PHYTOPLANKTON COMMUNITIES IN ECOLOGICAL ASSESSMENT OF LACUSTRINE ECOSYSTEMS IN THE WETLAND SLAVYANSKY RESORT, UKRAINE

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Abstract: We recognized 350 species and infraspecific taxa of algae from nine taxonomic Divisions (Cyanoprokaryota, Euglenophyta, Chrysophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta and Charophyta) in 121 phytoplankton samples collected during 2007–2013 from seven lakes in the wetlands of the Regional Landscape Park Slavyansky Resort. Among them, we selected fourteen dominant species of algae with more than 75% abundance and characterized their habitats with bio-indication methods in respect of substrate preference, temperature, oxygenation, pH, salinity, organic enrichment, N-uptake metabolism and trophic states. Most active species were salt-tolerant and confined to the slightly alkaline water, with a moderate content of dissolved oxygen and low organic pollution, which characterize the unique environment of these protected saline lakes. Despite the fact that the ecologically active species do not exceed 5% of the recorded species diversity, they constitute the major part of algal abundance and biomass. Therefore, monitoring of dominant species is the most direct way for adequately assessing the ecological state of the protected water bodies in the wetlands.

Keywords: bio-indicators, lakes, phytoplankton, protected area, salinity, Ukraine

Introduction:

Insofar as dynamics of planktonic algae is most sensitive to environmental conditions, their ecological characteristic is essential for assessment of water bodies in general and of wetlands in hot dry climate in particular (Barinova et al. 2009, 2011; Barinova and Nevo 2012). The necessity of environmental impact assessment for reservoirs with reserve status is obvious and algal bio-indication is most effective for this purpose. The algal diversity research in the Regional Landscape Park Slavyansky Resort formed under periodic desiccation as well as various anthropogenic impacts have been studied sporadically since the second half of the 17th century and more regularly by us since 2007 (Lyalyuk and Klymiuk 2011; Klymiuk et al. 2014; Barinova et al. 2014). Phytoplankton is one of the biological quality constituent to be assessed according to the Water Framework Directive (Milestone 6 report – Baltic Sea GIG 2006). Quantitative variables of plankton communities reflect the general

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conditions of algal growth while the dominant species as the most ecologically active ones characterize optimal conditions. According to Yurtsev (1968) the group of active species, more sensitive than the overall species composition, conveys the correspondence between community and the environment in which it was formed. The assessment of the status of water bodies using ecological activity of algal species is exemplified for diatoms by Kharitonov (1981) in the north of Magadan region, Akhmetova (1986) in the East Balkhash Lake and Svirid (2000) in the biospheric Berezinski reserve; for Cryptophyta of Ukraine - by Gorbulin (2011), for algal flora of reservoirs in West Siberia by Valeyeva (2011), and for the algae of the Listvenka brackish lake in the reserve "Khakassia" by Naumenko and Makeeva (2011).

The aim of this work was to determine the most active species of planktonic algae and preferred conditions of their habitats for environmental assessment of ecosystems in the lakes of protected wetlands in the Regional Landscape Park Slavyansky Resort.

Materials and methods:

Description of study site

The studied lakes Ripne, Veysove, Garache, Slipne, Levadne, Chervone and Ozero are mostly of thermokarst origin, small, and shallow (Fig. 1). These lakes are insulated from each other and some of them periodically dry up. Sediments of the lakes are diverse varying from sand to medical mud. Water is slightly yellow or colourless with pH 6.3–8.0, and conductivity is 1.31–11.26 mS/cm. The depth of the lakes is negligible (about 0.5–2.5 m) and only in the lake Ripne does it reach 8.5 m. They form a unique community of organisms, including algae, which are the basis for the formation of therapeutic mud. In the lake Ripne there is industrial fishing for mud and brine mud baths for the Slavyansky Resort – one of the oldest mud-bath resorts of Ukraine (Kurulenko and Tretyakov 2008). The species' composition of the lakes was divided in two groups of distinct communities (Klymiuk et al. 2014):

- the northern group of deeper perennial lakes Ripne, Veysove, Garache and Slipne;
- the southern group of smaller partly ephemeral lakes Levadne, Chervone and Ozero.

Sampling and Laboratory Studies

The material for this work comes from samples collected monthly during 2007–2013 in lakes Ripne, Veysove, Garache, Slipne, Levadne, Chervone and Ozero. Phytoplankton samples were collected in the littoral and profundal zones of the lakes. The algae studied in live and fixed (4% formaldehyde solution) states, using light microscopes MBI-3 and Micros MC 50 (Austria) with magnification of 40X–90X (with immersion). Determination of algal species was performed using international series determinants of marine and freshwater algae.

Conductivity and pH was analyzed with ionometric method; hardness, alkalinity, free alkalinity, HCO_3^-, and Cl^- – with the titration methods (Globan 1987). Elementary analysis was conducted with ICP-OES on Shimadzu ICPE-9000 equipment.

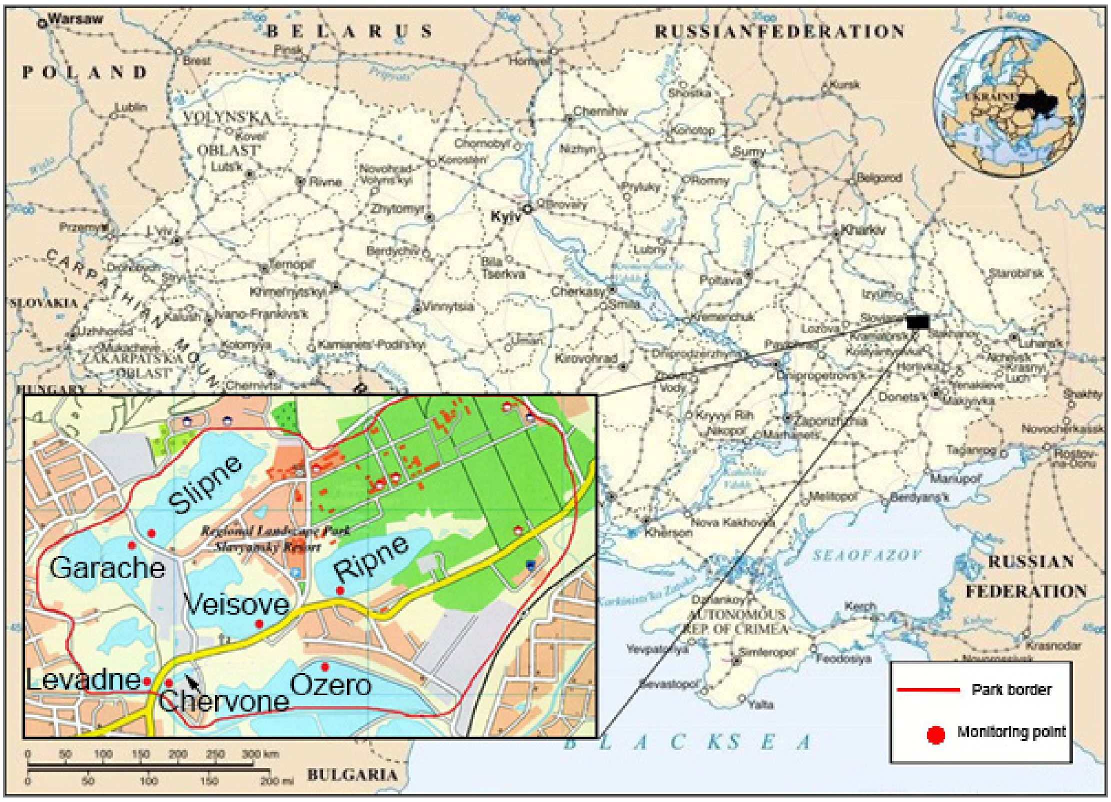
The ranks of species activity were assessed according to Yurtsev's scale (1968), with modifications:

- especially active, 75-100% of the total individuals in the sample;
- highly active, 50-75%;
- moderately active, 15-50%;
- least active, 0-15%.

The ranking of species activity was determined for each sample, than generalized for the sampling area as a whole.

The ecological characteristics of active algal species were obtained from the database compiled for freshwater algae of the world on the basis of multiple analyses of algal biodiversity by S.S. Barinova et al. (2006), added with the data from Ter Braak and Šmilauer (2002) and Van Dam et al. (1994), with respect to substrate preference, temperature, oxygenation, pH, salinity, organic enrichments, N-uptake metabolism and trophic states. The ecological groups were separately assessed according to their significance for bio-indications. Species that respond predictably to environmental conditions were used as bio-indicators for particular variables of aquatic ecosystems, the dynamics of which are related to environmental changes.

Figure no. 1 Study site in the Regional Landscape Park Slavyansky Resort



Results and discussion:

We studied 121 phytoplankton samples from seven lakes of the Regional Landscape Park Slavyansky Resort collected in May-November 2007, March-November 2008 and April 2012-June 2013.

Altogether 334 species of algae (350 species and infraspecific taxa) from nine taxonomic Divisions (Cyanoprokaryota, Euglenophyta, Chrysophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta and Charophyta) have been recorded by our sampling (238 species and infraspecies) with addition from published sources (Klymiuk et al. 2014; Tsarenko et al. 2006, 2009).

Water in the lakes is quite hard, slightly alkaline, with a high content of chlorides and conductivity which varies widely (1310–11260 µS/cm^{-1}) from lake to lake and depending on the season (Tab.1, Annexes).

The analysis of average seasonal abundance and biomass showed that the trophic state of the lakes ranges from mesotrophic to eu-polytrophic (Tab. 2, Annexes). It should be noted that full compliance of the trophic state estimates based on abundance and biomass was observed only for the lakes Slipne, Levadne and Ozero.

For a follow-up analysis, we chose species that represented more than 50% of abundance in community in optimal conditions (Tab. 3, Annexes). The most abundant species were the diatoms *Chaetoceros muelleri* (6–13·10^3 cells L^{-1}) in lakes Slipne and Levadne, *Cyclotella stelligera* (about 8·10^3 cells L^{-1}) in lake Levadne, dinophyte *Peridiniopsis oculatum* (about 4·10^3 cells L^{-1}) in lake Ripne, and green algae *Ankyra ocellata* (about 1–2·10^3 cells L^{-1}) in lakes Veysove and Garache. All these are highly tolerant species with wide ecological amplitude, except the most abundant *Chaetoceros muelleri* that prefers saline waters as has been revealed by the bio-indication approach (Klymiuk et al. 2014).

Species activity ranking according to Yurtsev's scale (1968) helps us to reveal species that prosper in a given type water bodies and climatic conditions. For the ecological assessment of the lakes environment we divided the species into four ranks of activity: especially active, highly active, moderately active, and the least active, of which the especially active species indicate optimal condition.

Especially active species were found in the lake Garache in which they amounted to 4.96% of the total species list and highly active forms of 0.83%, but comprising about 99% biomass (Tabs. 3 and 4, Annexes).

Five especially active species (2.84% of total species) and 1.14% of highly active species were revealed in the lake Veysove. In lake Slipne there are four especially active species (1.77% of the total species number), and two highly active (0.88%). The lakes Ripne and Levadne contain two especially active species each, representing 1.12% and 3.39% of the total species' number respectively. Six highly active species (3.35%) are revealed in the lake Ripne whereas in the lake Levadne this group is not registered. In lakes Chervone and Ozero no especially to highly active species have been recorded.

In lake Ripne the especially active species ecology *Oocystis lacustris* and *Peridiniopsis oculatum* occupy the plankton and plankton-benthic habitats (Tab. 3, Annexes) characteristic of a low- to moderately oxygenated, brackish conditions, of medium level of organic pollution.

The especially active species of the lake Veysove (*Ankyra ocellata*, *Chaetoceros muelleri*, *Cylindrotheca closterium*, *Cymbella tumidula* and *Lyngbya maior*) are benthonic, planktonic or occasionally epiphytic, preferring a moderate temperature, medium oxygenated brackish water, slightly contaminated with organic substances (Tab. 3, Annexes).

The lake Garache species *Ankyra judayi*, *A. ocellata*, *Cymbella tumidula*, *Dunaliella salina*, *Gymnodinium uberrimum* and *Pseudoschroederia robusta* are especially active in planktonic, benthic or epiphytic habitats. They photosynthesize in brackish slightly alkaline waters with various oxygen contents, moderately polluted with organic substances.

Chaetoceros muelleri, *Hyaloraphidium contortum* var. *tenuissimum*, *Monoraphidium minutum*, *Peridiniopsis oculatum* are especially active in the plankton and benthos of lake Slipne where they prefer brackish water with a sufficient level of dissolved oxygen, moderate temperature and moderate level of organic pollution.

In the lake Levadne the especially active species *Chaetoceros muelleri* and *Cyclotella stelligera* are confined to plankton-benthic habitats of brackish, slightly alkaline moderate temperature water with a low level of dissolved oxygen and insignificantly organically polluted.

The ecology of especially active species in lakes Ripne, Veysove, Garache, Slipne and Levadne is congruent with the chemical parameters of the water (Tab. 1, Annexes). In lakes Chervone and Ozero no especially active species have been recorded so far (Tab. 4, Annexes). These lakes are most susceptible to drying of all the studied in the Park, which can explain their unusual species composition and phytoplankton abundance (Klymiuk et al. 2014).

Pearson's correlation analysis between the number of species in community and number of especially active species revealed a direct correlation between these variables (0.67*). Figure 2 shows that much more active species thrive in the richest communities of the four deeper lakes of the northern group.

The best representation of especially active species in the deep lakes Ripne, Veysove, Garache and Slipne is correlated with a general increase in species richness in these lake's algal communities, in turn inversely correlated with salinity (Fig. 3) (Klymiuk et al. 2014).

Figure no. 2 Ratio of the total species number, especially active species and conductivity in the Slavyansky resort lakes

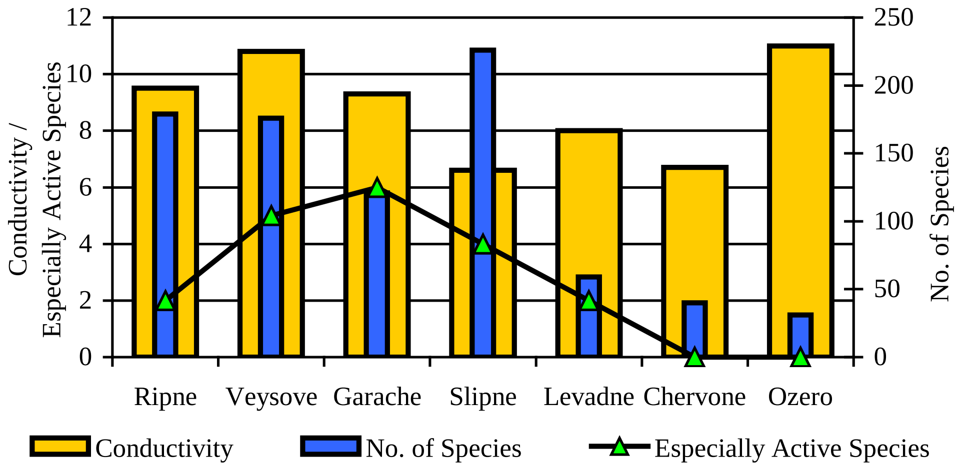
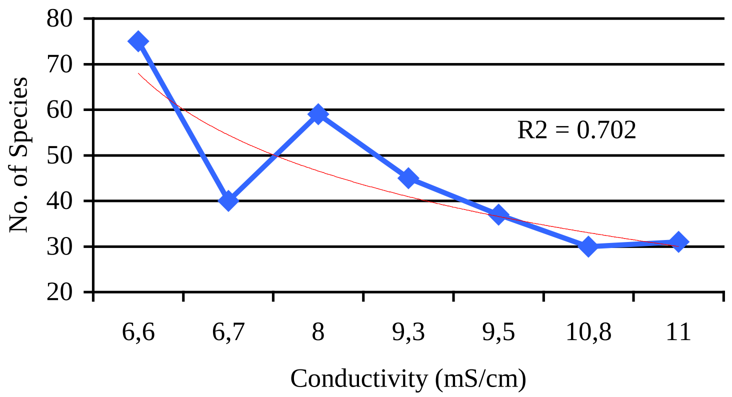


Figure no. 3 Relationships between species numbers and water conductivity in the Slavyansky resort lakes



Salinity is the major regulating factor not only in relation of the total number of species in algal communities under salinization impact (Barinova et al. 2010a, 2011; Naumenko and Makeeva 2011; Klymiuk et al. 2014), but also the phytoplankton abundance and biomass (Krupa et al. 2014), as well as composition of dominant species (Barinova et al. 2010b, 2011; Naumenko and Makeeva 2011). The species most active in such saline-brackish environment can be effectively used as bio-indicators to monitor the state of ecosystems in protected water bodies (Barinova et al. 2010b).

Conclusions:

The ecological assessment of seven lakes in the protected wetland of Slavyansky Resort using of species activity approach is based on fourteen especially active species (of Yurtsev's 1968 classification). They constitute 1.12% to 4.96% of the total species number, but more than 75% of phytoplankton population. Based on the ecology of these species, it can be concluded that the conditions in the deeper lakes of the northern group (Ripne, Veysove, Garache and Slipne) are mesotrophic-eutrophic promoting the development of plankton-benthic-epiphytic communities. The greens and diatoms among them prefer moderately oxygenated brackish water with a medium level of organic pollution. In the partly or completely desiccate lakes of southern group (like lake Levadne, eutrophic), the fresh-brackish slightly alkaline moderate temperature waters with a low level of dissolved oxygen and insignificant organic pollution the plankton-benthic communities are dominated by diatoms. Since the especially active species make up the bulk of abundance and biomass of a complex lake community, it is possible to single out a small number of species allowing a rapid assessment of ecological changes. Therefore we arrive at an express method of environmental assessment as a part of the program of wetland lakes monitoring and protection (for instance the one carried out in the U.S.A. Citizen Lake Monitoring Program Handbook, 2013). Most active species from the lakes of Slavyansky Resort wetlands are salt-tolerant, which corresponds to the unique environment of these mineralized partly desiccated lakes, with salinity on increase.

Rezumat:

EVALUAREA ECOLOGICĂ A COMUNITĂȚILOR DE FITOPLANCTON ÎN ECOSISTEMELE LACUSTRE DIN ZONA UMEDĂ STAȚIUNEA SLAVYANSKY, UCRAINA

Au fost observate 350 de specii și taxoni infraspecifici de alge aparținând la nouă încrengături (Cyanoprokaryota, Euglenophyta, Chrysophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta și Charophyta), colectate din 121 de probe de fitoplancton în perioada 2007-2013 din șapte lacuri din zona umedă a Parcului Regional Stațiunea Slavyansky. Dintre acestea au fost selectate 14 specii de alge dominante, cu o abundență mai mare de 75% și s-a realizat caracterizarea habitatelor prin folosirea metodei de biosemnalizare în ceea ce privește substratul, temperatura, oxigenarea, pH-ul, salinitatea, dezvoltarea masei organice, metabolismul azotului absorbit și statutul trofic. Cele mai multe dintre speciile active au fost tolerante față de salinitate, dar limitate de apa slab alcalină, cu un conținut moderat de oxigen dizolvat și o poluare organică scăzută, condiții care caracterizează aceste lacuri sărate cu statut de protecție. Chiar dacă speciile active din punct de vedere ecologic nu depășesc 5% din numărul total de specii observate, totuși ele participă în cea mai mare parte la abundența și biomasa algelor. De aceea, monitorizarea speciilor dominante reprezintă calea cea mai directă pentru a evalua starea ecologică a apei din zonele umede.

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Annexes:

Table no. 1 Amplitudes of physico-chemical parameters at the studied lakes

Variable	Ripne	Veysove	Garache	Slipne	Levadne	Chervone	Ozero
Hardness, mg-eq L^{-1}	8.8-72.4	62.25-96	7.9-73.0	8-23.3	18.6-32.2	8.7-19.6	72.7-126
Free Alkalinity, mg-eq L^{-1}	0-0.3	0-0.32	0-0.4	0-0.4	0-0.1	0-0.5	0-0.4
Alkalinity, mg-eq L^{-1}	1.5-2.9	2.5-4.2	3.6-7.7	2.5-5.8	3.1-9.3	6.3-6.9	2.4-3.5
HCO_3^-, mg L^{-1}	85.4-160.8	134.2-256.2	219.6-541.4	134.2-353.8	189.1-561.2	353.8-420.9	140.3-195.2
Fe, mg L^{-1}	0-0.0096	0-1.31	0	0	0	0	0
Zn, mg L^{-1}	0	0-0.3	0	0	0	0	0-0.0457
Ba, mg L^{-1}	0-0.26	0-0.363	0-0.2	0-0.15	0	0	0
Li, mg L^{-1}	0-0.248	0-0.963	0-0.399	0-0.206	0	0	0.262-0.886
Mn, mg L^{-1}	0-0.0906	0.022-1.8	0-0.109	0-0.117	0	0	0-0.359
B, mg L^{-1}	0-3.72	0-12.5	0-9.45	0-13	0-0.616	0-0.507	0-5.6
S, mg L^{-1}	119-1350	905-1800	277-1570	155-592	295-679	91.2-333	955-1940
Si, mg L^{-1}	0-10.3	1.52-16.8	2.01-15.7	0-18.8	4.68-10.2	4.55-12.9	0-8.74
Sr, mg L^{-1}	1.13-28.3	13.4-38.1	2.32-23.9	0.983-7.28	2.47-6.51	1.12-4.18	16.2-28
K, mg L^{-1}	2.15-266	29.6-318	13.3-265	11.5-260	5.9-27.4	4.51-67.9	75.9-207
Mg, mg L^{-1}	19.7-276	100-263	71.6-202	35.9-217	74.5-131	27-78.3	126-319
Ca, mg L^{-1}	123-2250	1020-2930	159-1440	79.6-388	230-458	120-305	1140-2160
Na, mg L^{-1}	813-15800	14800-40000	641-28800	453-2390	327-9130	91.2-5000	16300-38200
pH	7.1-7.9	6.3-7.6	6.6-7.9	7.1-8	6.7-7.6	7.4-7.5	6.7-7.3
Conductivity, µSm cm^{-1}	5210-10280	10450-11080	4980-10980	3590-7230	3400-9810	1310-8890	10840-11260
Cl^-, mg L^{-1}	11675-26342.4	28500-47040	3822-24650	1725-4586.4	6700-9300	4325-5575	24750-35500

Table no. 2 Major biological variables of the Slavyansky Resort lake communities and classification by trophic state according to Dokulil, 2003

Variable	Ripne	Veysove	Garache	Slipne	Levadne	Chervone	Ozero
No. of Species	4-36	3-42	1-31	3-56	12-29	13-21	12-15
Abundance, cells L^{-1}	412·103	2022·103	11797·103	3666·103	5977·103	641·103	470·103
Abundance Trophic state	Mesotrophic	Eutrophic	Eu-polytrophic	Eutrophic	Eutrophic	Meso-eutrophic	Mesotrophic
Biomass, mg L^{-1}	1.83	1.13	1.38	3.86	2.32	0.93	1.11
Biomass Trophic state	Meso-eutrophic	Mesotrophic	Mesotrophic	Eutrophic	Eutrophic	Mesotrophic	Mesotrophic

Table no. 3 Percentage of especially active species and their ecology in the algal communities of the Slavyansky Resort lakes

Species	Lakes					Hab	T	Oxy	Sal	pH	D	S	Het	Tro
	1	2	3	4	5									
Ankyra judayi			99			Ep						b		
Ankyra ocellata		75-90	93-97			Ep			oh					
Chaetoceros muelleri		99		79	94	P-B	temp	st-str	hl	alb		o		e
Cyclotella stelligera					95	P-B		st	i	ind	es	x		
Cylindrotheca closterium		82-95				B			mh					
Cymbella tumidula		83	83			B		str	i	alf		o	ats	
Dunaliella salina			76-87			P		st	mh					
Gymnodinium uberrimum			82									x-b		
Hyaloraphidium contortum var. tenuissimum				92		P-B			i			b		
Lyngbya maior		81				P						b		
Monoraphidium minutum				81		P-B		st-str				b-a		
Oocystis lacustris	76-92					P-B		st-str	hl			b-o		
Peridiniopsis oculatum	99			77		P		st						
Pseudoschroederia robusta			92-99			P-B		st-str	i			o-a		

Note. Lakes: 1 – Ripne; 2 - Veisove; 3 - Garache; 4 - Slipne; 5 - Levadne. Ecological types (Hab): B - benthic; P-B - planktic-benthic; P - planktonic; Ep - epiphytic. Temperature (T): temp - temperate. Streaming and oxygenation (Oxy): st - standing water; str - streaming water; st-str - standing-streaming. Salinity (Sal): mh - mesohalobe; oh - oligohalobe; i - oligohalobious-indifferent; hl - oligohalobious-halophilous. Acidity (pH): ind - indifferent; alf - alkaliphil; alb - alkalobiont. Saprobity (Watanabe et al. 1986) (D): es - eurysaprob. Saprobity (Pantle and Buck 1955) (S): (x - xenosaprob; x-b - xeno-betamesosaprob; o - oligosaprob; b-o - beta-oligosaprob; o-a - oligo-alphamesosaprob; b - betamesosaprob; b-a - beta-alphamesosaprob. Nitrogen uptake metabolism (Het) (Van Dam et al. 1994): ats - nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen. Trophic state (Tro) (Van Dam et al. 1994): e - eutraphentic.

Table no. 4 Number of species of different degrees of activity in the Slavyansky Resort lakes

Lake	Especially active	Highly active	Moderately active	Least active	Total number of species
Garache	6	1	11	103	121
Veysove	5	2	11	158	176
Slipne	4	2	12	208	226
Ripne	2	6	12	159	179
Levadne	2	0	4	53	59
Chervone	0	0	6	34	40
Ozero	0	0	7	24	31