Inventory of biological diversity of algae flora of reservoirs of southern Kyrgyzstan and its sustainable development

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Abstract. The article provides data on the inventory of the biological diversity of algae flora in water bodies of Southern Kyrgyzstan and its sustainable development. During 1998-2005, 2019-2023, we conducted a study of the biological diversity of algae flora in reservoirs of southern Kyrgyzstan, such as the Akbuury River and its tributaries, the Papan Reservoir, the Naryn and Kara-Darya rivers, hot springs, the Isfayramsay, Isfara, Shakhimardansay, Sokh, Aravansay, Naukatsai rivers, and also studied the flora algae of rice fields, fish ponds, treatment facilities, Aravanakbuurynsky, Otuzadyr, Yakkalyk, Jupas, Kayirma canals and others, which are located in three regions of Osh, Jalalabad and Batkent regions of Southern Kyrgyzstan. The results of the study show that in these studied years, when inventorying the algae flora of the reservoirs of southern Kyrgyzstan, 697 species, variations and forms of algae were discovered. During 1970-1995, B. Karimov studied the algae flora of reservoirs of southern Kyrgyzstan such as the Gulcha River, thermal springs, lakes Kulun, Karasu, Sary-Chelek, ponds of the Uzgen fish farm, the basin of the Karadarya, Kara-Unkur, Karasuu, Akbuura rivers, as well the Kyrgyz-Ata, Abshirsai basins, the Kyzylsuu and Kurshab river basins, the Naiman and Turtkul reservoirs, as a result of the author's research, 665 species, variations and forms of algae were discovered. For the first time, we combined the results of these two works-ours and the work of B. Karimova and compiled a general comparative floristic list of algae in the reservoirs of southern Kyrgyzstan. As a result of the inventory, it was found that 850 species, variations and forms of algae are common in the water bodies of southern Kyrgyzstan, of which the dominant leading divisions in terms of quantity are Bacillariophyta, which has 464 species, variations and forms of algae, followed by the subdominant divisions - Chlorophyta (177), Cyanophyta (165), in other divisions of algae the number of species is very scarce (Euglenophyta - 12, Xanthophyta - 10, Chrysophyta - 7, Pyrrophyta and Rhodophyta - 6 each, Charophyta - 3). To preserve the natural riches of the algae flora of water bodies and their sustainable development, it is recommended to protect water bodies from incoming contaminated wastewater containing toxic chemicals.
1 Introduction

Currently, due to climate change towards warmer temperatures, the area of ice tongues is expected to melt on high mountains and reduce water levels in water bodies. This has a negative effect on the biological diversity of aquatic organisms, including microscopic algae flora. Furthermore, population growth and urbanization, coupled with industrial and agricultural activities, are increasing water consumption and leading to the discharge of wastewater contaminated with toxic chemicals. Untreated wastewater can heavily pollute rivers, affecting aquatic life, including the microscopic flora.

It is necessary to conduct an inventory of the microscopic biological diversity of the algal flora every ten years and perform a demographic analysis of this unique microorganism.

The importance of biological diversity in microscopic algae is significant. They participate in nature as primary producers and key links in the food chain, influencing gas metabolism and ecosystem productivity. Without green phototrophic organisms, there would be no life for primary consumers. Algae are considered the primary producers in nature, food for herbivores, and form the base of the food chain.

Algae are also important in increasing soil fertility in natural conditions. They are used in wastewater treatment and as a biological additive in livestock farming complexes. Additionally, algae suspension is used in soaking cotton seeds to improve plant resistance to wilt diseases.

2 On the study of the algal flora of water bodies in Southern Kyrgyzstan.

Algological studies of reservoirs in Kyrgyzstan began in the second half of the 19th century. The algae of Issyk-Kul in northern Kyrgyzstan have been extensively studied (K.E. Hirn, 1900). However, the algae in reservoirs in the mountainous, especially high-mountainous, parts of Central Asia, including southern Kyrgyzstan, were not extensively studied until the 1940s.

A.M. Muzafarov has been working on this problem since 1939. He studied the algal flora of Shakhimardansay (Muzafarov, 1947) and showed the influence of various factors on the development and distribution of algae in water bodies of the high-mountain, mountain, and foothill zones.

M.M. Muzafarov explored some reservoirs in the Chatkal and Talas ranges from Namangan to Dzhambul, examining rocks, rivers, and individual lakes. In 1946-1948, several high-mountain expeditions were carried out to study the algal flora of reservoirs in the Kara Darya basin, as well as its main tributaries, the Tar, Karakulja, and Yassy rivers. Work was also conducted in the Central Tien Shan in high-mountain reservoirs associated with large glaciers.

Numerous northern Alpine cold-water forms of algae were identified here. As a result of algological expeditions, more than 1000 species were discovered (2024).
samples were collected and processed. Original and extensive field material made it possible to show the influence of external factors on the development of algae, their seasonal changes and zonal distribution in mountain reservoirs of Central Asia. The algae flora of mountain and arctic water bodies was compared. A systematic summary was compiled in the form of a list of 812 species and forms of algae found in mountain reservoirs (Muzafarov, 1958) [13]. A significant number of species and forms new to science have been identified. Many forms are presented for the first time for Central Asia. In some and for the Countries independent states (CIS) territory.

A.E. Ergashev (1968) based on the processing of 20 samples collected in the summer of 1967, in the Orto-Tokoy Reservoir, lists 60 species and forms of algae, some of which turned out to be new to the flora of Central Asia. In the thermal springs of Kyrgyzstan, the author discovered 28 species and forms of algae (Ergashev, 1976) [21].

For the first time, data on the abundance and biomass of phytoplankton in this reservoir have been obtained. In 1990-1993 The algae flora of reservoirs in the south of Kyrgyzstan was studied by employees of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan (Khalilov et al., 1991-1993). S. Khalilov et al. (1991) [19] provide data on the phytoplankton of ponds in the south of Kyrgyzstan (Kurshab village). In the spring-summer period, 72 algological samples were collected, during the processing of which 130 species and varieties of algae were identified from the following systematic groups: 22 blue-green, 38 diatoms, 6 dinophytes, 8 euglena, 20 volvox, 13 chlorococcal, 16 ulotrix, 7 desmidia. The role of environmental factors in their development was noted, and the abundance of euglenophyte and dinophyte algae was established.

In later works by S. Khalilov et al. (1993) [20], algae of the Naukatsai River and ponds of the Naukat village are described. The algological study was carried out in the spring and summer of 1990. 192 algological samples were collected. As a result of their processing, 284 taxa were discovered. The predominance of green and blue-green algae was noted. Data on the abundance and biomass of algae in the studied objects are presented.

B.K. Karimova (1978) examined in detail the thermal springs of southern Kyrgyzstan. In subsequent years (1980-1985), the algal flora of the hard-to-reach lakes Kulun, Karasuu, Sary-Chelek, ponds of the Uzgen fish farm, the basin of the Karadarya, Kara-Unku, Karasuu, Akbuura rivers, etc. was studied. An expedition was organized to the basins of the Kyrgyz-Ata and Abshirsai rivers.

Samples collected by hydrobiologists of the Department of Zoology of Osh State University in lakes Kulun, Karasuu, Naiman and Tortkul reservoirs were processed. The algal flora of the reservoirs of the Alai Valley (the Kyzylsuu river basin) and the Kurshab and Akbuura river basins was studied (Karimova, 1970).

To clarify the role of algae in the sanitary condition of water bodies, the algal flora of the Akbuura and Abshirsai rivers was studied. Microalgae Chlorella and Scenedesmus were used in the treatment of industrial and municipal wastewater in Osh. B. Krimova, during the period of research activities in the reservoirs of southern Kyrgyzstan, discovered 665 species, variations and forms of algae. Of these, 112 species and forms of algae are Cyanophyta, 11 are Euglenophyta, 3 are Dinophyta, 7 are Chrysophyta, 376 are Bacillariophyta, 14 are Xanthophyta, 3 are Rhodophyta, 139 are Chlorophyta, 2 are Charophyta (Karimova, 2002) [9].

Kh.A. Alimjanova, M.A. Shayimkulova (2008) [1] studied the algae flora of the Akbuura River and its importance in assessing water quality, the research was carried out during 1998-2005. The study is of a monitoring nature: earlier, more than 20 stations were identified for sample collection; later, floristically similar stations were divided into three parts with 12 permanent stations, that is, upper (1-3 MS), middle (4-7 MS) and lower (8-12 MS) parts of the river. Algae samples were taken sporadically from other stations: in the upper, middle and lower parts of the Akbuura River, and from some sections of the Yakkalyk canal.
During the study, 346 algological samples were collected and processed, of which phytobenthos - 160, periphyton - 116, phytoplankton - 51. When processing algae samples, we identified 260 species and forms of algae from the Akbuura River. Of these, Cyanophyta – 45 (16.63%), Rhodophyta – 1 (0.38%), Xanthophyta – 1 (0.38%), Chrysophyta – 1 (0.38%), Bacillariophyta – 147 (56.96%), Pyrrophyta – 3 (1.15%), Euglenophyta – 5 (1.92%), Chlorophyta – 56 (21.53%), Charophyta – 1 (0.38%).

During the years under study, we also studied indicator saprobic species, of which 260 species of algal flora of the Akbuura River, 113 are saprobic indicator algae. Of the 113 species, 20 (17.6%) are xenosaprobic, 29 (25.6%) are oligosaprobic, 48 (42.4%) are beta-mesosaprobic, 15 (13.2%) are alpha-mesosaprobic, 1 (1.7%) – polysaprobic forms.

According to the formula of R. Pantle, N. Buck (1955) [24], the saprobity index (Si) in 1977-1995, in the upper, middle and lower parts of the Akbuura River was 1.1: 1.5: 2.2, respectively. Also in the period 1998-2003 – respectively 1.1: 1.5: 2.0. And in the period 2004-2005. 1.2: 1.6: 1.9. Thus, the results of the study give us the right to assert that the average long-term saprobity index changes from the upper part to the lower part, as well as from year to year, while the saprobic zone of the Akbuura River changes from alpha-oligosaprobic to betaII-betaI-mesosaprobic zone, water quality from 2 to 3rd grade with categories 2b-3b, 2b-3a and 2b-3a and the course of the study period.

Literary data shows that little has been studied of the reservoirs of the Batket region and some reservoirs of the Osh and Jalalabad regions of Southern Kyrgyzstan. A lot of time has passed since the reservoirs studied. Currently, climate change and the impact of anthropogenic factors on the environment, including water and reservoirs, requires periodic inventories of aquatic organisms, including algal flora, and an assessment of their current demographic status.

In this regard, we have set a goal for us: To carry out an “Inventory of the biological diversity of the algae flora of water bodies of Southern Kyrgyzstan and assess its sustainable development”. To achieve this goal, it is necessary to solve the following research problems:

1). Identify little-studied or unstudied water bodies that have been studied for a long time; 2). Collection of algological materials from monitoring stations marked for research purposes and their processing, as well as determination of the species composition of the algae flora; 3). Drawing up a systematic, geographical and ecological and comparative list of algal flora; 4). Systematic analysis of the biological diversity of algal flora; 5). Current demographic state of the algae flora in water bodies of Southern Kyrgyzstan and their solutions for sustainable development.

The objects of study are the algae flora of water bodies such as the rivers Isfairamsay, Sokh, Shakhimardansay, Isfara, Akbuury, Aravansay, Naukatsai and the Aravanakbuurynsky, Otuzadir, Yakkalyk, Jupas, Kayirma canal, as well as lakes Mashalangkul, Aidynkul, Kulikubbon, Zorkul, Tegirmachkul and Papan reservoir, cold, warm and hot springs, rice fields, fish ponds, sewage treatment plants and others. These objects have been studied little, locally, some have not been studied, and reservoirs have been studied a long time ago. During the period 1998-2005, 2019-2023. We conducted monitoring studies at permanent monitoring stations of reservoirs in southern Kyrgyzstan.

3 Materials and methods

An expedition was organized for the season of the year and algological samples were collected - biomaterials in the amount of 560, of which plankton 105, benthos 270, periphyton - 120, floating “cakes” - 65. During the collection of material, the temperature of water and air, depth, transparency and color of water, smell, flow speed were determined; described the presence of accumulations of these filamentous algae and their fouling, as well as sources of pollution, the content of oxygen dissolved in water, the dynamics of free carbon dioxide, and pH.
its temperature, transparency, and oxygen content. Plankton samples were taken with a silk gas plankton net (No. 76-78). Quanta
tive samples of 1 liter in volume were taken with a Molchanov and Zhukinsky bathometer. After settling, quantitative samples were filtered with a No. 6 membrane filter.

Benthos and fouling from the surface of underwater rocks (shallow places) in the contact zone of silt and from other objects were removed with a scalpel or knife from a certain (10 cm²) area, accumulations and large forms of algae (species of the genera Cladophora, Spirogyra, Oedogonium, etc.), as well as floating “cakes” on the surface with hands or rakes. Part of the sample was transported alive with the addition of nutrient media, the rest was fixed with 4% formaldehyde (3-7 drops). Most live samples were studied in situ [5].

Laboratory processing of samples was carried out in two steps: first, blue-green, green, pyrophytic, euglenic, yellow-green, golden, red algae, then the samples were purified from various mixtures and the determination of diatoms began. Permanent preparations of diatoms were prepared mainly by the calcination method, partly by the cold method (according to Brun). The material, washed from formaldehyde, was applied in a thin layer to a cover glass and calcined for 2-3 hours on an electric hotplate. The further process of work was carried out according to the method of V.S. Sheshchukova [22].

The species composition of algae was determined using domestic and foreign identification guides, as well as monographs on algae—“Identifier of freshwater algae of the USSR” [2,4,6,7,8,10,11,16,17] and others. Some taxonomic changes in the names of the classes of diatoms (Centrophyceae, Pennatophyceae) and green algae (Chlorococcophyceae) were taken from the sources of S.P. Wasser [3].

Qualitative analysis of plankton consisted of determining the species composition of algae and their occurrence—containers (looked through 5-6 drops). When establishing the frequency of occurrence of algae, a 9-point scale was used: 1—single, 2—very rarely, 3—rarely, 5—often, 7—very often, 9—mass (abundant).

The amount of algae was assessed on a relative frequency scale (1-9) after recalculation per 100 fields of view in accordance with the categories (first and second) of cell size [18]. The first category included algae cells up to 50 microns in size, the second—from 50 to 200 microns in size.

4 Results and discussion

Our research is an actual continuation of research by a prominent scientist, academician A.M. Muzafarov and his student, corresponding member of the National Academy of Sciences of Kyrgyzstan, Doctor of Biological Sciences, Professor Burul Karimova.

We conducted the study at monitoring stations and by season during 1998-2005 and 2019–2023. The peculiar ecological conditions of the reservoirs of southern Kyrgyzstan, including rivers—fast flow (3.7-4.2 m/s, sometimes 4.2-4.7 m/s), transparency (sometimes greatly reduced to 3-4 cm, and sometimes crystal clear), insignificant content of nutrients, coastal erosion, the influence of anthropogenic factors (discharge of various runoff, etc.)—causes the absence of overgrowth or very weak development of typical planktonic species and contributes to the formation of algal flora in the form of phytobenthic groups, films, fouling.

As a result of the study, the collected algological materials were processed and the species composition of algae was determined and systematic, geographical and environmental lists of algae were compiled. Analysis of floristic studies of these field materials shows that from the studied reservoirs of Southern Kyrgyzstan, we identified 697 species, varieties and forms (510 species, 160 variations, 27 forms) of algae (Table 1).
Table 1. Algae flora of water bodies of Southern Kyrgyzstan (Alimjanova, Shayimkulova, 1998-2005, 2019-2023)

<table>
<thead>
<tr>
<th>Department</th>
<th>Number of species, varieties and forms</th>
<th>Total</th>
<th>Percentage of total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanophyta</td>
<td>163-16</td>
<td>129</td>
<td>18.51%</td>
</tr>
<tr>
<td>Rhodophyta</td>
<td>5</td>
<td>5</td>
<td>0.71%</td>
</tr>
<tr>
<td>Xanthophyta</td>
<td>9</td>
<td>9</td>
<td>1.29%</td>
</tr>
<tr>
<td>Chrysophyta</td>
<td>7</td>
<td>7</td>
<td>1.00%</td>
</tr>
<tr>
<td>Bacillariophyta</td>
<td>237</td>
<td>134</td>
<td>54.54%</td>
</tr>
<tr>
<td>Pyrrophyta</td>
<td>5</td>
<td>5</td>
<td>0.71%</td>
</tr>
<tr>
<td>Euglenophyta</td>
<td>9</td>
<td>9</td>
<td>1.29%</td>
</tr>
<tr>
<td>Chlorophyta</td>
<td>123</td>
<td>25</td>
<td>21.52%</td>
</tr>
<tr>
<td>Charophyta</td>
<td>2</td>
<td>1</td>
<td>0.43%</td>
</tr>
<tr>
<td>Total:</td>
<td>510</td>
<td>160</td>
<td>27</td>
</tr>
</tbody>
</table>

The results of the analysis of the taxonomic composition of algae in water bodies of Southern Kyrgyzstan show that among the departments Bacillariophyta is especially rich and diverse, which contains 380 species and varieties, i.e. more than half of the total amount of algae (54.54%). The second place is occupied by Chlorophyta - 150 species and varieties or 21.52%, the third - Cyanophyta - 129 or 18.51%. Euglenophyta and Xantophyta, in comparison with other departments, include only 9 species and varieties of algae, or 1.29% of their total number. Other departments include a small number of species: Chrysophyta - 7 (1.00%), Rhodophyta and Pyrrophyta each have 5 species (0.71%), Charophyta - 3 (0.43%).

Above in the study of the algae flora of the reservoirs of the South of Kyrgyzstan there was a mention of the research work of the scientist of Kyrgyzstan, Doctor of Biology, Professor, Corresponding Member of the National Academy of Sciences of the Republic of Kyrgyzstan B.K. Karimova and her studied objects in the reservoirs of the South of Kyrgyzstan, that she discovered 665 species and forms of algae of the given region being studied. Of these, the leading divisions in terms of the number of algae are Bacillariophyta, which cover 376 species, variations and forms of algae. They are followed by the subdominant departments Chlorophyta (137 species, variation and forms), Cyanophyta (112 species, variation and forms). The remaining divisions of algae have a very small number of species (Xanthophyta - 14 species, Euglenophyta - 11, Chrysophyta - 7, Dinophyta and Rhodophyta 3 species each, Charophyta - 2) (Table 2).
Table 2. Algal flora of water bodies of Southern Kyrgyzstan in the period from 1970 to 2023

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanophyta</td>
<td>112</td>
<td>165</td>
<td>169</td>
<td>456</td>
</tr>
<tr>
<td>Rhodophyta</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Xantophyta</td>
<td>14</td>
<td>9</td>
<td>10</td>
<td>33</td>
</tr>
<tr>
<td>Chrysophyta</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Bacillariophyta</td>
<td>376</td>
<td>380</td>
<td>464</td>
<td>1220</td>
</tr>
<tr>
<td>Pyrrophyta/Dinophyta</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Euglenophyta</td>
<td>11</td>
<td>9</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td>Chlorophyta</td>
<td>137</td>
<td>150</td>
<td>177</td>
<td>464</td>
</tr>
<tr>
<td>Charophyta</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>665</td>
<td>697</td>
<td>860</td>
<td>2000</td>
</tr>
</tbody>
</table>

The combined list of algae flora shows that the number of algae species increased from 665 species to 697, respectively, with the period of research by B. Karimova (1970-1995) according to the period of research by Alimjanova Kh.A., Shayimkulova M.A. (1999-2005 and 2019-2023), and after combining the list of these two research periods, we now have a general idea of the number of species and the demographic state of water bodies in Southern Kyrgyzstan from 1970 to 2023. shows 860 the number of algae species (Table 2).

By the number of species, the leading is Bacillariophyta with a coverage of 464 species (54.6%), more than half of the total number of algae, followed by Chlorophyta - 177 (21.0%), Cyanophyta - 165 (19.2%). In other departments, the number of species and varieties is poorer: Euglenophyta - 12 (1.4%), Xantophyta - 10 (1.2), Chrysophyta - 7 (0.8%), Rhodophyta - 6 (0.7%), Pyrrophyta/Dinophyta - 6 (0.7%), Charophyta - 3 (0.4%).

For the conservation and sustainable development of the biodiversity of the algae flora of the reservoirs of Southern Kyrgyzstan in the future, periodic measures to protect water bodies from toxic chemical pollution of wastewater from enterprises, production of industrial, municipal and agricultural wastewater, which are located along the shore of water bodies, are necessary.

5 Conclusions

The following conclusions follow from the above:

1. Conducting periodic research on the reservoirs of Southern Kyrgyzstan makes it possible to study unstudied objects, little studied or studied by the statute of limitations. As a result, a study to conduct an inventory of the biological diversity of algae flora both in natural conditions and in literary analyzes revealed that year after year there is a replenishment of different species, variations and forms of algae: 665 → 697 → 860 and represents the overall picture of number of species from 1970 to 2023.
2. During the study of the inventory and demographic state of the algae flora of the reservoirs of Southern Kyrgyzstan, we noted for the first time that the number of algae flora of the reservoirs of Southern Kyrgyzstan consists of 860 species, variations and forms.

3. In terms of the number of species and varieties, the leading dominant departments are Bacillariophyta, consisting of 464 (54.6%) species and varieties, followed by the subdominant departments Chlorophyta - 177 (21.0%), Cyanophyta - 165 (19.2%). In other departments, the number of species and varieties is very scarce: Euglenophyta - 12 (1.4%), Xanthophyta - 10 (1.2), Chrysophyta - 7 (0.8%), Rhodophyta - 6 (0.7%), Pyrrophyta/Dinophyta - 6 (0.7%), Charophyta - 3 (0.4%).

4. For the conservation and sustainable development of the biodiversity of the algae flora of the reservoirs of Southern Kyrgyzstan, periodic measures to protect water bodies from toxic chemical pollution of wastewater from enterprises, production of industrial, municipal and agricultural wastewater, which are located along the shore of water bodies, are necessary in the future.

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