orders. Euglenaceae (48%), Chlamydomonadaceae, Selenastraceae, and Fragilariaceae (10% each) were the leading families. The most common species were: *Trachelomonas volvocina var. volvocina, Peridinium cinctum* (83% of samples), *Trachelomonas volvocina var. derephora, Chlamydomonas globosa, Chrysococcus rufescens* (67%). Algae from 7 classes, 8 orders, 9 families, and 14 genera formed the phytoplankton of this pond. The genus *Trachelomonas* should be noted in taxonomic significance - 23.8% of the total number of species, varieties and forms of algae. A low species representation characterized most of the algae genera of the pond (1-2 species). 92% of genera had only 1–2 species. The genus coefficient calculated for the phytoplankton of the pond reaches 1.4. The division Euglenophyta had the highest saturation of genera with species and intraspecific taxa. Other departments were characterized by genera with few species. The proportion of flora was: 1:1.56:2.22:2.33.

10 species of algae (11 species) from 6 divisions were identified in the phytoplankton of the Nalyvnyii pond. The ratio of divisions in the floristic spectrum of the studied reservoir was as follows: the leading place was occupied by Chlorophyta - 4 species, represented by 4 intraspecific taxa - 36.3% of their total number, Euglenophyta, Bacillariophyta - 2 (2) - 18.2% each, respectively. Cyanoprocaryota, Miozoa, and Ochrophyta each had 1 taxon below the

genus (9.1% each). Chlorophyceae – 36%, and Euglenophyceae – 18% were leading at the class level., Chlamydomonadales (27%) and Euglenales (18%) were dominant at the level of orders. Euglenaceae and Chlamydomonadaceae were the leading families (18%). The genera *Trachelomonas* and *Chlamydomonas* Ehrenb. were the most abundant species and intraspecific taxa. (36.4% of the total number of species and intraspecific taxa). At the same time, most genera (78%) were represented by only 1 type of algae. The species *Schroederia setigera* had the highest frequency of occurrence (100%). Overall, algae from 7 classes, 8 orders, 9 families, and 9 genera formed the phytoplankton of the pond. The proportion of flora was 1:1:1,1:1,2.

Comparison of the species composition of phytoplankton according to the Sorensen coefficient (SCSI) indicates a relatively small (0.29–0.49) level of similarity between the studied water bodies. Ponds Soniachne No. 1 and No. 2 were most similar. This was caused by the similarity of their morphometric and hydrochemical indicators (Fig. 1).

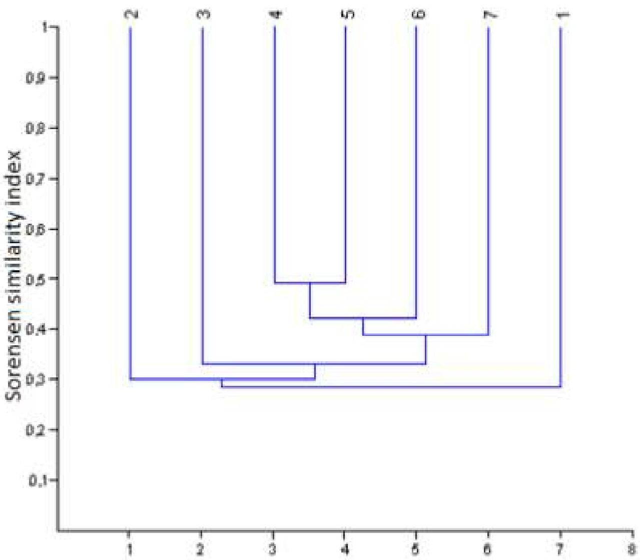

Fig. 1. Dendrogram of species composition similarity of phytoplankton in ponds of the Central Polissia

Note. Here and in fig. 2 and 3: 1 – Novohrad-Volynskyi No., 2 – Novohrad-Volynskyi No. 2, 3 – pond in the village of Kodnia, 4 - pond No. 1 of the village Soniachne, 5 - pond No. 2 of the village Soniachne, 6 - pond in the village Ivanivka, 7 - Nalyvnyii pond.

In total, 103 species of algae, represented by 105 intraspecific taxa, including those containing the nomenclature type species, from 7 divisions were found in the studied ponds. For each division it was Euglenozoa - 27 species, represented by 29 intraspecific taxa - 27.6% of their total number, Chlorophyta - 37 (37) - 35.2%, Bacillariophyta – 21 (21) – 20.0%, Miozoa – 6 (6) – 5.7%, Cyanoprocaryota, Ochrophyta – 5 each (5) – 4.8% each, Charophyta – 2 (2) – 1.9%.

9 species of algae were identified for the Ukrainian Polissia for the first time: *Synura lapponica* Skuja, *Euglena hemichromata* Skuja, *E. parvula* Christjuk, *Lepocinclis globosa* France, *Phacus striatus* France, *Trachelomonas volvocina var. papilata* Lemmerm., *Neochloris dissectum* (Korschikov) P. Tsarenko, *Chlamydomonas oblonga* E.G.Pringsh., *Macrochloris dissecta* Korschikov.

Bioindication analyses of phytoplankton. The bioindication analysis of the species composition of phytoplankton in ponds showed that planktonic forms are the leading ones in terms of being confined to the place of residence (23–50% of the number of taxa of the species and intraspecies rank, for which literature information was found). However, the share of planktonic-benthic forms (13–53%) was quite noticeable in the phytoplankton of the studied water reservoirs. Benthic forms ranged from 0 to 16%. The complex of planktonic and benthic organisms was dominated by Chlorophyta (46%), Euglenozoa (25%), and Bacillariophyta (21%). Representatives of the divisions Chlorophyta (40%) and Euglenozoa (24%) mainly belonged to the plankton. Benthic forms were found only among diatoms, planktonic-benthic-littoral - blue-green; green algae were part of the vegetation and littoral.

Analysis of the geographic limitation of algae showed that phytoplankton of all ponds was dominated by cosmopolitan species (67-92% of species, varieties and forms for which literature information was found). However, the share of Holarctic forms was quite noticeable (7-29%) (Fig. 3). The largest share of Holarctic species was found among the representatives of the Euglenozoa department (87% of all species and intraspecific taxa). Most of the species (45%) among Chlorophyta (45%) were cosmopolitan.

Indifferent species about to pH dominated (80-100%) in the next ponds: Nalyvne pond, and ponds in the Ivanivka and Kodnya villages. Alkaliphiles dominated (60-75%) in the ponds of Soniachne and No. 2 of Novohrad-Volynskyi. In pond No. 1 of Novohrad-Volynskyi, indifferents and alkaliphiles were found in equal amounts.

Most species of ponds were oligohalobs-indifferent - (50–80%). However, in most ponds the share of oligohalobs-halophobes (25%) and oligohalobs-halophiles were significant (10-25%) (Fig. 5).

The ranking of diatoms by groups of indicators according to Watanabe showed that 44% are saproxenes, 44% are eurysaprobes, and 12% are saprophylls. The share of eurysaprobes, i.e. indicators of moderately polluted waters, was the largest in pond No. 1 of Novohrad-Volynskyi (67%). Saproxens, indicators of clean water, dominated in ponds of the Soniachne village and No. 2 Novohrad-Volynskyi (57 - 100%).

Most species of pond algae were eurythermic (67–100%) but in Novohrad-Volynskyi ponds No. 1 and 2 there were indifferent species (17% each). The part of thermophilic forms reached 6–17%.

Species indicators of water flow and oxygen saturation were ranked as slow-flowing (60–92%) and stagnant (8–40%), which indicates a low level of water saturation with oxygen and a weak current. The largest share of standing water indicators was noted in pond Soniachne No. 1 (40%), and slow-flowing - Kodnya pond (92%).

Analysis of the ratio of species indicators of saprobity established that β-mesosaprobic species predominate in studied ponds. This species corresponds to the "fairly clean" water quality category. The proportion of oligo-β-mesosaprobs (9–22%) and oligo-α-mesosaprobs (9–25%) was noticeable (Fig. 2). Saprobity indices in terms of number and biomass, were in pond No. 1 in the city of Novohrad-Volynskyi - 1.89 and 1.69 respectively, in pond No. 2 in the city of Novohrad-Volynskyi - 1.73 and 1.76, in the pond in the village of Kodnya - 1.90 and 1.84, in pond No. 1 in the village. Soniachne – 1.79 and 1.87, No. 2 – 1.85 and 1.87, in Ivanovsky – 1.86 and 1.77, Nalyvnyi – 1.71 and 1.76.

The average abundance varied from 0.41 to 2.88 million cells/dm^3. Phytoplankton biomass varied from 0.20 to 2.31 g/m^3 (Table 2). According to phytoplankton biomass, the water quality of these reservoirs belongs to the II-III water quality class.

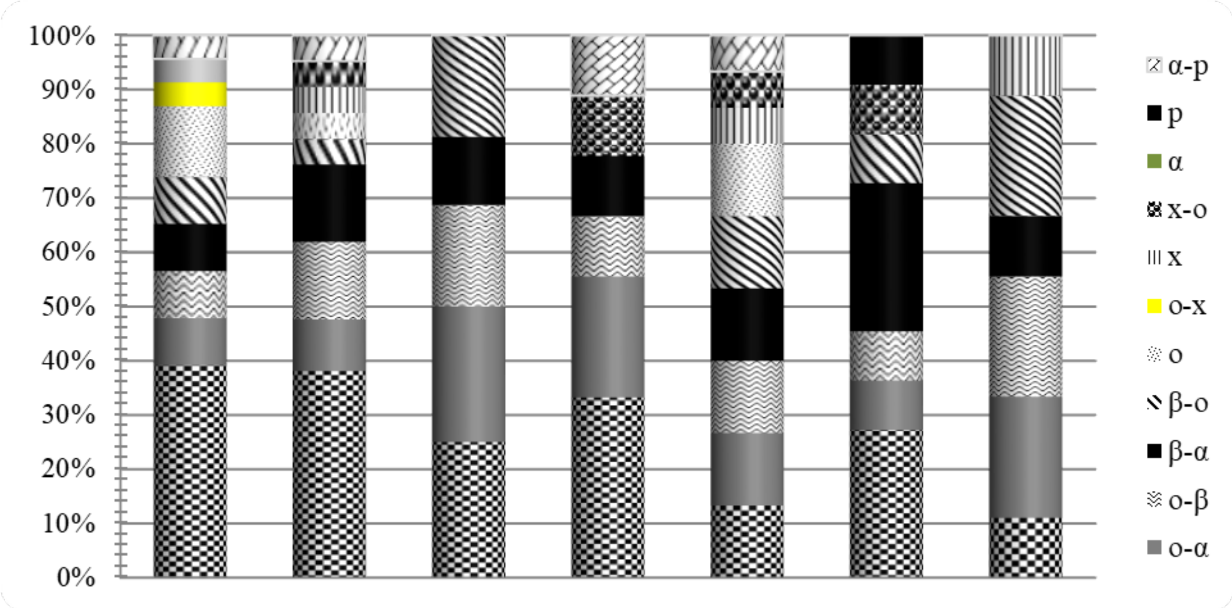

Fig. 2. Algae distribution of pond plankton by saprobity (according to the results of research in 2018–2020)

Table 2

Abundance and biomass of phytoplankton in ponds

Ponds	Abundance (million cells/dm³)	Biomass (g/m³)
Novohrad-Volynskyi No. 1	1,04 ± 0,29	2,02 ± 0,52
Novohrad-Volynskyi No. 2	2,88 ± 0,65	2,31 ± 0,71
Soniachne No. 1	0,82 ± 0,17	0,69 ± 0,08
Soniachne No. 2	2,60 ± 0,88	1,76 ± 0,49
Kodnia	2,50 ± 0,71	2,37 ± 0,67
Ivanivka	0,57 ± 0,17	2,25 ± 0,96
Nalyvnyi	0,41 ± 0,26	0,20 ± 0,09

Chlorophyta (23 – 66% of the total biomass), Euglenozoa (9 – 49%), and Miozoa (11 – 61%) were the structure-forming divisions in the phytoplankton biomass in the ponds in the cities of Novohrad-Volynskyi, Kodnyansk and Soniachnyi. Also, Bacillariophyta (5 – 13%) in the ponds of Soniachne village was dominated by biomass. Phytoplankton biomass in the pond of Ivanivka village was formed mainly by Miozoa (80%) and Euglenozoa (12%). Bacillariophyta (54%), Miozoa (18%) and Euglenozoa (15%) formed phytoplankton biomass of the Nalyvne pond. The share of Ochrophyta in the formation of phytoplankton biomass of the pond in the Kodnya village was noticeable (10%).

The dominant complex (according to abundance) of the ponds of the Novohrad-Volynskyi, Kodnya village and No. 1 in Soniachne village was formed by Euglenozoa (35-52%) and Cyanopracaryota (14-54%). In pond No. 2 in the Soniachne village Chlorophyta (78%) and Bacillariophyta (9%) dominated. The largest share of representatives of the divisions Miozoa (41%) and Euglenzoa (24%) was noted in the pond in the village of Ivanivka. Cyanoprocaryota dominated in Nalyvnyi pond (73%).

The dominant species complex of the ponds' phytoplankton (according to abundance and biomass) was formed by 5–18 species, which accounted for 33–62% of the species richness of the water bodies.

The assessment of informational diversity was made according to the

Shannon index calculated by biomass and the number of phytoplankton. The average values of the Shannon index calculated by the number (H_N) and biomass of phytoplankton (H_B) were 2.29±0.22 bits/ex and 1.81±0.28 bits/g for pond No. 1 in Novohrad-Volynskyi, respectively, 2.54±0.26 and 2.19±0.23, for pond No. 2 in the city of Novohrad-Volynskyi, 2.92±0.65 and 2.57±0.54 for the pond in the village of Kodnya, 1.95±0.23, 1.60±0.26 and 2.38±0.23, 2.30±0.14 for ponds №1 and №2 in the Soniachne village, respectively, 2.44±0.38 and 1.78±0.35 for the pond in the village. Ivanivka, 1.45±0.70 bits/ex and 1.51±0.17 bits/g for the Nalyvnyi pond (Fig. 3). The informational diversity, calculated according to the Shannon index, indicated the predominance of the polydominant structure of the phytoplankton of the ponds. However, the Nalyvnyi pond was characterized by an oligodominant structure.

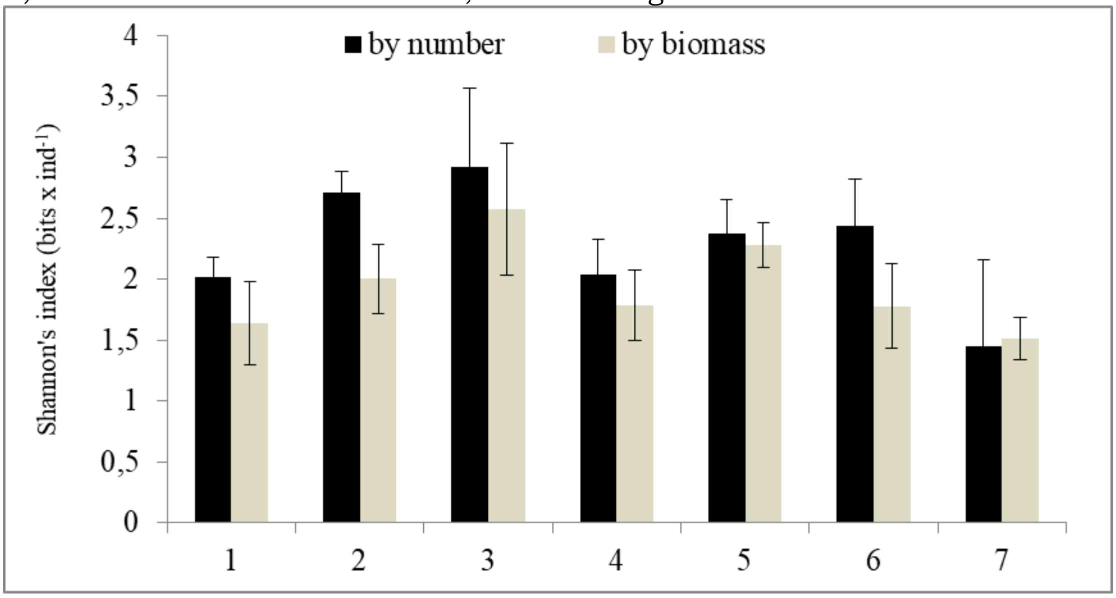

Fig. 3. Shannon's diversity indexes of phytoplankton by biomass and number of algal cells in studied ponds (mean ± SEM).

Discussion

Structural and functional characteristics of phytoplankton in ponds of the Central Polissia region were analyzed. 103 species of algae, represented by 105 intraspecific taxa, including those containing the nomenclature type species, from 7 divisions, 11 classes, 20 orders, 31 families, and 60 genera were found in the studied ponds of the Zhytomyr and Novohrad-Volyn districts. Phytoplankton of the ponds of Soniachne et al. Ivanivka is characterized as euglenoid-green-diatomic, pond No. 2 in Novohrad-Volynskyi and Nalyvnogo is green-euglenoid-diatomic, No. 1 in Novohrad-Volynskyi is euglenoid-green-dinophytic, p. Kodnya - green-euglenoid-golden.

The occurrence of 9 types of algae, which were not previously found in the territory of Ukrainian Polyassia according to (Tsarenko et al., 2006; 2009; 2011; 2014), five of which are representatives of the Euglenozoa. In general, several authors noted an increase in the species richness of Euglenozoa in the water ecosystems of Polissia as a result of organic pollution of water ecosystems (Shcherbak, 2020; Shcherbak & Shelyuk, 2020; Shelyuk, 2021). Comparison of the species composition of phytoplankton according to the Sorensen coefficient indicates a significant uniqueness of the studied reservoirs (SCSI = 0.29–0.49).

The bioindication analysis showed that in the phytoplankton of the ponds, the leading role belonged to planktonic and planktonic-benthic forms according to the place of residence, cosmopolitan species according to geographical distribution, oligohalobs-indifferent according to their relation to halobity, indifferents, and alkaliphiles according to their relation to pH, eurytherms according to temperature limitation. The predominance of slow-flowing and standing forms of algae was established, indicating a low level of rheophilic and saturation of water with oxygen due to the morphometric and hydrological features of reservoirs of artificial origin. According to Watanabe's ratio of indicator species, saproxenes and eurysaprobes prevailed, indicating a moderate level of pollution by organic substances. The ranking of species-indicators of saprobity showed the predominance of β-mesosaprobionts (11–38%), oligo-β-mesosaprobionts (9–22%) and oligo-α-mesosaprobionts (9–25%). The average value of the saprobity index by number in the ponds was in the range of 1.71–1.90 and by biomass – 1.70–1.87 (II class of water quality).

The average numbers of phytoplankton in pond No. 1 of Novohrad-Volynsky reached 1.04 ± 0.29, biomass – 2.02 ± 0.52, in pond No. 2 – respectively 2, 88 ± 0.65 and 2.31 ± 0.71, in the rate of Today - 2.50 ± 1.01 and 2.37 ± 0.67, in rate No.1 p. Soniachne - 0.82 ± 0.17 and 0.69 ± 0.08, #2 - 2.60 ± 1.18 and 1.76 ± 0.49, in the village. Ivanivka – 0.57 ± 0.17 and 2.05 ± 1.36, in Nalyvnyi – 0.41 ± 0.26 million cells/dm^3 and 0.20 ± 0.09 g/m^3. In terms of phytoplankton biomass, the water quality of these reservoirs belongs to II-III class.

Chlorophyta (23–66% of the total biomass), Euglenozoa (9–49%), Miozoa (11–61%), and Bacillariophyta (5–13%) were the structure-forming divisions in the formation of pond phytoplankton biomass. Chlorophyta (35–78%) and Cyanoprocaryota (14–73%), Miozoa (2–41%), and Euglenozoa (5–24%) were dominant in numbers.

In the phytoplankton of the ponds, 5–18 dominant species were found in terms of the number and biomass of algal cells, which accounted for 33–62% of the species richness of the reservoirs. Shannon's diversity index indicated the predominance of the polydominant structure of phytoplankton in most ponds.

Global and regional changes in the environment, the climate-ecological transformation of territories and water areas, and anthropogenic activity not only directly affect species richness and the number of groups but also change the habitat of biota, interactions between organisms, determining the impact on the stability and development of ecosystems. Reservoirs formed in the process of human activity are a new type of reservoir and an integral element of landscapes. Studies of these water bodies make it possible to establish the mechanisms of formation and functioning of phytoplankton in artificially created ecosystems. Understanding these regularities is necessary for developing methods for monitoring and managing ecosystems at different levels of anthropogenic transformation. It is necessary to ensure the proper level of their functions and ecological services (Minicheva et al; 2003Shelyuk, 2022). The study of the succession of groups of hydrobionts and the peculiarities of the functioning of the autotrophic link of reservoirs of anthropogenic distribution is necessary, at least given their significant distribution not only in the territory of Ukraine but also in the countries of Europe, Asia and America.

Conclusion

This study analyzed the structural and functional characteristics of phytoplankton in ponds of the Central Polissia region. The seasonal phytoplankton development and ecological characteristics of algae water quality of ponds were moderate. Phytoplankton assemblages were characterized by high biodiversity, differentiated structure, and differences in dominant species, which highlight the critical role of artificial water bodies in biodiversity. Understanding the changes in phytoplankton communities of artificial water bodies may contribute to understanding the directions of management of these water bodies and provide reference data for wider research.

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