

CONTRIBUTION TO THE KNOWLEDGE OF THE DIVERSITY OF CYANOBACTERIA AND ALGAE IN SELECTED PROTECTED AREAS OF THE CANTON OF SARAJEVO

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Abstract

The Canton Sarajevo has the highest number of protected natural areas, among the other cantons in the Federation of Bosnia and Herzegovina, including natural monument and protected landscape as follows: Skakavac, Bijambare, Vrelo Bosne, Trebević and Bentbaša. Each of these areas is characterized by specific geomorphological, hydrological, pedological, biological and ecological features, serving as centers of biological diversity for flora, fauna and fungi. This paper provides insights into the diversity of cyanobacteria and algae within selected protected areas of the Canton Sarajevo. To date, 268 taxa of cyanobacteria and algae have been identified within these areas. Bijambare boasts the highest species count (155), followed by Vrelo Bosne (66) and Skakavac (66). Data on the diversity of these organisms in Bentbaša and Trebević are currently unavailable, highlighting the need for more detailed and systematic research in these areas. Beyond establishing a list of cyanobacteria and algae, continuous monitoring of their habitats in the protected areas of Canton Sarajevo is essential. Given that cyanobacteria and algae are excellent bioindicators of aquatic ecosystems, incorporating them into planning documents for ongoing monitoring is a crucial step in preserving these valuable regions.

Key words: *algae, biodiversity, cyanobacteria, monitoring, protected areas*

INTRODUCTION

According to the IUCN definition, a protected area is a clearly defined geographical space recognized, dedicated, and managed through legal or other effective means to achieve the long-term conservation of nature, along with associated ecosystem services and cultural values. Although Bosnia and Herzegovina adheres to international categorization of protected areas, these categories are not fully harmonized within environmental protection laws across its administrative entities. Management of protected areas in Bosnia and Herzegovina is aligned with the institutional distribution

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of responsibilities for environmental and nature conservation (Barudanović *et al.*, 2024; Đurić *et al.*, 2024).

The total area of protected lands in Bosnia and Herzegovina is notably low compared to other countries in the region and globally. The global target in the past decade was to protect 17% of terrestrial and 10% of aquatic territory in each country. According to official sources such as the *Federal Ministry of Environment and Tourism of Bosnia and Herzegovina* (<http://e-prirodafbih.ba>) and the *Republic Institute for the Protection of Cultural, Historical, and Natural Heritage* (<http://e-priroda.rs.ba>), the current official data indicate that approximately 3,13% of the national territory is under protection.

It is important to point out that the goal is to protect at least 30% of land and sea areas. This goal was formalized in December 2022 with the adoption of the Kunming-Montreal Global Biodiversity Framework (Kunming-Montreal Global Biodiversity Framework) during the Conference of Parties (COP15) of the United Nations Convention on Biological Diversity. Goal 3 of this framework calls on countries to "ensure and enable at least 30% of terrestrial, freshwater, coastal and marine areas, especially those of special importance for biological diversity and ecosystem functions and services, to be effectively preserved and managed" by 2030 (CBD, 2022).

In the Republika Srpska entity, there are 33 protected areas: two strict nature reserves (592.82 ha), three national parks (26,275.20 ha), 16 natural monuments (1,552.65 ha), three protected habitats (1,159.76 ha), five nature parks (38,340.46 ha), and three protected areas with sustainable use of natural resources (66.07 ha), totaling 73,023.33 ha or 2.96% of the entity's territory (Đurić *et al.*, 2024).

In the Federation of Bosnia and Herzegovina, the protected areas include one national park (36,629.08 ha), four natural monuments (9,207 ha), two nature parks (43,624.07 ha), and five protected landscapes (14,415.59 ha), totaling 103,875.74 ha across 12 designated areas. The most recently designated area is the Vjetrenica, Popovo Polje Protected Landscape, covering 4,712.19 ha. Overall, protected areas account for 3.98% of the Federation's territory (Đurić *et al.*, 2024).

It is important to note that the Brčko District has yet to designate any protected areas (Đurić *et al.*, 2024).

Regarding special levels of protection in Republika Srpska, three areas have been recognized under international agreements and conventions: one Ramsar site (Bardača Wetland Complex), one UNESCO World Heritage natural site (the "Perućica" Primeval Forest), and the "Janj" Forest, which is part of the UNESCO heritage listing "Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe." In contrast, the Federation of Bosnia and Herzegovina has slightly fewer internationally designated areas, with Hutovo Blato and Livanjsko Polje listed as internationally important wetlands under the Ramsar Convention (Đurić *et al.*, 2024).

The Vjetrenica Cave was officially registered on the UNESCO World Heritage List in 2024, during the 46th session of the World Heritage Committee. This decision was made on the basis of criteria related to exceptional universal value in terms of the preservation of natural diversity. Vjetrenica is recognized as one of the world's most important habitats for underground fauna, with numerous endemic and endangered species. It is

also an exceptionally well-preserved example of Dinaric karst and biodiversity (UNSECO, 2024).

The aim of this study is to establish a database and provide a review of the diversity of cyanobacteria and algae within protected areas, in order to support future inventory efforts and to integrate these findings into the monitoring of aquatic ecosystems.

MATERIALS AND METHODS

Study Area

Sarajevo Canton is one of the ten cantons within the Federation of Bosnia and Herzegovina, covering an area of 1,277 km². The canton stretches approximately 63.5 km along its longest axis, with an average width of about 20.5 km and a maximum width of roughly 55.6 km in its southern part (Drešković *et al.*, 2015).

From a geotectonic perspective, most of Sarajevo Canton lies within the central Dinarides region, characterized by Paleozoic clastics, Mesozoic carbonates, Jurassic-Cretaceous flysch, and Neogene molasse. To the north, it borders the inner Dinarides, which are composed of Paleozoic and Neogene clastics and carbonates, a diabase-chert formation with ophiolites and mélangé, Tertiary flysch, granite, andesite, dacite, tuff, and Tertiary molasse. The central, western, and northwestern portions of the canton belong morphostructurally to the Sarajevo-Zenica Basin. This basin is shaped by the Sarajevo-Busovača fault, oriented in a northwest-southeast direction. The basin and the surrounding mountains, Igman, Bjelašnica, Treskavica, Jahorina (to the south and southeast), Ozren and Bukovik (to the northeast), and Čemerska Mountain and Zvijezda (to the northwest), were formed during the Alpine orogenic phase and are part of the younger folded mountain systems of the Eurasian orogeny.

Geologically, the central part of the canton is covered by Quaternary deposits and Upper Miocene and Middle-to-Upper Miocene Cenozoic sediments including sandstones, marls, clays, limestones, and conglomerates. Lower and Middle Triassic deposits (Anisian and Ladinian) are found in the eastern and northern parts of the canton. The far northeastern section contains dolomites and limestones interbedded with chert, tuff, siliceous sandstones, marls, and calcarenites from the Middle and Lower Triassic.

The Bjelašnica and Igman Mountains also contain Middle and Lower Triassic deposits, transitioning southward (toward Treskavica) into Upper Triassic formations (limestones and dolomites with marl and sandstone layers), and eventually into Jurassic-Cretaceous flysch in the far southeast. The southwestern part of the canton features a highly complex geological structure that includes Silurian-Devonian, Devonian-Carboniferous, Permo-Triassic, and various Triassic deposits (Ćičić, 2002).

Climatically, Sarajevo Canton belongs to the southern portion of the northern temperate zone. The lower elevations are classified as Cfb (temperate oceanic climate with warm summers), while higher elevations transition to Dfb (humid continental climate with warm summers), and eventually to Dfc (subarctic climate with cool summers) on the highest mountain peaks.

The Cfb climate type is characterized by average temperatures not falling below -3°C in the coldest months, with precipitation evenly distributed throughout the year and maximum summer temperatures below 22°C . Over the last 30 years, at the Sarajevo-Bjelave station (630 m elevation), the average lowest temperature was recorded in January at 0.3°C , and the highest in July and August at 20.6°C . Average monthly precipitation is 78 mm, with the lowest in August (63.7 mm) and the highest in December (92 mm). In contrast, the Dfb zone features lower January temperatures (below -3°C), similar year-round precipitation patterns, and warm but not hot summers. At the Bjelašnica station (2,067 m), the annual average temperature is 2.0°C . January has the lowest monthly average (-6.6°C), while the highest is in August (11.5°C). Only July and August exceed 10°C in average monthly temperatures. Precipitation averages 93.7 mm monthly, peaking in November (113.5 mm) and dipping in January (78.5 mm) (FHMZ, 1992-2022).

Hydrologically, most of the canton (excluding the Rakitnica River, a Neretva tributary in the Adriatic Basin) belongs to the Black Sea drainage basin. The primary river system is the Bosna River, which originates in the central part of the canton and is fed by numerous tributaries.

The complex geological makeup, diverse topography, varied climate, and rich vegetation have led to a highly heterogeneous soil structure. Along river valleys, fluvisols dominate, along with luvisol–pseudogley complexes on Tertiary sediments and rendzina–dystric cambisol–pseudogley complexes on flysch formations. Higher elevations and slopes around the Sarajevo Basin, particularly in the south, southeast, and northeast, feature calcocambisols and mosaics of calcimelanosols on limestone substrates. In the north and in fragments of the south and southwest, mosaic patterns of calcimelanosols, calcocambisols, luvisols, and rendzina on limestone and dolomite prevail. The northwest and southwest areas feature dystric cambisols on acidic and silicate rocks (Burlica & Vukoper, 1983). This complex geotectonic, geological, geomorphological, climatological, hydrological, and pedological structure has fostered remarkable geodiversity and biodiversity within a relatively small area. Consequently, several protected natural areas have been recognized and designated within Canton Sarajevo. Currently, five areas are designated as protected: two natural monuments (Skakavac and Vrelo Bosne) and three protected landscapes (Bijambare, Trebević, and Bentbaša) (Tab. 1 & Fig 1).

Table 1. Protected Natural Areas in Canton Sarajevo (Federal Ministry of Environment and Tourism, 2024)

Protected Natural Area	Year of Establishment	IUCN Category	Area (ha)
Skakavac Natural Monument	2002 - 2010.	III	1430.70
Vrelo Bosne Natural Monument	2006.	III	603.44
Bijambare Protected Landscape	2006 - 2010.	V	497.0
Trebević Protected Landscape	2014.	V	400.2
Bentbaša Protected Landscape	2017.	V	160.9
TOTAL (ha)			3092.24

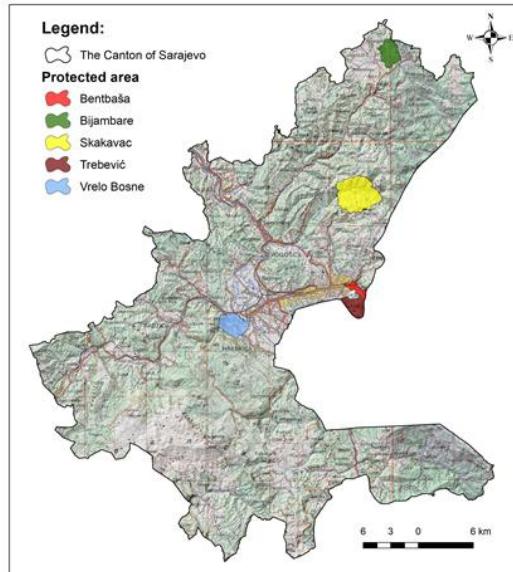


Figure 1. Protected Natural Areas of Sarajevo Canton
(Author: Hrelja, E., Source: Digital GIS Database, Faculty of Science, University of Sarajevo)

The total area of protected natural sites in Sarajevo Canton is 3,092.24 hectares (30.9 km²), which represents only 2.4% of the canton's total area. Both the number and extent of protected areas in Sarajevo Canton, and in Bosnia and Herzegovina as a whole, are below desirable levels. Only 18.7% of the protection targets set in the Bosnia and Herzegovina Spatial Plan for the period 1981–2000 have been achieved across different protection categories. An analysis of spatial planning documents at the entity level shows that the Federation of Bosnia and Herzegovina has planned to protect approximately 17% of its total territory, while Republika Srpska aims for around 15.5% (with a general target of 15–20% by 2025, according to amendments to the Spatial Plan of RS, 2013). This would bring national coverage to around 16% of Bosnia and Herzegovina's total area (Hrelja, 2022).

At the cantonal level, the management of protected areas is further defined through strategic development plans of regional self-government units, which elaborate on the development guidelines of entity-level documents. At the implementation level, these are governed by spatial plans. It is important to note that the management of all protected areas in the Sarajevo Canton is assigned to the Cantonal Public Institution for Protected Natural Areas (*Sl. Novine Kantona Sarajevo*, Br. 31, 2017).

Skakavac Natural Monument

The Skakavac Natural Monument is located approximately 12 km northeast of Sarajevo, on the slopes of Mount Ozren in the valley of the Perački Stream, which forms the core of the area's hydrographic network. The primary factor leading to its designation as a protected natural area is the Skakavac Waterfall. With a height of 98 meters, this waterfall serves as the nucleus of the protected zone and its central hydrographic and landscape feature. The water originates at the base of Bukovik peak, descending rapidly through a steep streambed until it reaches a gentle plateau, where the flow slows down and continues for several hundred meters before plunging off a vertical cliff of nearly 100 meters, forming one of the most beautiful waterfalls in Bosnia and Herzegovina (Dalmatin *et al.*, 2008).

Orographically, the area is very heterogeneous, consisting of numerous valleys (gorges such as those of the Babin, Stublinski, Perački, Sušica, and Jasikovica streams), mountain peaks, ridges, and sinkholes, making it visually attractive and a popular destination for tourists. In addition to hydrological and geomorphological features, the significant heterogeneity of natural factors (geological foundation, soil types, relief, climate, and water networks) has led to the development of rich biodiversity and diverse habitats. The area is known for its high biological diversity, with more than 1,500 species of higher plants recorded, including several hundred species of medicinal, edible, aromatic, and vitamin-rich plants. The fauna is also highly diverse, with a high percentage of endemic species from the Dinaric, Balkan, and Southeastern European regions. The area also holds important cultural and historical value, with two stećak necropolises located nearby: a larger one near the village of Luka and a smaller one near Donji Moćioći (Skakavac Natural Monument Management Plan 2011–2021).

Vrelo Bosne Natural Monument

Designated in 2006 as a Category III IUCN site, the Vrelo Bosne Natural Monument covers an area of 603.4 hectares. It is located in the southern part of the Sarajevo Basin, at the foot of Mount Igman. The main reason for its protection is the source springs of the Bosna River. In addition to the main spring, the area also contains multiple small streams and lakes, adding to its visual and ecological appeal.

The site is home to 131 tree species, 500 herbaceous plant species, over 50 species of medicinal and honey-bearing plants, more than 20 species of fungi and lichens, 102 species of microphytes, 19 mammal species, and 64 bird species, making it exceptionally important in terms of biodiversity (Dalmatin *et al.*, 2008).

Endemic species of subterranean fauna have been recorded in the area of Vrelo Bosne, which further confirms its value in the context of biological diversity. Among them, two endemic species of crustaceans from the order Amphipoda: *Niphargus ilidzensis* and *Gammarus bosniacus*. The species *N. ilidzensis* was first described in 1922. and is characteristic of the underground waters of the wider area of Ilidža, including the Vrelo Bosne area. While *G. bosniacus*, described in the same year, represents another important element of the subterranean aquatic fauna of this locality. The presence of

these endemic species within the Vrelo Bosne protected area indicates a high degree of specificity and sensitivity of the ecosystem, and additionally emphasizes the need for its preservation through long-term monitoring and habitat protection (Plan upravljanja Spomenikom prirode „Vrelo Bosne“ 2020-2030).

Vrelo Bosne has long served as a popular recreational area for Sarajevo residents and spa visitors from Ilidža. It was appreciated during the Ottoman Empire, but its current layout was largely developed during the Austro-Hungarian period at the end of the 19th and beginning of the 20th century (Drešković *et al.*, 2015). As a result of human activity within and around the area, numerous cultural and landscape features have been preserved. These include the Great Alley of Platanus and Chestnut Trees, the park grounds around Ilidža Spa and Stojčevac, the Roman Bridge water supply at Plandište, Austro-Hungarian villas, and the historic hotels of Ilidža, all of which contribute to the area's ecological, historical, and tourist value.

Bijambare Protected Landscape

Bijambare is located in the central Dinaric region of Bosnia and Herzegovina, approximately 25 km north of Sarajevo, between the villages of Nišići and Krivajevići in the northeastern part of the Crnorječka Plateau (Drešković & Đug, 2006; Hrelja *et al.*, 2021). Geologically and tectonically, the Bijambare region has been shaped by a long and complex geological history, resulting in diverse formations. The Crnorječka Plateau is a depression located between mountain ranges, with elevations ranging from 915 to 1,044 meters. It is polygenetic in origin, formed through a combination of tectonic, neotectonic, and exogenic processes. Its surface features both fluvial and karstic terrain, depending on the bedrock.

The main geomorphological indicators justifying the area's protection are its characteristic karst formations, caves, sinkholes, dolines, and limestone ridges, especially well preserved in the western and northwestern parts. Notable formations include the Main (Middle) Bijambare Cave, the Upper Cave, Đurićina Cave, and the Lower Cave. A particularly valuable feature of the protected area is its peat bog ecosystem (Drešković *et al.*, 2015). This soil type has formed on highly acidic, nutrient-poor substrates with low base saturation. Mosses of the genus *Sphagnum* dominate the vegetation, thriving in wet, acidic soils where peat forms from their decomposing remains. Peat formation began during the deglaciation period, when favorable climatic conditions emerged for intensified photosynthetic activity in the area's herbaceous and woody vegetation (Barudanović *et al.*, 2017).

Trebević Protected Landscape

Established in 2014 as a Category V IUCN site, the Trebević Protected Landscape covers 400.2 hectares. It is located in the Trebević region of Sarajevo Canton and is particularly attractive to visitors from Sarajevo due to its favorable location and climate, especially in winter. The installation of a cable car and improved road infrastructure has made the site more accessible from the city's historic core.

The area is characterized by significant geodiversity, particularly in terms of geological, geomorphological, and soil features. It also contains diverse flora and fauna, with more than 99 plant species, 14 fungal species, and over 26 bird species identified (Drešković *et al.*, 2015). Its long history of human settlement and activity has left a rich cultural and historical legacy, including the Čolina Kapa astronomical observatory (Bistrik Fortress), remnants of Draguljac Fortress, Austro-Hungarian water supply systems, remains of the 1984 Olympic bobsled track, scenic viewpoints, mountain lodges, and more.

Bentbaša Protected Landscape

The Bentbaša Protected Landscape is the newest designated natural area in Sarajevo Canton, established in 2017 as a Category V IUCN site. It is located in the far eastern part of the canton and administratively belongs to the Stari Grad Municipality of Sarajevo. At just 160.9 hectares, it is the smallest protected area in the canton. Based on the number and distribution of natural values and the degree of environmental modification, two zones have been designated within the protected area: a core zone (nucleus) and a buffer zone (Kantonalni zavod za zaštitu kulturno-historijskog nasljeđa, 2020–2030). The protection area includes a canyon section of the Miljacka River, beginning several hundred meters upstream from Sarajevo City Hall. The region is known for its distinct physical and biological features (Dalmatin *et al.*, 2008). These include the Miljacka watercourse with its canyon landscape, the valleys of its tributaries (Lapišnica and Moščanica), various springs and wells, caves, and unique landforms such as the Babin Zub cliff. Due to ecological factors, the Miljacka River and its tributaries, over a 5–6 km stretch, are considered an endemic and relict refuge of Tertiary flora and fauna, centered around the Da Riva area and the confluence of the Moščanica River (Dalmatin *et al.*, 2008). The site has recorded high biodiversity with more than 160 plant species and 134 butterfly species (Kantonalna javna ustanova za zaštićena područja, 2025).

Bentbaša's proximity to Sarajevo's historic center adds to its significance. In addition to natural values, the area is rich in cultural and recreational assets, including Goat's Bridge (*Kozija Čuprija* / The historic monument), Isa Bey's Tekke and *Zavija* (The natural and architectural ensemble), Sheik's Forest (*Šehova korija*), the Dervish Cave, and the *Ebu Hayat* Spring ("Spring of Life"). Recreational features include the Dariva promenade, bike trails, Ambassador's Alley, and the former railway path.

Sampling and Species Analysis

Algal phytobenthos sampling for this study was conducted at selected locations within the protected areas of Bijambare and Vrelo Bosne. For the checklist preparation of other protected sites, data from relevant literature sources were utilized. Algal material from the Bijambare Protected Landscape was collected during the autumn season of 2022, while material from the Vrelo Bosne Natural Monument was collected in autumn 2023. All collected samples were transported and analyzed at the Laboratory for Systematics and Ecology of Algae, Fungi, and Lichens. Epipelon samples were taken from the

uppermost layer of mud using a spoon or pipette aspirator. The collected material was preserved with 4% formalin. Laboratory processing of diatoms followed the methods described by Hustedt (1930).

Observations were performed using a Best Scope 2020 light microscope. Diatom species composition and their quantitative ratios were assessed using permanent slides examined at 1000x magnification. For each sample, a minimum of 400 valves were counted per slide. Diatom identification was based on the following references: Lange-Bertalot & Metzeltin (1996), Cantonati *et al.* (2017). The nomenclature of the identified algae was updated in accordance with Guiry (2024). Ecological data were analyzed using Omnidia software, version 6.0.8 (Lecointe *et al.*, 1993).

In order to prepare a comparative overview of cyanobacteria and algae within the protected natural areas of Canton Sarajevo, the results of previously conducted research were used: Skakavac (Barudanović *et al.*, 2014; 2016), Bijambare (Kapetanović *et al.*, 2011; Barudanović *et al.*, 2015; 2016 and Koštrebić, 2022) and Vrelo Bosne (Trožić-Borovac i Hafner, 2004; Barudanović *et al.*, 2016; Barudanović, 2020; Mašić i Macanović, 2020; Hadžić, 2023).

RESULTS AND DISCUSSION

The Canton Sarajevo, compared to other cantons in the Federation of Bosnia and Herzegovina, has the largest number of protected areas. The protected areas in KS are: Skakavac, Bijambare, Vrelo Bosne, Trebević and Bentbaša. Each of these protected areas is characterized by specific geomorphological, hydrological, pedological, and biological and ecological features. A distinctive feature of the declared protected areas is that they are centers of biological diversity in flora, fauna, and fungi. Certain groups of organisms within the protected areas are well-researched; however, for some other groups, no lists have been created yet, nor is there an organized database. A review of published studies on the protected areas in Canton Sarajevo indicates that the level of research on cyanobacteria and algae is least explored in the two newest protected areas: Trebević and Bentbaša, while the diversity of this group of organisms has been most extensively studied at Bijambare, Vrelo Bosne and Skakavac (Hrelja, 2017).

Taking into account the research conducted so far within the Protected Areas in Sarajevo Cantona, a total of 268 taxa of cyanobacteria and algae have been identified. The largest number of taxa was recorded in the Bijambare protected area (155), followed by the Vrelo Bosne (102) and Skakavac protected areas (66). There is no data on the number of cyanobacteria and algae taxa for the newly protected areas, Trebević and Bentbaša. The identified species belong to the following groups: Cyanophyta (28 taxa or 10.44%), Rhodophyta (1 taxon or 0.37%), Heterokontophyta (223 taxa or 83.20%), Dinophyta (1 taxon or 0.37%), and Chlorophyta (15 taxa or 5.59%). The results of the diversity research on cyanobacteria and algae within the protected areas in Sarajevo Canton are presented in tables, graphs, and original LM microphotographs (Tab. 2, 4, and Fig. 2).

Table 2. Percentage of cyanobacteria and algae taxa identified within the studied protected areas in Sarajevo Canton

Phylum	Classis	N	%
Cyanophyta	<i>Cyanophyceae</i>	28	10,44
Rhodophyta	<i>Florideophyceae</i>	1	0,37
Heterkontophyta	<i>Chrysophyceae</i>	1	0,37
	<i>Xanthophyceae</i>	2	9,74
	<i>Bacillariophyceae</i>	220	82,08
Dinophyta	<i>Dinophyceae</i>	1	0,37
Chlorophyta	<i>Chlorophyceae</i>	6	2,23
	<i>Zygnematophyceae</i>	8	2,98
	<i>Ulvophyceae</i>	1	0,37
	UKUPNO	268	100

When considering the distribution of identified taxa by classes, the results are as follows: *Cyanophyceae* (28 taxa or 10.44%), *Florideophyceae* (1 taxon or 0.37%), *Chrysophyceae* (1 taxon or 0.37%), *Xanthophyceae* (2 taxa or 0.74%), *Bacillariophyceae* (220 taxa or 82.08%), *Dinophyceae* (1 taxon or 0.37%), *Chlorophyceae* (6 taxa or 2.23%), *Ulvophyceae* (1 taxon or 0.37%) and *Zygnematophyceae* (8 taxa or 2.98%) (Fig. 3)

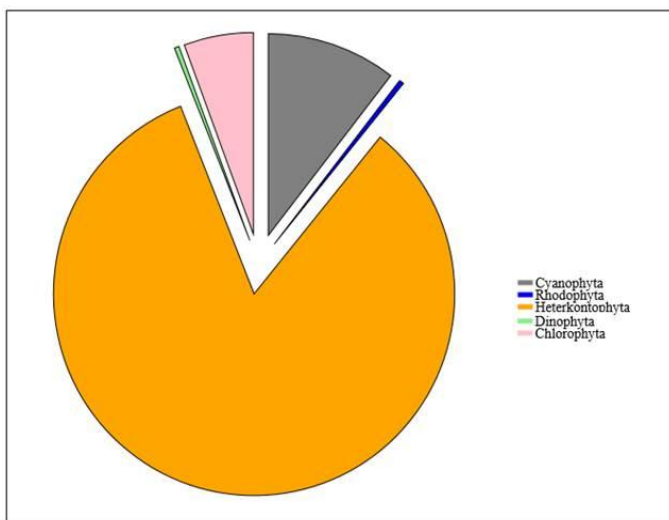


Figure 2. Percentage of cyanobacteria and algae species by class within the studied protected areas in Sarajevo Canton

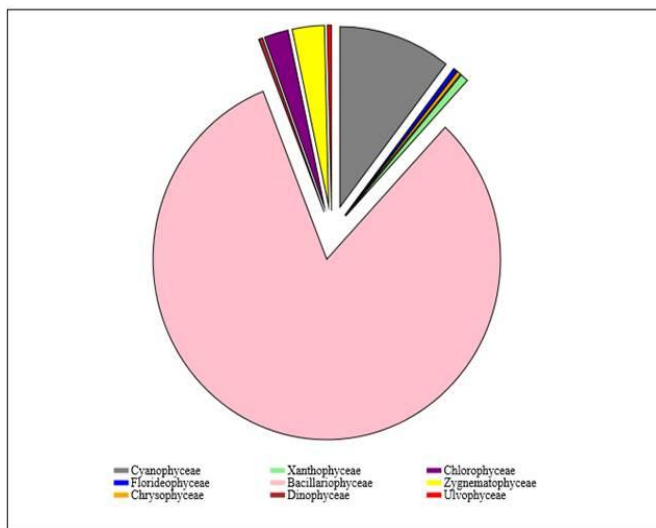


Figure 3. Percentage of cyanobacteria and algae species by class within the studied protected areas in Sarajevo Canton

By comparing the results obtained through research and those collected from published studies and reports, a checklist of cyanobacteria and algae in the Protected Areas of Sarajevo Canton has been prepared. The highest number of taxa was recorded in the Bijambare Protected Area (155 taxa), followed by the Vrelo Bosne Protected Area (102 taxa), while the Skakavac Protected Area recorded the lowest number of species (66 taxa) of cyanobacteria and algae. A comparative overview of the diversity of cyanobacteria and algae is presented in tables and graphs (Tab. 3 and Fig. 4).

Table 3. Comparative Overview of Cyanobacteria and Algae Diversity within the Studied Protected Areas in Sarajevo Canton

Protected area in Canton Sarajevo	Cyanophyceae	Floriideopgyceae	Chrysophyceae	Xanthophyceae	Bacillariophyceae	Dinophyceae	Chlorophyceae	Zygnematophyceae	Ulvophyceae	TOTAL
Bijambare	12	.	.	.	139	.	2	2	.	155
Vrelo Bosne	19	1	.	2	73	.	3	4	.	102
Skakavac	.	.	1	.	59	1	1	3	1	66
Trebević	.	.	.	.	.	.	.	.	.	N/a
Bentbaša	.	.	.	.	.	.	.	.	.	N/a

Within the Bijambare Protected Area, a total of 155 taxa of cyanobacteria and algae have been identified to date. The research within this protected area covered almost all wet habitats, primarily peat bog ecosystems and cavernicolous habitats. The identified taxa belong to the following classes: *Cyanophyceae* (12), *Bacillariophyceae* (139), *Chlorophyceae* (2) and *Zygnematophyceae* (2) (Tab. 3; Fig. 3, 4).

Within the Vrelo Bosne Protected Area, a total of 102 taxa of cyanobacteria and algae have been identified to date. The research within this protected area covered springs, streams, and pools. The identified taxa belong to the following classes: *Cyanophyceae* (19), *Florideophyceae* (1), *Xanthophyceae* (2), *Bacillariophyceae* (73), *Chlorophyceae* (3), and *Zygnematophyceae* (4) (Tab. 3; Fig. 3, 4).

Within the Skakavac Protected Area, a total of 66 taxa of cyanobacteria and algae have been identified to date. The research within this protected area covered various wet habitats, but the primary focus was on the Skakavac stream below the waterfall of the same name. The identified taxa belong to the following classes: *Chrysophyceae* (1), *Bacillariophyceae* (59), *Dinophyceae* (1), *Chlorophyceae* (1), *Ulvophyceae* (1) and *Zygnematophyceae* (3) (Tab. 3; Fig. 3, 4).

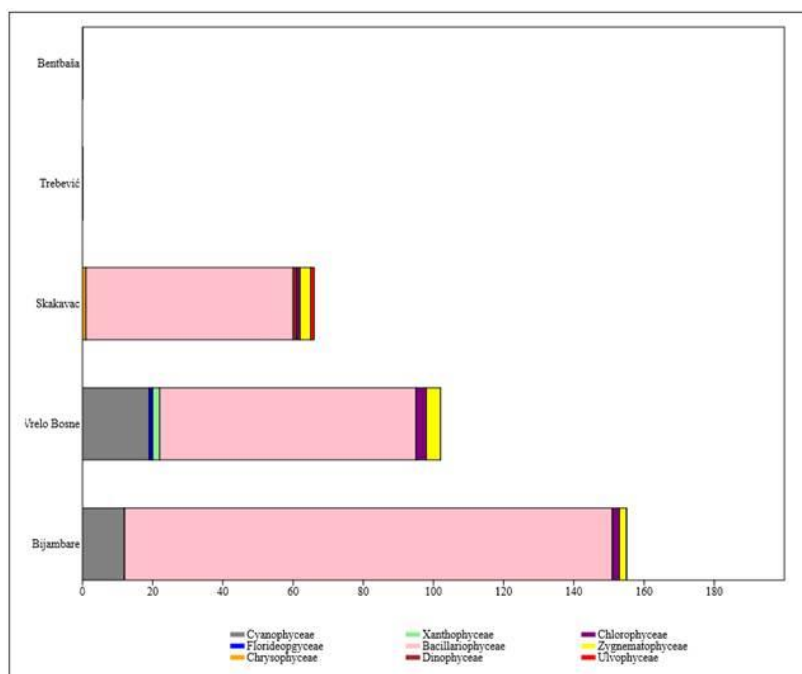


Figure 4. Comparative Overview of Cyanobacteria and Algae Diversity within the Studied Protected Areas in Sarajevo Canton

Data on the diversity of cyanobacteria and algae for the Trebević and Bentbaša protected areas have not been recorded in existing documents. In this regard, future detailed research is essential to gather data that can be used to prepare a digital database of cyanobacteria and algae, as well as their distribution within the protected areas. Given all the information provided, it can be concluded that the protected areas in Sarajevo Canton are characterized by a high degree of cyanobacteria and algae diversity. Considering that two protected areas have not been studied in terms of the diversity of this group of organisms, it is estimated that the number of species is likely even higher. Since cyanobacteria and algae are excellent bioindicators of aquatic ecosystems, it is necessary to include them in planning documents for continuous monitoring of these ecosystems.

Table 4. Comparative Overview of Cyanobacteria and Algae Diversity within the studied natural protected areas in Canton Sarajevo

ID	Diversity of cyanobacteria and algae in Protecte Areas of Canton Sarajevo	Odjel	Klasa	Skakavac ^{1,2}	Bijambare ^{2,3,4,8}	Vrelo Bosne ^{2,5,6,7}	Trebević	Bentbaša	Ukupno
1.	<i>Achnanthydium minutissimum</i> (Kütz.) Czarn.	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
2.	<i>Amphora ovalis</i> (Kützing) Kützing var. <i>ovalis</i>	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
3.	<i>Cocconeis pediculus</i> Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
4.	<i>Denticula tenuis</i> Kütz.	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
5.	<i>Diatoma vulgare</i> Bory	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
6.	<i>Eunotia minor</i> (Kützing) Grunow in Van Herck	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
7.	<i>Melosira varians</i> Agardh	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
8.	<i>Navicula</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
9.	<i>Pinnularia viridis</i> (Nitzsch.) Ehrenb.	Heterokontophyta	<i>Bacillariophyceae</i>	1	1	1	0	0	3
10.	<i>Achnanthes</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	0	1	1	0	0	2
12.	<i>Caloneis silicula</i> (Ehr.) Cleve	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
13.	<i>Campylodiscus hibernicus</i> Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
14.	<i>Chroococcus minutus</i> (Kützing) Nägeli	Cyanophyta	<i>Cyanophyceae</i>	0	1	1	0	0	2
15.	<i>Cocconeis placentula</i> var. <i>lineata</i> (Ehrenberg) Van Heurck	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
16.	<i>Cyanothece aeruginosa</i> (Nägeli) Komárek	Cyanophyta	<i>Cyanophyceae</i>	0	1	1	0	0	2
20.	<i>Diatoma hyemale</i> (hiemale) (Roth) Heiberg	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
21.	<i>Diatoma mesodon</i> (Ehrenberg) Kützing	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2

22.	<i>Diploneis oblongella</i> (Naegeli) Cleve-Euler	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
23.	<i>Ellerbeckia arenaria</i> (D.Moore ex Ralfs) Dorofeyuk & Kulikovskiy	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
25.	<i>Encyonema ventricosum</i> (Kützing) Grunow in Schmidt & al.	Heterokontophyta	<i>Bacillariophyceae</i>	0	1	1	0	0	2
27.	<i>Epithemia adnata</i> (Kützing) Brébisson	Heterokontophyta	<i>Bacillariophyceae</i>	0	1	1	0	0	2
32.	<i>Gomphonema olivaceum</i> (Hornemann) Brébisson var. <i>olivaceum</i>	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
33.	<i>Gomphonema</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
34.	<i>Gomphonema subclavatum</i> Grunow	Heterokontophyta	<i>Bacillariophyceae</i>	0	1	1	0	0	2
35.	<i>Hantzschia amphioxys</i> (Ehr.) Grunow in Cleve et Grunow	Heterokontophyta	<i>Bacillariophyceae</i>	0	1	1	0	0	2
36.	<i>Navicula lanceolata</i> (Agardh) Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
38.	<i>Navicula tripunctata</i> (O.F.Müttler) Bory	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
39.	<i>Nitzschia</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
40.	<i>Oscillatoria</i> sp.	Cyanophyta	<i>Cyanophyceae</i>	0	1	1	0	0	2
42.	<i>Spirogyra</i> sp.	Chlorophyta	<i>Conjugatophyceae</i>	1	0	1	0	0	2
43.	<i>Stauroneis smithii</i> Grunow	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
44.	<i>Stauroneis phoenicenteron</i> (Nitzsch) Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
45.	<i>Ulnaria ulna</i> (Nitzsch.) Compere	Heterokontophyta	<i>Bacillariophyceae</i>	1	0	1	0	0	2
46.	<i>Achnanthes exigua</i> Grunow	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
47.	<i>Achnanthidium pyrenaicum</i> (Hustedt) H.Kobayasi	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
50.	<i>Amphipleura pellucida</i> (Kützing) Kützing	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1

51.	<i>Amphora minuta</i>	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
54.	<i>Audouinella violacea</i> (Kützinger) Hamel	Rhodophyta	<i>Florideophyceae</i>	0	0	1	0	0	1
56.	<i>Aulocoseira ambigua</i> (Grunow) Simonsen	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
57.	<i>Caloneis alpestris</i> (Grunow) Cleve	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
65.	<i>Chamaesiphon confervicola</i>	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
66.	<i>Chamaesiphon incrustans</i> Grunow in Rabenhorst	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
74.	<i>Closterium acerosum</i> Ehrenberg ex Ralfs	Chlorophyta	<i>Conjugatophyceae</i>	0	0	1	0	0	1
75.	<i>Closterium ehrenbergii</i> Meneghini ex Ralfs	Chlorophyta	<i>Conjugatophyceae</i>	0	0	1	0	0	1
78.	<i>Cocconeis placentula</i> Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
81.	<i>Craticula cuspidata</i> Kützinger	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
83.	<i>Cymatopleura elliptica</i>	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
85.	<i>Cymatopleura solea</i> var. <i>apiculata</i>	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
87.	<i>Cymbella helvetica</i> Kützinger	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
89.	<i>Cymbella aspera</i> (Ehrenberg) Cleve	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
90.	<i>Cymbella cistula</i> (Ehrenberg) O.Kirchner	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
91.	<i>Cymbella lanceolata</i> C.Agardh	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
92.	<i>Denticula elegans</i> Kützinger	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
93.	<i>Denticula kuetzingii</i> Grunow 1862	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
101.	<i>Diploneis ovalis</i> (Hilse) Cleve	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1

102.	<i>Discostella stelligera</i> (Cleve & Grunow) Houk & Klee	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
109.	<i>Encyonema minutum</i> (Hilse) D.G.Mann	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
113.	<i>Epithemia</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
114.	<i>Epithemia argus</i> (Ehrenberg) Kützing	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
125.	<i>Eunotia minor</i> (Kützing) Grunow	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
130.	<i>Fragilaria vaucheriae</i> (Kütz.) Petersen	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
141.	<i>Gomphonema micropus</i> Kützing	Heterokontophyta	<i>Bacillariophyceae</i>	0	1	1	0	0	2
142.	<i>Gomphonema minuscula</i>	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
144.	<i>Gomphonema acuminatum</i> Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
145.	<i>Gomphonema olivaceum</i> (Hornemann) Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
147.	<i>Gyrosigma obtusatum</i> (Sullivan & Wormley) Boyer	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
148.	<i>Gyrosigma acuminatum</i> (Kützing) Rabenhorst 1853	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
149.	<i>Gyrosigma scalproides</i> (Rabenhorst) Cleve 1894	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
154.	<i>Homoeothrix varians</i> Geitler	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
163.	<i>Lyngbia martensiana</i> (Meneghini) Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
167.	<i>Microspora</i> sp.	Chlorophyta	<i>Chlorophyceae</i>	0	0	1	0	0	1
168.	<i>Mougeotia genuflexa</i> (Roth) C.Agardh	Chlorophyta	<i>Conjugatophyceae</i>	0	0	1	0	0	1
174.	<i>Navicula veneta</i> Kütz.	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
175.	<i>Navicula lanceolata</i> Ehrenberg	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1

176.	<i>Navicula radiosa</i> Kützing	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
188.	<i>Nitzschia sigma</i>	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
191.	<i>Nitzschia dissipata</i> (Kützing) Rabenhorst	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
192.	<i>Nitzschia fonticola</i> (Grunow) Grunow	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
193.	<i>Nitzschia recta</i> Hantzsch ex Rabenhorst	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
198.	<i>Oedogonium fonticola</i> A.Braun ex Hirn	Chlorophyta	<i>Chlorophyceae</i>	0	0	1	0	0	1
199.	<i>Oedogonium</i> sp.	Chlorophyta	<i>Chlorophyceae</i>	0	0	1	0	0	1
202.	<i>Oscillatoria princeps</i> Vaucher ex Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
206.	<i>Phormidium favosum</i> Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
207.	<i>Phormidium inundatum</i> (Kützing) Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
208.	<i>Phormidium papyraceum</i> Gomont ex Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
209.	<i>Phormidium retzii</i> (Meneghini) Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
210.	<i>Phormidium</i> sp.	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
223.	<i>Pinnularia rupestris</i> Hantzsch in Rabenhorst	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
231.	<i>Placoneis</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
233.	<i>Planothidium lanceolatum</i> (Brébisson ex Kützing) Lange-Bertalot	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
234.	<i>Plantkolyngbya</i> sp.	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
235.	<i>Plectonema tomasinianum</i> (Bornet 1889) Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
236.	<i>Plectonema wollei</i> Farlow ex Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1

237.	<i>Pseudoanabaena catenata</i>	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
239.	<i>Rhoicosphaenia abbreviata</i>	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
247.	<i>Sellaphora</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
249.	<i>Shizothrix fasciculata</i> (Nägeli in Kützing) Gomont	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
250.	<i>Spirulina</i> sp.	Cyanophyta	<i>Cyanophyceae</i>	0	0	1	0	0	1
262.	<i>Surirella linearis</i> W.M.Smith in Schmidt & al.	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
263.	<i>Surirella</i> sp.	Heterokontophyta	<i>Bacillariophyceae</i>	0	0	1	0	0	1
267.	<i>Tribonema viridae</i> Pascher	Heterokontophyta	<i>Xanthophyceae</i>	0	0	1	0	0	1
268.	<i>Vaucheria</i> sp.	Heterokontophyta	<i>Xanthophyceae</i>	0	0	1	0	0	1

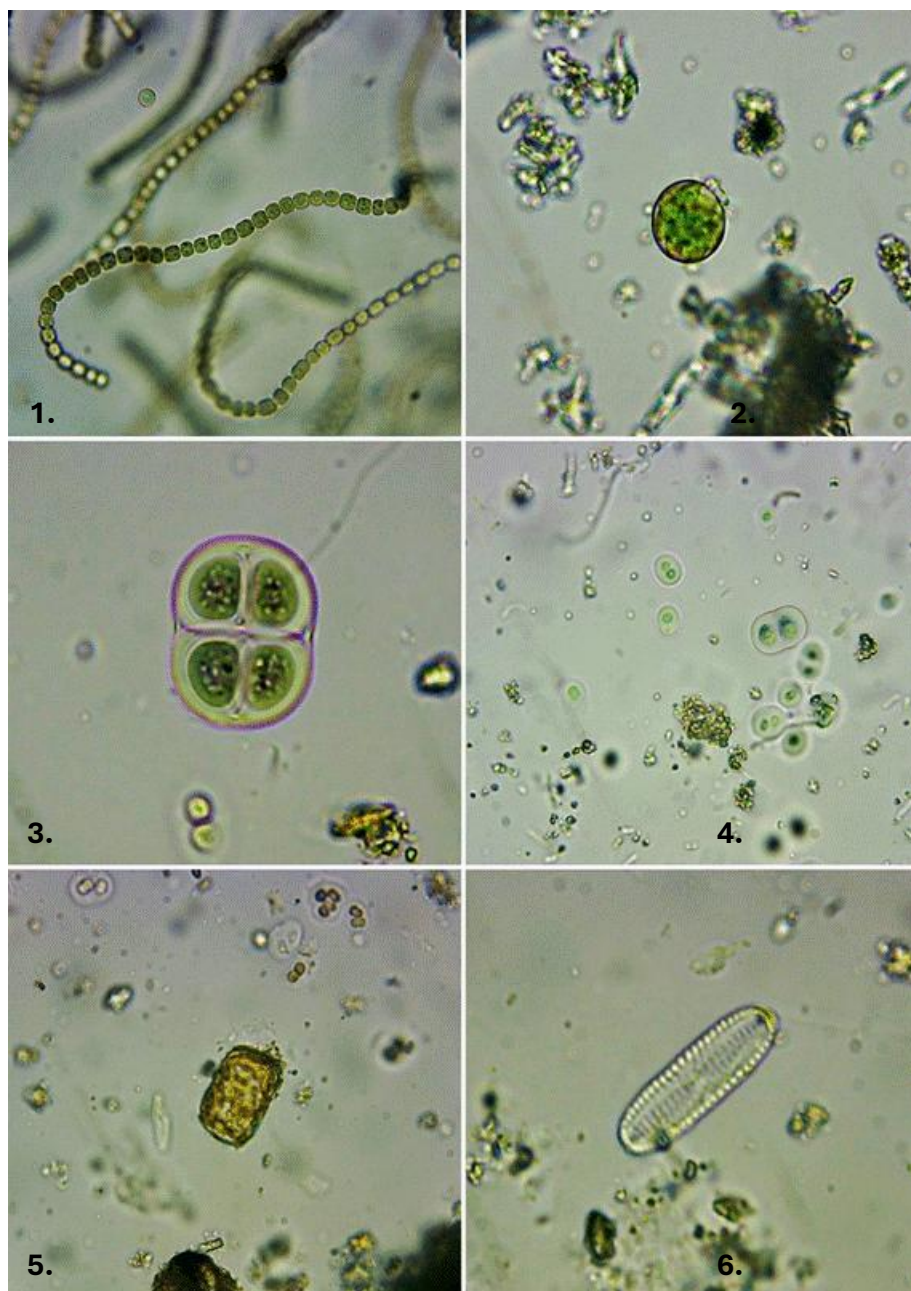


Plate A. Selected taxa of cyanobacteria and algae identified in the Protected areas in Canton Sarajevo: 1. *Nostoc commune*, 2. *Chlorella vulgaris*, 3. *Chroococcus turgidus*, 4. *Chroococcus minutus*, 5. *Orthoseira roeseana*, 6. *Pinnularia borealis*

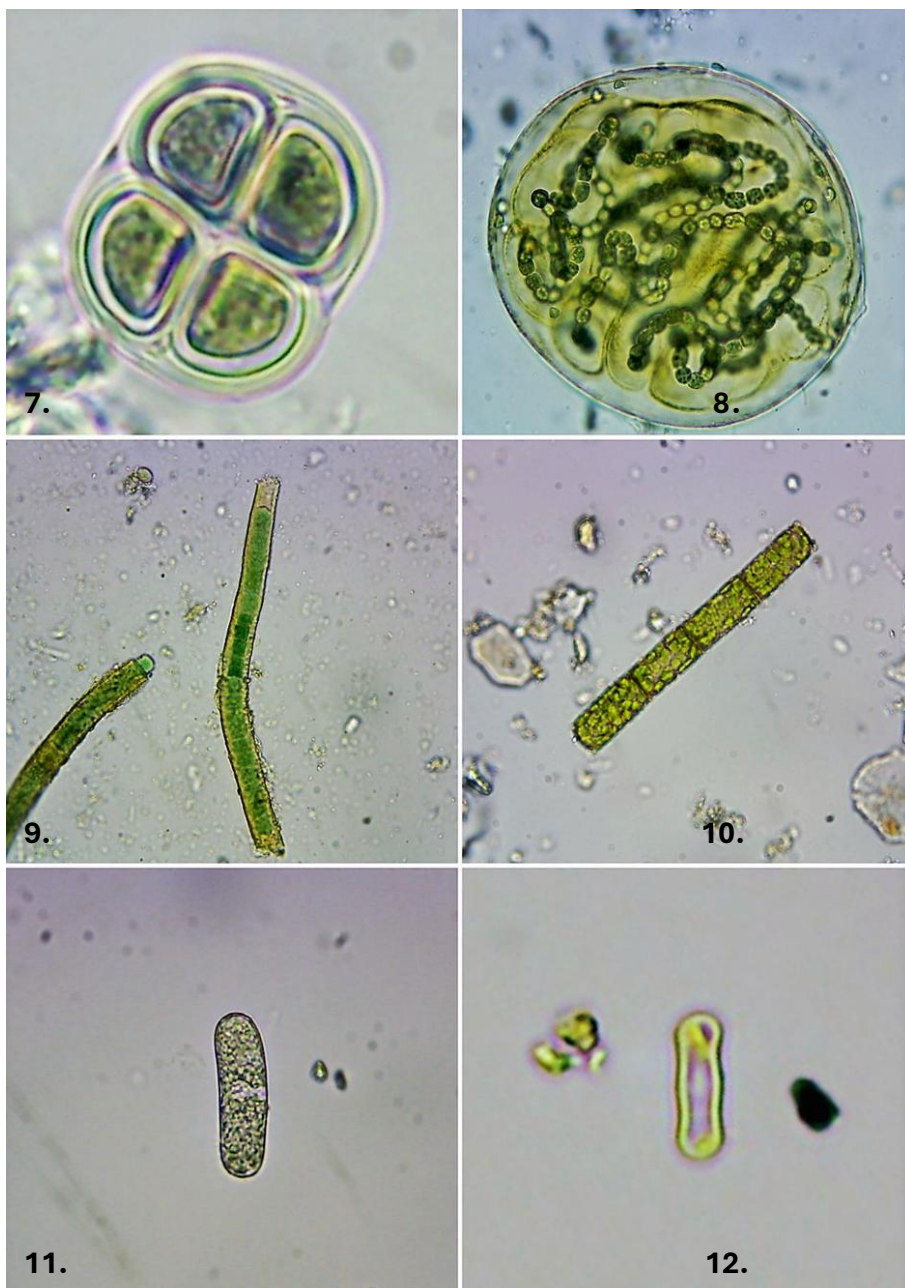


Plate B. Selected taxa of cyanobacteria and algae identified in the Protected areas in Canton Sarajevo: 7. *Chroococcus turgidus*, 8. *Nostoc commune*, 9. *Phormidium calcareum*, 10. *Orthoseira dendroteres*, 11. *Cyanothece aeruginosa*, 12. *Humidophila contenta*

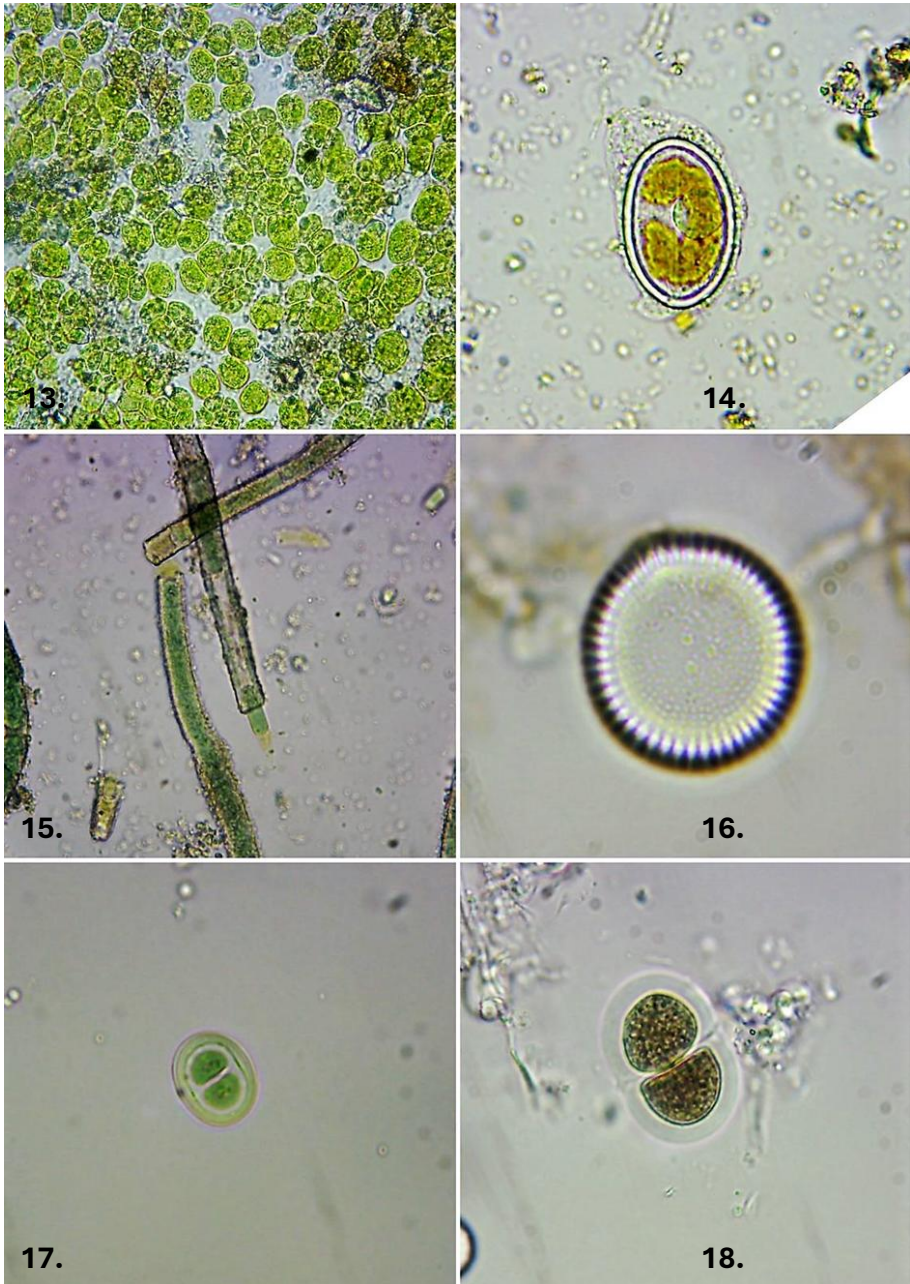


Plate C. Selected taxa of cyanobacteria and algae identified in the Protected areas in Canton Sarajevo: 13. *Chlorella vulgaris*, 14. *Cocconeis pediculus*, 15. *Phormidium calcareum*, 16. *Orthoseira roeseana*, 17. *Chroococcus minutus*, 18. *Chroococcus turgidus*

RESULTS AND DISCUSSION

The study of cyanobacteria and algae in protected areas across Europe varies depending on specific locations and the research efforts made in those areas. Europe is rich in diverse protected areas, such as national parks, biosphere reserves, strict nature reserves, and other regions with special protection statuses that contribute to maintaining ecosystems. Additionally, the study of underwater organisms, such as marine invertebrates, fish, and marine algae, can be challenging due to access and logistical issues (Ismail & Goeden, 2022).

Many research institutions, universities, and organizations in Europe focus on water ecosystems, including the study of cyanobacteria and algae. These researchers often collaborate with local authorities and nature protection agencies to collect data on the presence, diversity, ecology, and water quality in protected areas. Studies frequently focus on monitoring water quality and assessing ecological status using bioindicator organisms, including cyanobacteria and algae. Monitoring cyanobacteria is particularly important due to the potential for toxic blooms in water bodies, which can pose risks to the environment and human health (Benayache *et al.*, 2019).

Cyanobacteria and algae represent an essential component of aquatic ecosystems in protected areas throughout Europe. The study of cyanobacteria and algae in protected areas has several critical aspects. Firstly, it provides information about the state of aquatic ecosystems and any potential changes in their biological diversity. This is crucial for monitoring and conserving the health of aquatic ecosystems, especially in the context of climate change and anthropogenic impacts. Secondly, the study of cyanobacteria is important for assessing water quality and safety for human use. Identifying potentially toxic species of cyanobacteria and monitoring their presence allows for preventive measures and risk management of toxic blooms. The study of cyanobacteria and algae in protected areas is of significant importance for the continuous monitoring of the ecological status of surface and groundwater, the conservation of sensitive microhabitats and the species contained therein, and their potential ecological restoration. Numerous aquatic microhabitats within protected areas provide valuable ecosystem services that improve the quality of life for humans. In this regard, it is essential to protect them from anthropogenic impacts and various tourist activities, utilizing various mechanisms and tools such as the Convention on Biological Diversity (CBD) to preserve biodiversity in Europe (Li *et al.*, 2023; Pergl *et al.*, 2020). To assess the diversity of cyanobacteria and algae in protected areas across Europe, databases and the scientific papers contained within them were analyzed. Papers focusing primarily on this group of organisms were selected. In this regard, studies on cyanobacteria and algae in the following European countries were analyzed: Ukraine (Polesian Nature Reserve, Podilsky Tovtry National Park, and the Nature Park of Priazov), Czech Republic (Soos Nature Reserve), Spain (Corrubedo National Park), Turkey (Artabel Lakes Nature Park), and Bulgaria (Bulgarka National Park) [Bren *et al.* (2022), Atici, 2018, Stoyanov *et al.* (2016), Kapustin, 2014, Momeu *et al.* (2012), Vinogradova *et al.* (2009), Gross *et al.* (2002), and Calvo *et al.* (1999)].

In the study investigating the Polesian Nature Reserve, the author (Kapustin, 2014) examined algal biodiversity and identified a total of 707 taxa. The presence of many rare and endangered species of algae was noted. Notably, seven species were listed in the Red Book of Ukraine. The dominant groups in terms of species number were Chlorophyta (160), Bacillariophyta (159), Streptophyta (144), and Euglenophyta (111), while others appeared in smaller numbers.

In addition to this protected area, Ukraine also has the Nature Park of Priazov, where research by Bren *et al.* (2022) indicates the existence of 11 classes, 32 orders, 61 families, and 92 genera. The greatest species richness at the departmental level was observed in Cyanophyta (43.8% of the total species), Bacillariophyta (32.0%), and Chlorophyta (20.9%). The leading algal orders in the studied habitats were Oscillatoriales and Synechococcales (20 species). The most diverse families were *Oscillatoriaceae* (13 taxa), *Nostocaceae*, *Leptolyngbyaceae*, *Naviculaceae* (8 taxa), *Microcoleaceae* and *Bacillariaceae* (7 taxa).

The Soos Nature Reserve, located in the westernmost part of the Czech Republic, has a total of 35 species. The study (Gross *et al.*, 2002) highlights the area's interesting pH range of 1.6 to 2.6, with very little algal biomass, which is mostly composed of *Chlamydomonas acidophila* (Chlorophyta, Chlamydomonadales), *Lepocinclis teres*, *Euglena mutabilis* (Euglenophyta, Euglenales), and *Eunotia exiqua*, among others.

In a selected study of algae in the Artabel Lakes Nature Park in Turkey, the author (Atici, 2018) identified a total of 98 species belonging to the departments: Bacillariophyta, Chlorophyta, Cyanobacteria, Euglenophyta, Pyrrophyta, and Cryptophyta. The study emphasized that the samples from this Nature Park were analyzed from both planktonic and benthic samples from 18 freshwater lakes.

The results of studies on benthic marine algae from the saline marshes of Corrubedo National Park on the Iberian Peninsula (Calvo *et al.*, 1999) indicate a total of 84 taxa. A total of 84 species were identified, including 49 Cyanophyta, 6 Rhodophyta, 10 Heterokontophyta, and 19 Chlorophyta. Many taxa are of biogeographical interest. *Vaucheria arcassonensis*, *V. intermedia*, and *Wittrockiella paradoxa* are new records from the Iberian Peninsula. Cyanophyta and Chlorophyta together comprise 81% of the reported species, with chlorophyte algae and *Vaucheria sp.* making up the most widespread population.

In five karstic speleo objects of the National Park of Podilsky Tovtry, the authors (Vinogradova *et al.*, 2009) recorded 86 species. These belong to Cyanoprokaryota (35 species), Chlorophyta (35), Bacillariophyta (7), Xanthophyta (4), Streptophyta (3), and Eustigmatophyta (2). A total of 56 species were cited for the first time in this National Park, and eight species were new to Ukraine. In the caves, 67 species were recorded, with green algae (49-58%) dominating, and cyanoprokaryotes making up 11-29%.

In Bulgaria, in the Bulgarka National Park, the authors (Stoyanov *et al.*, 2016) described 194 species belonging to 11 departments. Some of the species present include *Chroococcus turgidus*, *Cylindrospermum muscicola*, *Geitlerinema amphibium*, *Gloeothece fuscolutea*, *Heteroleibleinia rigidula*, and *Jaaginema gracile*, among others

Research on cyanobacteria and algae in protected areas of Bosnia and Herzegovina has not been extensively conducted. Sporadic data can be found in works by Kamberović *et al.* (2023), Stanić-Koštroman *et al.* (2021), Kamberović *et al.* (2021), Kamberović *et al.* (2019), Kamberović *et al.* (2016), Kapetanović *et al.* (2011), Kapetanović *et al.* (2007), Barudanović *et al.* (2025), Šovran *et al.* (2024), Barudanović *et al.* (2019), Mašić (2020), Mašić & Barudanović (2020), and Mašić *et al.* (2019). Unfortunately, there is currently no unified database listing the identified species in protected areas of Bosnia and Herzegovina or a display of their distribution across different aquatic ecosystems and wetland habitats. By comparing the composition of cyanobacteria and algae in protected areas of Sarajevo Canton with protected areas across Europe, it can be concluded that the number of taxa is high and characterized by specific diversity. Therefore, future efforts should focus on conducting fundamental research and expanding the list of cyanobacteria and algae in protected areas of Sarajevo Canton, as well as establishing a unified digital database on the diversity of cyanobacteria and algae in protected areas of Bosnia and Herzegovina.

CONCLUSIONS

The number and area of protected natural areas in Bosnia and Herzegovina (B&H), as well as in each of its administrative units, are not at a satisfactory level. B&H has a significantly lower level of protection compared to IUCN recommendations. Additionally, a significant number of protected areas are isolated without established adequate management mechanisms. The low level of protection is aligned with the country's various political and economic processes, which tend to prioritize resource exploitation over conservation. The importance of geodiversity and biodiversity is not viewed from the perspective of the ecosystem services that these protected areas provide, nor from the needs that can be met within them.

Protected natural areas, through their ecosystem services, are highly significant for society and the economy at local, regional, national, and global levels. They play a vital role in addressing the challenges of climate change, maintaining water quality, preserving natural pollinators, conserving biodiversity, geodiversity, and landscapes, as well as supporting tourism and recreation.

The study on the diversity of cyanobacteria and algae in the protected areas of Sarajevo Canton has shown that these habitats provide exceptionally favorable ecological conditions for their development. Compared to available scientific data from B&H and Europe, these areas facilitate the formation of stable communities of these organisms. However, there is still insufficient data for the newly protected areas, Bentbaša and Trebević, indicating a need for further research in the future.

Given that there is no unified biodiversity database for cyanobacteria and algae in B&H, its urgent establishment is necessary. Such a database would not only enable systematic monitoring and better understanding of this group of organisms but also play a crucial role in the long-term conservation of aquatic and wetland habitats within protected areas. Cyanobacteria and algae, being highly sensitive organisms, can serve as early

indicators of ecological changes, helping to enable timely responses and more efficient natural resource management within protected areas. Their continuous monitoring and protection would contribute to the preservation of these valuable ecosystems for future generations.

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DOPRINOS POZNAVANJU RAZNOLIKOSTI CIJANOBAKTERIJA I ALGI U ODABRANIM ZAŠTIĆENIM PODRUČJIMA KANTONA SARAJEVO

Sažetak

Kanton Sarajevo ima najveći broj zaštićenih prirodnih područja među ostalim kantonima u Federaciji Bosne i Hercegovine, uključujući spomenike prirode i zaštićene krajolike: Skakavac, Bijambare, Vrelo Bosne, Trebević i Bentbaša. Svako od ovih područja karakteriziraju specifične geomorfološke, hidrološke, pedološke, biološke i ekološke značajke, služeći kao centri biološke raznolikosti za floru, faunu i gljive. Ovaj rad pruža uvid u raznolikost cijanobakterija i algi unutar odabranih zaštićenih područja Kantona Sarajevo. Do danas je unutar tih područja identificirano 268 taksona cijanobakterija i algi. Bijambare se mogu pohvaliti najvećim brojem vrsta (155), a slijede Vrelo Bosne (66) i Skakavac (66). Podaci o raznolikosti ovih organizama u Bentbaši i Trebeviću trenutno nisu dostupni, što naglašava potrebu za detaljnijim i

sistemske istraživanjem na tim područjima. Osim uspostavljanja popisa cijanobakterija i algi, kontinuirano praćenje njihovih staništa u zaštićenim područjima Kantona Sarajevo je ključno. S obzirom na to da su cijanobakterije i alge izvrsni bioindikatori vodenih ekosistema, njihovo uključivanje u planske dokumente za kontinuirano praćenje ključan je korak u očuvanju ovih vrijednih područja.

Ključne riječi: *alge, bioraznolikost, cijanobakterije, praćenje, zaštićena područja*