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Rehabilitation of surface water of the Savvinsky pond (Moscow) using algolization method with Chlorella Kessleri BPKM A_{1-11} ARM strain.

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Abstract: The study is based on the evaluation of the effectiveness of the alga *Chlorella Kessleri* BPKM A_{1-11} ARM used as a phytoepurator in the surface waters of the Savvinsky pond having experienced the «algal blooms». Analyses were carried out under an optical microscopy for a period of four years, at the rate of three samples per year and the taxonomic proportions were determined according to the Pantle & Buck method. The results show a progressive decrease in organic pollution given by the variation of the saprobity index «S» with a low negative slope of -2%. The water quality was restored with the oxygen concentration close to saturation between 7.5 and 9.6 mgO_2/L. The S values at the end of the algolisation process vary between 1.42 and 1.50 corresponding respectively to the water quality 2b «Completely clean» and 3a «Sufficiently clean». The analysis of the graphs in linear coordinates shows histograms with taxa dominant to more than 29.2% (diatoms) and 25% (cyanobacteria) before rehabilitation and low dominance up to 15% at the end of the rehabilitation process. We note the effectiveness of the algolization with the complete elimination of the «algal blooms» which returns the pond to a stable and reversible ecological state. However, the graphs in logarithmic coordinates with α varying between $-1.52 < \alpha < -0.89$, show that despite the rehabilitation, the pond is subjected to an «Environmental Stress» with an «Average» load.

1. Introduction

The scale of anthropogenic activities, regional and global climate changes, pose a real threat to aquatic ecosystems, in particular for aquatic fauna and flora. These therefore compromise the viability of aquatic ecosystems and water quality (Bogdanov, 2008; Chen *et al.*(2021). The assessment of the quality and ecological state of surface waters, as well as their transformation under the effect of a set of natural and anthropogenic factors, is becoming more and more urgent (Karomat, 2014).

Phytoplankton, which includes microalgae and phototrophic bacteria participate at 50% of the world's primary production and thus play a major role in the sequestration of atmospheric carbon dioxide (Seidl and Mouchel, 2003). Due to their extensive specific cell surface, microalgae have particularly interesting absorption capacities for the decontamination of polluted environments and the fight against eutrophication (Chen *et al.*(2021), Varon and Mara, 2004). The high growth rates of microalgae, associated with their nitrogen and phosphorus absorption capacities, can thus be taken advantage of for the purification of urban or industrial waters or livestock effluents (Boutin *et al*. (1997); Karomat, 2014).

They have long been used in lagooning processes – which use aquatic plants as purifying agents**.** In these polluted environments, they maintain cooperative or even synergistic relationships with the bacteria, which increase the purifying efficiency of the system (Chumanchenko *et al*.(2016). The oxygen produced by the microalgae promotes a reduction in the energy expenditure linked to its continuous supply in the so-called activated sludge systems (Batrachenko *et al*.(2020). The use of microalgae for the depollution of heavy metals has also been considered and would lead to higher potential performances and at a lower cost, compared to more conventional treatment technologies (Cauchie, 2000; Chen *et al.* (2021).

This ability to concentrate the metallic elements by bio-sorption and by bioaccumulation suggests not only applications in the detoxification of polluted environments, but also processes for the recovery of metals of interest such as gold, or even the sequestration of radioactive elements (Batrachenko *et al*. 2020; Karim *et al.*, 2016). To date, about twenty species of microalgae are cultivated for valorization purposes, mainly for aquaculture and agri-food (Evans and Saleh, 2015). Some of the microalgae belong to the «green lineage» which is at the origin of all terrestrial plants and which is characterized by the presence of a green plastid (Dekayir, 2008). In comparison with terrestrial plants and bacteria, microalgae are at the dawn of biotechnologies whose applications are proving to be as varied as promising for food, health, energy or even bioremediation (Varon and Mara, 2004; Ouahabi *et al.*, 2024).

The present article aims to verify the effectiveness of a microalgae genus *Chlorella*, strain *Chlorella Kessleri* BPMK A_{1-11} ARW used in a bio-remediation process to combat the «algal blooms» of ponds in the Balashikha region (Moscow, Russia). To achieve this, the most reliable way is based on the bio-indication method (Antsiferova, 2023; Bogdanov,1997). This gives a global idea of the state of biodiversity in the aquatic ecosystem through the population of phytoplankton and cyanobacteria communities found there (Barinova and Medvedeva, 1996). Among the most recognized bio-indicators in ecological monitoring, we note diatoms and cyanobacteria which constitute the main habitats of aquatic environments (Razumovsky, 2022). Diatoms, following their very short life cycles, constitute size indicators of various changes that take place in the ecosystem over time and space. These two communities therefore give the idea about the ecological and biological state of an aquatic ecosystem (Karomat, 2014).

To identify and understand the transformations of modern aquatic ecosystems, the method of graphical comparison of taxonomic proportions in diatom complexes is used to have an image on the evolution of aquatic ecosystems in different climatic environments and landscapes (Batrachenko *et al*.(2020). It is on the basis of the analysis of diatoms that there is a real possibility of identifying the criteria for the global assessment of the impact of the negative charge on natural ecosystems, as well as scenarios for the transformation of these ecosystems over time and space (Bespalova, 2019; Razumovsky, 2022).

It also makes it possible to evaluate the orientation of changes in the qualitative characteristics of waters and to identify their transitions through critical status**.** This article will focus on one of the monitoring methods which are based on graphical methods in two forms, one in linear coordinates and the other in double logarithmic coordinates.

2. Methodology

2.1 Sampling points.

Savvinsky pond is located in the suburbs of Moscow in the Balashikha region. It is crossed from north to south by the Black river (Chornaya) which then flows into the large Perkhorka river, located further south of the city of Moscow. Savvinsky has a perimeter of 2180 m, an area of 92459 m^2, a volume of 462295 m^3 with a depth varying between 2 and 5 m. Three points have been targeted to carry out the sampling of surface waters of this pond (**Figure 1**).

Figure 1: Pond surface water sampling points with their coordinates (Satellite picture, 2020).

2.2 Materials

The equipment used in conducting this research work includes the following:

- → Optical microscopy
- → Microsoft Excel software
- → Statistics analysis with SPSS 20.

2.3 Methods

The material comes from the microscopic analysis of surface water samples from the Savvinsky artificial pond in the suburbs of Moscow. The pond is located between 55° 43’59" N and 38° 01’54" E with a water surface of 116228 m^2. The analysis was carried out three times a year following the growing seasons of phytoplankton and cyanobacteria respectively in May/June, August and September from 2017 to 2020. The saprobity index was calculated according to the method of Pantle & Buck modified by Sladecĕk, where "S" is given by the formula in Eqn 1 (Antsiferova and Nkurunziza, 2023).

$$S = \frac{\sum sh}{\sum h} \qquad \textbf{Eqn 1}$$

Where **Σ*sh***: *the sum of the product of the saprobity index of the species and its relative abundance and* ***Σ h:*** *the sum of the relative abundances of the species.*

When constructing graphs, the number corresponding to the number of identified taxa is plotted on the X-axis, and the relative number inherent in the given taxon in the analyzed complex is plotted on the Y-axis. In this case, the taxa are classified according to the variation in the indicator of relative abundance in the direction of its decrease: from the most massive taxa to the last rarest of them (Barinova *et al.*(2010).

In a linear coordinate system, we obtain a graph (or a histogram) of the ratio between the total number of taxa and their relative number (proportions in percentage) in the decreasing direction of the latter. In the logarithmic coordinate system, the resulting lines can be constructed in two ways: taking into account the entire spectrum of taxa (so as not to lose part of the information) or only taking into account the dominant and concomitant taxa. For the present article, the entire spectrum has been taken into account, due to the fact that we are in the presence of very few taxa. In all the cases, in the logarithmic coordinate system, the coefficient of determination (R^2) has been calculated for the resulting lines, which makes it possible to evaluate the statistical reliability of the graphic constructions carried out. The validity is estimated from the correlation coefficient « *r*», which must be greater than 0.75 (i.e. R^2> 0.57) (Razumovsky, 2022).

3. Results and discussion

3.1. Saprobity index

The results of the saprobity index given in **Table 1,** show a slight variation in this index in an interval of 1.42 for good quality waters and 2.18 for those of low quality.

Table 1. Saprobity index, water quality, water temperature and dissolved oxygen of the Savvinsky pond by month and by year from 2017 to 2020**.**

		Index	**Water quality**				**Parameters**	
Year	**Month**	**Saprobity index S**	**Clean (2a)**	**Sufficiently clean (3a)**	**Slightly polluted (3b)**	**Polluted (4a)**	**Water Temperature ^{0}C**	**Dissolved oxygen mgO$_2$/L**
2017	June	1.65	-	x	-	-	19	9,2
	August	1.90	-	x	-	-	19	9
	September	1.68	-	x	-	-	22	8
2018	June	1.96	-	x	-	-	19	8,3
	August	1.90	-	x	-	-	22	8,1
	September	2.18	-	-	x	-	21	7,5
2019	June	1.86	-	x	-	-	16	9
	August	1.86	-	x	-	-	21	8,7
	September	1.91	-	x	-	-	22	8,2
2020	June	1.72	-	x	-	-	18	9,1
	August	1.42	x	-	-	-	21	9,6
	September	1.50	-	x	-	-	21	9,5

The trend curve (**Figure 2**) has an overall negative slope of 2% during the entire rehabilitation process and a poor correlation coefficient R^2 = 0.14. Although low, this slope attests to the positive results and the success of the algolization process with the decrease in organic water pollution as shown by the saprobity index S which is below 1.5 in September 2020. These results perfectly corroborate with those of Barinova who showed that algolization is a continuous process that takes a long period ranging from 3 to 4 years (Bogdanov, 2008; Antsiferova and Nkurunziza, 2023). At this value, the water in the Savvinsky pond is completely clean and does not «algal blooms». Considering the degree of crisis of ecosystems, the pond is at a reversible degree of stability.

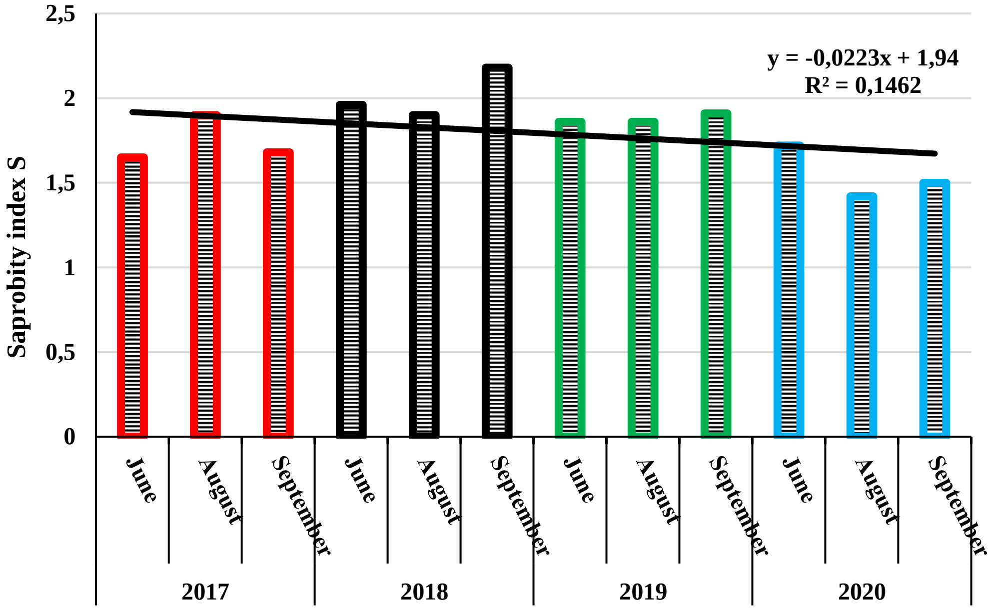

Figure 2: Variation of the saprobity index during the algolisation process.

3.2. Temperature

The temperature plays a preponderant role in the algolisation process, because the photosynthesis of microalgae and cyanobacteria and many other plants depend on it. High temperatures observed in summer 2018 (**Table 1**) had an impact on water quality with the increase in the values of the saprobity index up to 2.18 in September 2018. We noticed the multiplication and the net dominance of cyanobacteria species with peaks that reached more than 23%. This has caused a change in the ecological niche that is not favorable to the multiplication of diatoms.

3.3 The quality of the surface water

It is given by the values of the saprobity index. Except for the month of September 2018 with a water quality 3b «Slightly polluted», for the entire period of algolisation, the pond experienced a water of good quality 3a «Sufficiently clean ». The best results were observed in August 2020 with a water quality 2b «Completely clean» with S equal to 1.42. With this quality the water is well rehabilitated and can be used in leisure activities such as swimming and even for consumption after treatment.

3.4. Dissolved oxygen

The oxygen concentration is one of the parameters of the surface water quality. This parameter is much related to the variation of the temperature and to the multiplication of algae. With regard to the dissolved oxygen concentration values, the rehabilitation of the surface waters of the Savvinsky pond was successful because the concentration of dissolved oxygen gradually increased during the algolization process. The pond is therefore saturated with oxygen at more than 9.6 mgO_2/L which is a indication of the good health of the pond favorable for the life of animals requiring oxygen saturation such as fish. This testifies to the decrease of blue algae (cyanobacteria) that consume this oxygen during the oxidation process (Chen *et al*., (2021); Daniele *et al*.(2020).

3.5. Graphs in linear coordinates.

Thus, to study the taxon complexes of ponds, the analysis by diagrams gives an idea of the impact of natural or anthropogenic influences on the abundance of taxa by highlighting the dominant species in percentage in the pond (Karomat, 2014; Antsiferova and Nkurunziza, 2023).This information facilitates the work of monitoring the ecological evolution of the pond. In a linear coordinate system, the graph is analyzed taking into account the contours of the histograms and the distribution of abundant taxa. The dominant taxa (from 8 to 10% and more), the concomitant taxa (from 1 to 2%) represent a kind of stable set and adapted to the environment, and the «chaotic» part of the taxon complex is located at the back of the histogram (**Figure 3 and Figure 4**). They are representatives of taxa whose presence or absence in each biotope is sporadic or random.

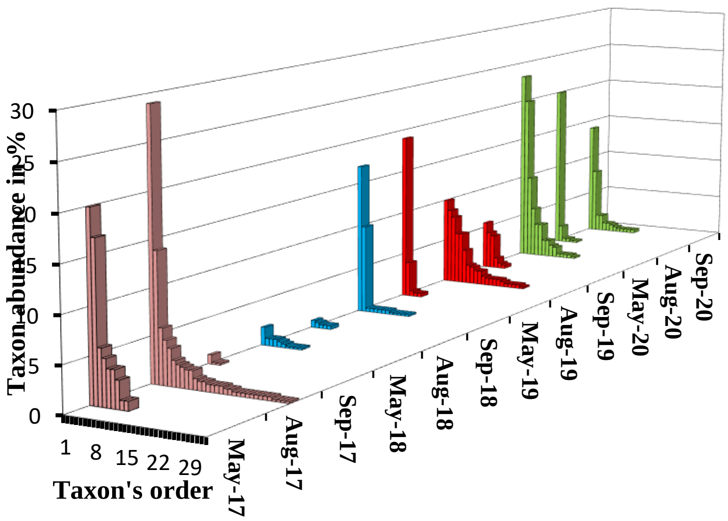

Figure 3. Taxonomic structure of diatom complexes (Linear coordinate system).

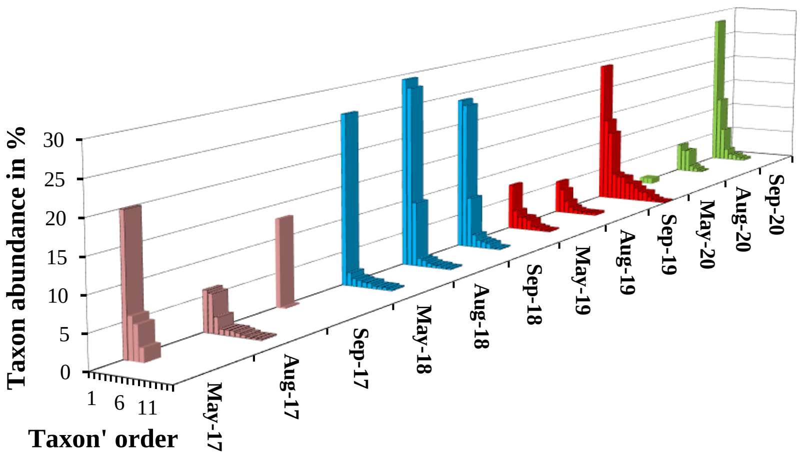

Figure 4. Taxonomic structure of cyanobacteria complexes (Linear coordinate system).

Thus, by analyzing the ecological situation of the Savvinsky pond during the growing seasons from 2017 to 2020, we note that in general, diatoms are very abundant from the beginning of the growing season in May and reach the maximum in August. They are almost absent at the end of the growing season (**Figure 3**); where there is a dominance of one or two taxa characteristic of conditions not favorable to the multiplication of diatoms. At the end of the growing season, the diatoms decrease in favor of the multiplication of cyanobacteria (**Figure 4**). Diatoms and cyanobacteria have different life cycles and are competing with each other (Evans and Saleh, 2015; Barinova *et al.* (2010). During the algolisation, we note that the mono-dominance processes have been reduced; the peaks on the histograms have decreased smoothly from September 2017 to September 2020 with peaks of minus 15%.

In case of natural and anthropogenic impact on the ecosystem, the type of logistic trend is replaced by the exponential trend. The shape of the histogram's changes from sigmoid (with the relative number of the first taxon up to 20%) to concave (with the relative number of the first taxon up to 40%) and there are dominance peaks of 1-2 taxa (Bespalova, 2019; Chumachenko *et al.*(2016).

The analysis of the variation of the taxa and the shape of the histograms shows that in general during the four years of algolisation, most of the histograms have sigmoid shapes (convex - concave) with peaks of the first taxon < 20%. According to the criteria for evaluating the level of load on the aquatic ecosystem and its state in a linear coordinate system, the pond is qualified in «Background state» (Bespalova, 2019). Considering the evolution per year and per growing season, the variation of the ecological state depends on abiotic factors such as temperature, carbon dioxide (CO_2), dissolved oxygen and others.

In July 2017, the histogram is sigmoid in shape with the first taxon which has a peak of < 20% testifying to the good quality waters (**Figure 3**)**.** The saprobity index is 1.65 with the charge quality 3a «Sufficiently clean» (**Table 1**).

In August, the histogram changes shape and becomes concave (exponential trend type) with the peak of the first taxon *Fragilaria construens* (Ehr.) Grun., which reaches 28%. The saprobity index increases slightly up to 1, 90. Cyanobacteria are less abundant there with the peaks of the first taxa < 20% (**Figure 4**). The opposite effect is noticeable at the end of the 2017 growing season until the middle of the 2018 growing season. At this period, sigmoid-shaped histograms are observed, with a clear dominance of cyanobacteria, the first taxa observed of which have abundance «Very often» such as *Rhabdoderma lineare* Schmidle and Laut. Emend. Hollerb., in May, *Microcystis aeruginosa* Kütz. Emend. Elenk., and *Microcystis wesenbergii* Komarek in August with peaks >25%.

Diatoms are almost absent. This is partly explained by the slightly elevated water temperature 22°C (**Table 1**) which was a limiting factor for their development in August 2018. Only one taxon was able to develop up to 17% *Navicula lanceolata* (Ag.) Kütz. (β-α) with an average abundance «Often».

On the contrary, cyanobacteria increase during this period. The saprobity index has changed slightly with values between 1.96 and 1.90 respectively for May and August 2018. The histogram takes the concave shape and the first taxon reaches a peak of 16%. This testifies to a change in the ecological niche with an impact on the saprobity index, the value of which has increased up to 2.18 corresponding to the quality of charge 3b «Slightly polluted». The peak of the first taxon for cyanobacteria remains high at more than 20%, which shows that the pond is under «Environmental stress» following a slight anthropogenic load.

In 2019, the histograms acquired a sigmoid shape (logistic trend line type), the proportion of species with average abundance estimates increased especially in August for diatoms (**Figure 3**). The peaks of the first diatom taxa decreased smoothly, reflecting the most optimal conditions for the development of the pond ecosystem. For the entire growing season, the saprobity index remained little variable between 1.86 for the months of May and July, and 1.91 for the month of September with the water quality 3a « Sufficiently clean ». The increase in the saprobity index observed in September is due to the dominance of the taxon *Merismopedia tenuissima* Lemm, (β-α) observed at an abundance «Often». With the water temperature rising up to 22°C in September, the diatom community has decreased in favor of the multiplication of cyanobacteria (**Figure 4**) which find favorable living conditions for their development.

In 2020, the histogram takes the concave form for the community of diatoms that multiply with dominant taxa going to peaks of more than 20%, sign of an ecosystem under environmental stress. There is a development of diatoms in abundance «Very often» such as the genus *Fragilaria*, with species such as *Fragilaria capucina* Desm.(O-β), *Fragilaria construens* (Ehr.) Grun. (β). This multiplication is explained by the delay that the algolisation process experienced just at the beginning of the growing season because of the lockdown that was applied throughout the Russian territory following the COVID-19 pandemic. This delay facilitated the multiplication of diatoms which easily dominated the pond due to lack of competitors for light consumption. A pronounced decrease in cyanobacteria has been noticed, which makes it possible to classify the ecosystem in an ecological state of very good conditions. This is evidenced by the saprobity index which is 1.86 with a water charge quality of 3a «Sufficiently clean».

It is noted that despite the rehabilitation process by algolisation, there are still species that can cause the pond to bloom, such as the diatoms genus *Nitzschia* under two species *Nitzschia acicularis* W. Sm. and *Nitzschia linearis* W. Sm., observed in 2017, 2018 and 2019. The genus *Navicula* is also observed in 2018 under four species *Navicula cuspidate* Kütz., *Navicula hungarica* var. capitata Ehr., *Navicula gracilis* Ehr., *Navicula lanceolata* (Ag.) Kütz., *Navicula radiosa* Kütz. This led to the increase of the saprobity index up to 2.18.

For cyanobacteria their dominance is noticeable only in 2019 up to 15 species. We especially notice the presence of genera that may be responsible for the «algal blooms» such as *Phormidium*, *Anabaena* (4 species) and *Ostillatoria* (2 species) observed in 2019 and 2020.

We notice that at the end of the 2020 growing season, the number of species responsible for «algal blooms» in the pond decreases in a remarkable way. The genus *Nitzschia* disappears for diatoms and for cyanobacteria only the genus *Ostillatoria* remains.

3.6 Graphs in logarithmic coordinates

The construction of the graph in logarithmic coordinates, took into account the entire spectrum of taxa in order not to lose part of the information.

For diatoms, with $R^2 > 0.64$, statistical reliability is respected to conduct an analysis with graphs in logarithmic coordinates. The study of the transformations of the diatom and cyanobacteria complexes according to the variation by growing season, gives more information on the ecological state of the pond. Thus, depending on the position of the trend curves in logarithmic coordinates, two kinds of grouping of lines and lines which deviate widely from the global spectrum are observed for diatoms (**Figure 5**).

The first grouping **(1)** in **Figure 5** with a well-located centre of «rotation» appears for the lines representing the end of the growing season in September for the most part and the beginning of the growing season in May. This state corresponds to the second phase of transformation of diatom complexes for small lakes and ponds (Razumovsky, 2022; Antsiferova and Nkurunziza, 2023). For this phase, the ecological system is maintained only by the dominant taxa and shows that during this period, the pond experiences a slight natural and anthropogenic pressure following the accumulation of pollutants after a summer period. The situation in May is almost similar to that of the end of September by the fact that the growth and multiplication activity of microalgae and cyanobacteria is limited by the fall in temperature in autumn and the beginning of winter. At this period, the photosynthesis activity is very reduced and most of the phytoplankton are in phase.

The second grouping **(2)** in **Figure 5** is made of parallel condensed lines representing for the most part the month of August. This generation formation reflects the transformation of the structure of diatom complexes along the temperature gradient, with a maximum water temperature that is usually observed at this time of year.

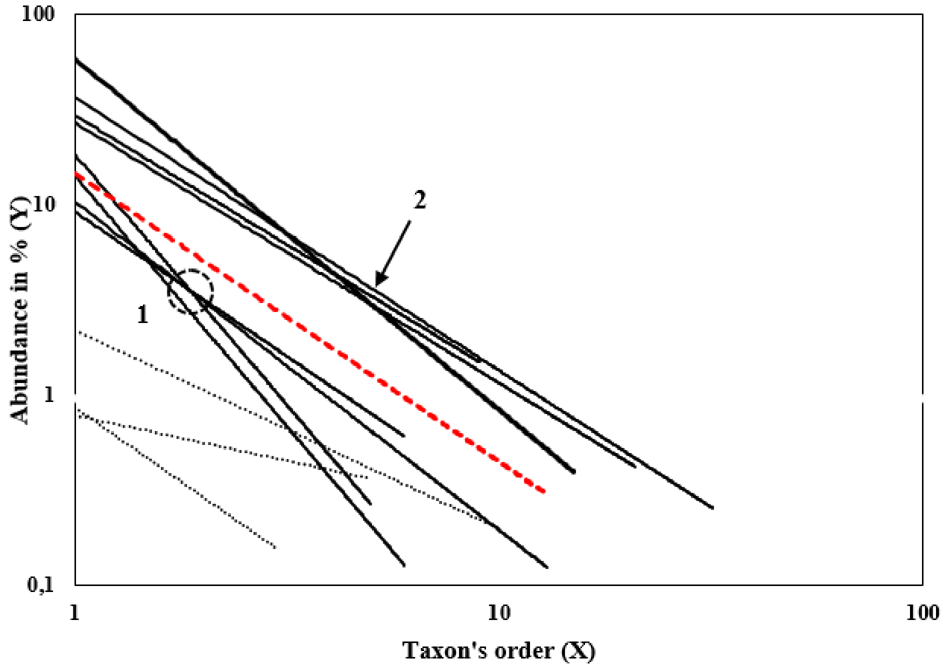

Figure 5. Transformation of diatoms complexes [0.64 < R^2 < 0.99]. (Logarithmic coordinate system).

We also notice lines (dotted lines) which do not form any grouping and which deviate from the first two groups. These lines represent the transformations of the diatom complexes that occurred due to the influence of the natural factor associated with the abnormally high summer temperatures from September 2017 until August 2018 (**Table 1**). There has been a decrease in species diversity, with a change in ecological niches, which has led to a change in the structure of communities. The September 2020 line (in dotted lines) comes out of all the lines forming a grouping with rotation and is located in the transition position between the two main groupings. This indicates the transition from a state of stability to a new state of stability of the pond (Bulent *et al*.(2024).

Cyanobacteria show a low statistical reliability with [0.58 <R^2< 0.98] for the entire spectrum of lines (**Figure 6**). By simulating the transformation of cyanobacteria complexes to that of diatoms, we observe similarities in species variation according to the growing season.

In the first grouping **(1)**, there is the appearance of a zone of «rotation» characteristic of the formation of small ponds. It corresponds to the September growing season of most of the study years. The pond is therefore in the second phase of transformation and is colonized by a complex of dominant species (**Figure 3 and Figure 4**). Thus the pond is under a «Slight anthropogenic load».

It should also be mentioned that ecological changes are not always caused by an anthropogenic load on water bodies, and that many cases of progress and even ecological regression in the rivers considered are due to the natural eutrophication of communities (Karomat, 2014; Smirnova and Batanina, 2021). The second grouping **(2)** with a second type of transformation has been identified for the pond. The first and the second group intersect to form a «rotation» centre more offset to the right. Considering the transformations of cyanobacteria, this shows that the pond is in the first phase of transformation (**Figure 6**) where the entire ecosystem is more maintained by dominant and concomitant species. The dotted line of September 2019 stands out from the spectrum of other lines. It marks the period when a great multiplication of cyanobacteria was observed due to the high water temperature up to 22 ^{o}C (**Table 1**).

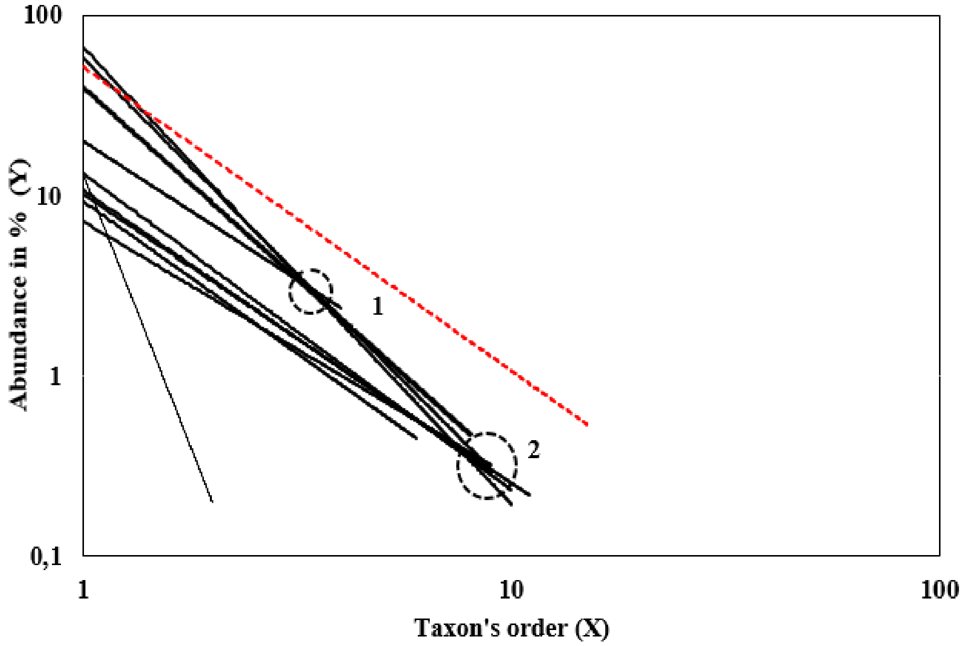

Figure 6. Transformation of cyanobacteria complexes [$0.58 < R^2 < 0.98$]
(Logarithmic coordinate system).

3.7. Analysis by combination of diatoms and cyanobacteria.

The global analysis of the evolution of the pond by combining all the communities of diatoms and cyanobacteria for a period of the whole year, makes it possible to have an overview of the evolution of the ecosystem over the entire growing season.

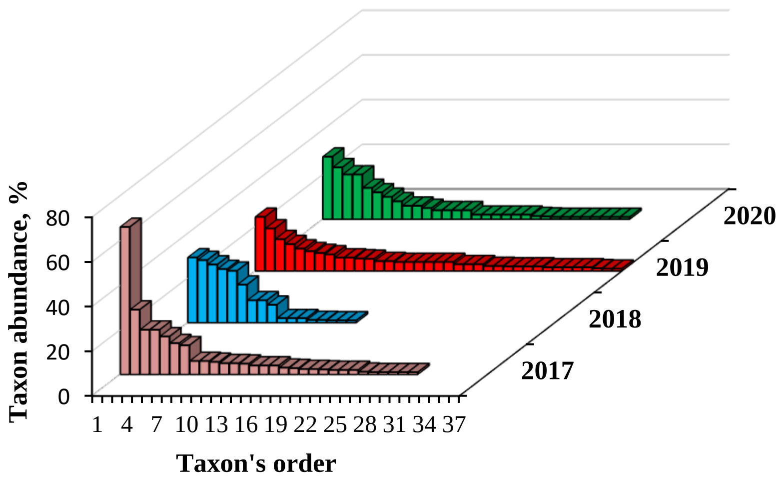

Figure 7. Taxonomic structure of microalgae and cyanobacteria communities of the Savvinsky pond
(Linear coordinate system).

Thus, by doing an analysis of the histograms in linear coordinates, we notice that in 2017 the histogram has the concave shape (type of exponential line) with a peak of more than 29.2% for the first taxon. This shows that the pond is under a «Slight anthropogenic load» (**Figure 7**).The year 2018 is characterized by a histogram in sigmoid shape (type of broken line) indicating good ecological condition of the pond. However, there is a decrease in the taxa which are composed mainly by the dominant and concomitant species. An abiotic factor such as the high water temperature which was observed from the end of the growing season in 2017 until the end of summer 2018 (**Table 1**) is partly responsible for this decrease. Only species resistant to high temperatures have developed, especially cyanobacteria with peaks between 29% and 10% for most species. For diatoms, only one taxon with a peak reaching 17% was able to develop. This shows how much the temperature plays a preponderant role in the transformation of the communities of phytoplankton and cyanobacteria. From 2019 the pond is making a transition to another ecological status with a new ecological niche.

We notice the multiplication of species indicating good environmental conditions with a concave-shaped histogram with peaks of the first taxa reduced, slightly more than 20%. This indicates a slight anthropogenic load on the pond. In 2020, we have a sigmoid histogram indicating good conditions of stability of the pond. However, with peaks of taxa 1-2 greater than 20% show once again that the pond remains under natural and anthropogenic load voltage. This resumption of the increase in the dominant taxa is partly explained by the fact that the algolisation was done late due to lack of access on the pond. The graph in the logarithmic coordinate system shows a grouping of the trend lines with the appearance of a centre of «rotation» (**Figure 8**). This indicates that the pond is under a slight load. According to the different levels of transformations, the pond is at a second level of transformation where the entire ecosystem is maintained by a complex of dominant and concomitant taxa (Barinova *et al.*(2014). The trend line of 2018 deviates slightly from the center of "rotation", thus showing a change in the niche for phytoplankton. This shows the impact of an abiotic factor that is the high temperature observed during the summer of 2018.

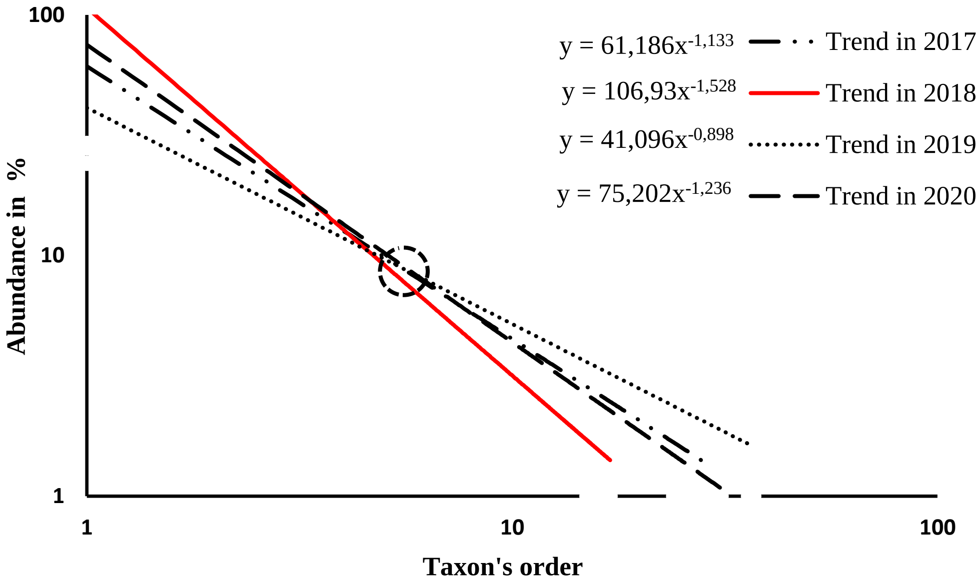

Figure 8. Transformations of microalgae and cyanobacteria communities of the Savvinsky pond [$0.73 < R^2 < 0.91$]. (Logarithmic coordinate system).

The analysis of the ecological status in the logarithmic coordinates system can also be based on the criteria for evaluating the level of load on the ecosystem taking into account the index α of the power function (trend) (Antsiferova, 2023). The more the index decreases, the more the state of the ecosystem is threatened. For the Savvinski pond, the index α is in the range $-1.52 \leq \alpha < -0.89$ (**Figure 8**). In 2017, the index α is equal to -1.13 i.e. $\alpha < -1.0$ which corresponds to an «Average» load level, and under these conditions, the ecosystem is in a state of «Environmental stress» (Bespalova, 2019).

In 2018, we observe a state of regression of the ecosystem with the index $\alpha = -1.52$. Thus the pond is subjected to a «High» load level. This partly explains the decrease in species observed during this period. In 2019, with the index α equal to -0.89, i.e. $\alpha > -1.0$, this indicates that the pond is at a «Low» load level, which means that the ecosystem is in a «background state». We then observe the multiplication of species since the conditions are very favorable. At the end of the algolisation process in 2020, the value of the index α is equal to -1.23, i.e. $\alpha < -1.0$. Thus, the pond is evaluated at an «Average» level of load and is subjected to a state of « Environmental stress ».

Conclusion

Based on the results of this study, it can be concluded that the rehabilitation of ponds that have experienced an «algal blooms» by algolization with a strain of *chlorella Kessleri* algae has been successful. The algae was able to inhibit the multiplication of algae responsible for the «algal blooms» of pond waters and the water recovered its normal quality with an oxygen concentration close to saturation at the end of the algolisation (rehabilitation) process. It should be noted that the changes related to anthropogenic activities have not been evaluated in this work. We conclude that based on the abundance and biomass results, the pond is class III «Satisfactory», which is corresponding to «good quality water». So the Savvinsky pond is at a stage of reversible change depending on the degree of crisis. Finally, given the percentages of the dominant peaks, the pond is in an unprotected ecosystem.

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