Plant & Fungal Research (2024) 7(2): 36-45
https://doi.org/10.30546/2664-5297.2024.7.2.50.011
© The Institute of Botany, MSE, Baku, AZ1004, Azerbaijan
December 2024

Systematic study and bioecological characteristics of the algal flora of the Caspian coastal areas of the Absheron Peninsula

Aytaj B. Muradova
Shakar J. Mukhtarova
Institute of Botany, Ministry of Science and Education of the Republic of Azerbaijan, A. Abbaszade st., 1128th crossing, AZ1004, Baku, Azerbaijan
Yashar M. Feyziyev[1]
Institute of Molecular Biology and Biotechnologies, Ministry of Science and Education of the Republic of Azerbaijan, Izzat Nabiyev st.11, Baku, AZ1073, Azerbaijan

Abstract: The study of the Caspian Sea's algal flora started in the 1960s. However, over the past 20 years, there has been a significant gap in the study of the algal flora in the Azerbaijani part of the sea. As a result, it is now crucial to expand these studies and compare the obtained data with the previous results. The algal flora of the Caspian Sea has been poorly studied taxonomically. The main goal of our research was to identify the biodiversity of the algae of the Caspian Sea, to examine its taxonomic structure and to determine the influence of some external environmental factors. The article contains new information on the marine macrophytes and microscopic algal flora of the coastal zones of the Absheron Peninsula. During our research, 26 species of algae were identified. Species belong to divisions Rhodophyta (1 species), Charophyta (3 species), Cyanobacteria (3 species), Chlorophyta (10 species) and Bacillariophytina (subphylum) (9 species). Chlorophyta division was the dominant group, constituting 38.5% of algal flora, followed by Cyanobacteria – 11.5%, Charophyta – 11.5%, Rhodophyta – 3.9% Bacillariophytina – 34.6%, Bacillariophytina – 34.6%. The leading families of the algal flora were Oscillatoriaceae Engler, Spirogyraceae Bessey, Cladophoraceae Wille and Naviculaceae Kützing.

Keywords: *Bacillariophytina, Cyanobacteria, ecology group, macrophyte, species, taxonomic analysis*

INTRODUCTION

Algae have a wide biodiversity, and due to limited biogeographic inventories in the world it is difficult to carry out their identification [Norton et al., 1996]. H.C. Bold and M.J. Wynne [1985] noted that the morphological diversity of algae makes them difficult to identify. Most carbon fixation is connected with phytoplankton. Although most macroalgae live only in coastal areas and continental shelves, they account for a significant proportion of biomass productivity in the oceans. Loss of aquatic biodiversity reduces the efficiency of the processes by which organisms acquire resources, produce biomass and recycle essential nutrients [Cardinale et al., 2012]. Since freshwater systems occupy less than 0.5% of the water surface, marine ecosystems account for the largest share of productivity.

The ecology of seaweeds greatly depend on two environmental factors. They live in sea water and require sufficient light for photosynthesis. Another general requirement is the presence of a fixation point, so seaweeds live mainly in the littoral zone (in nearshore waters) and on rocky substrates within this zone [Pereira, Correia, 2015]. Seaweeds occupy several ecological niches. On the coasts, they are moistened only by sea foam, some species can attach to the substrate at a depth of several meters. On some coasts, seaweed colonies may extend out to sea. In this habitat, seaweed must withstand rapid changes in temperature and salinity, as well as the speed of alternating ebb and flow [Pereira, 2009; Pereira, Correia, 2015]. Alternatively, thanks to pneumatocysts ("gas-filled bubbles"), macroalgae can keep their thalomes in water, leaves are transported from the coast to the deep ocean by wind and currents [Gaspar et al., 2020; Pereira, Correia, 2015]. As the importance of algae in still and running waters became clear, the number of research conducted on these organisms began to increase.

The species composition and distribution of macrophyte algae in the Caspian Sea were studied in detail by E.B. Zaberzhinskaya [1968]. A complete research history of the macrophyte algae of the Caspian Sea is described in the publication of E.B. Zaberzhinskaya [1968], N.G. Karaeeva [1972]. These data revealed that the anthropogenic impact on the algal flora of the Caspian Sea has not been specifically studied. The first impact of the pollution

[1]E-mail: ya_feyziyev@yahoo.com
Received: 10.10.2024; Received in revised form 23.10.2024; Accepted: 29.11.2024

on macrophytes spread on the shores of the Caspian Sea in Azerbaijan is related to the development of the oil and chemical industry, which began in 1950. Thus, the coast of the Absheron Peninsula is industrialized and urbanized and considered the main area of industrial pollution. Nevertheless, studies of algal flora conducted on the coast of the peninsula from 1957 to the 1970s show that the algal flora at that time was quite typical and included endemic and rare species. A comparative analysis of the results of algae composition studies at stations with different degrees of pollution shows that green algae are more resistant to pollution than red algae. According to the observations of M.S. Kireeva and T.F. Shchapova [1957] on the shores of the peninsula of the Caspian Sea, algae of the Rhodophyta division were relatively dominant. Red algae were registered by N.G. Karaeva [1960, 1972] in the late 50s and early 60s of the last century (20th century) near Sumgayit city, Baku and the islands of the Absheron archipelago, in the area from Cape Bayil to Cape Bandovan. A large underwater biomass of red algae covers the area from Cape Amiya south to the beginning of the Shahdili (including the islands of the Absheron Archipelago) and from Cape Puta south to Jigil Island. Due to changing natural factors, differences in algae biodiversity are obvious. In moderately polluted areas, some red algal genera – *Laurencia* J.V. Lamouroux, *Polysiphonia* Greville, etc., can not tolerate increased pollution and gradually disappear, resulting in a decline in the number of these species. Some resistant species of this division (*Colaconema savianum* (Meneghini) R. Nielsen, *Lophosiphona obscura* (C. Agardh) Falkenberg) gradually lose their reproductive capacity, which leads to their quantitative decline.

Little information is available on the quantitative distribution and floristic composition of phytoplankton in the Caspian Sea. Furthermore, due to the lack of data characterizing the entire marine area by a year and season of a given period, it is challenging to evaluate the impact of biotic and abiotic factors on annual and interannual changes in water level, depending on depth and area, especially during precipitation. It should be emphasized that the species composition of phytoplankton in the Caspian Sea is much weaker than in the Black and Azov Seas. About 343 species were recorded in the Caspian Sea, 750 in the Black Sea, and 417 in the Azov Sea [Petrov, 1967; Babaev, 1968; Proshkina-Lavrenko, Makarova, 1968]. The phytoplankton in the Caspian Sea is dominated by green algae (127), diatoms (111), and blue-green (74) taxon [Zinova, 1967]. As a result of the microscopic processing of algal samples, 17 species and subspecific taxa belonging to blue-green algae were discovered in the Middle and Southern parts of the Caspian Sea [Kiselev, 1938]. Valuable information on benthic blue-green algae was found in the work of M.S. Kireeva and T.F. Shchapova (1957). This article summarized the results of research conducted in 1934-1938. The authors, summarizing their results and literature data, identified 33 species of blue-green algae distributed in the benthos of the Caspian Sea.

The research aimed to reveal the biodiversity of the Caspian Sea algoflora, to study its taxonomic structure, and the effect of some external environmental factors on algae.

MATERIAL AND METHODS

Research areas. About 45% of the total volume of lake waters in the world is accounted for by the Caspian Sea. The research was conducted in coastal areas of the peninsula (Bilgah, Nardaran, Pirshagi, Shikhov, Sahil). Unlike the seas, which have connections with the ocean and other water reservoirs, it has its own hydrometeorological and biological regime. The Caspian Sea's phytoplankton is home to both freshwater and brackish water algae. This is due to the low salinity of the sea. Currently, the average salinity of the Caspian Sea is 12.7-12.8%.

Algal samples were collected from the coastal part of the peninsula in May-December 2023. Cape Shikhov is located in the northwestern part of the end of the peninsula. Bilgah settlement is located in the northern part of the peninsula between the Kalaga-Amburan capes. The coastal part of Sahil and Nardaran settlements is characterized by the presence of a complex relief. Pirshaghi is located on the coast of the Caspian Sea in the north of the peninsula. The map-scheme of the researched districts was prepared with ArcGIS version 10.7 and Google Earth (Fig.1, Fig. 2).

Sample collection and identification. Algological samples collected in the Azerbaijani part (from the surf zone 50 m, and sometimes up to 100 m distance (upper-, supra-, sublittoral and from the coastal part) of the Caspian Sea were used for the research. The water column, seabed, solid substrate (hygrotechnical structures, rock, stone), and macrophyte algae were studied as living substrates. A plankton cup was used to collect samples; then the water was passed through a filter of polyethylene materials No. 25 and No. 77 and phytoplanktons were collected [Schwoerbel, 2013]. A bathymeter and a 3-liter balloon were used to collect

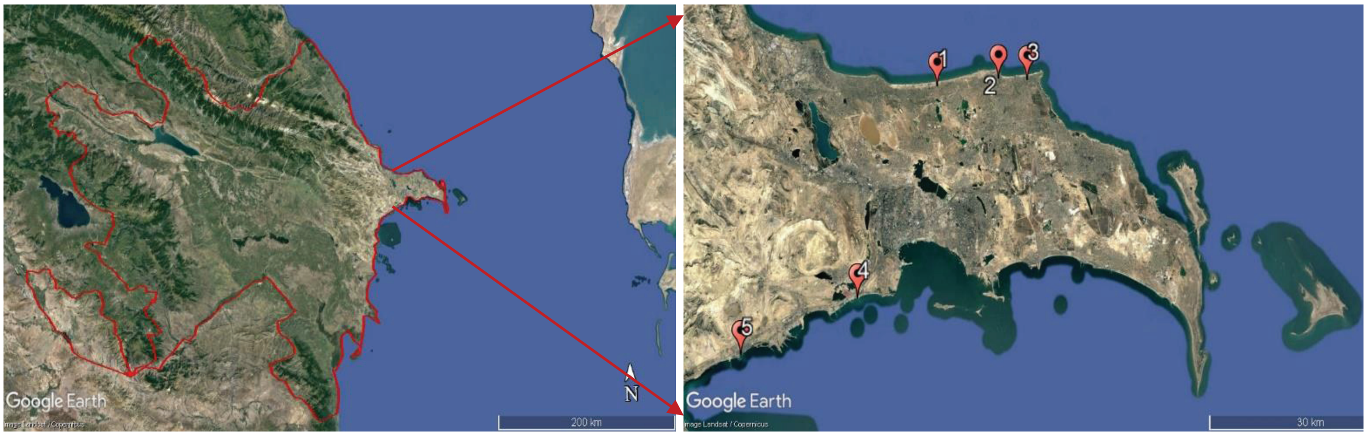

Figure 1. Sampling areas in littoral zones of the settlements of the Caspian Sea: 1. Pirshagi, 2. Nardaran, 3. Bilgah, 4. Shikhov, 5. Sahil.

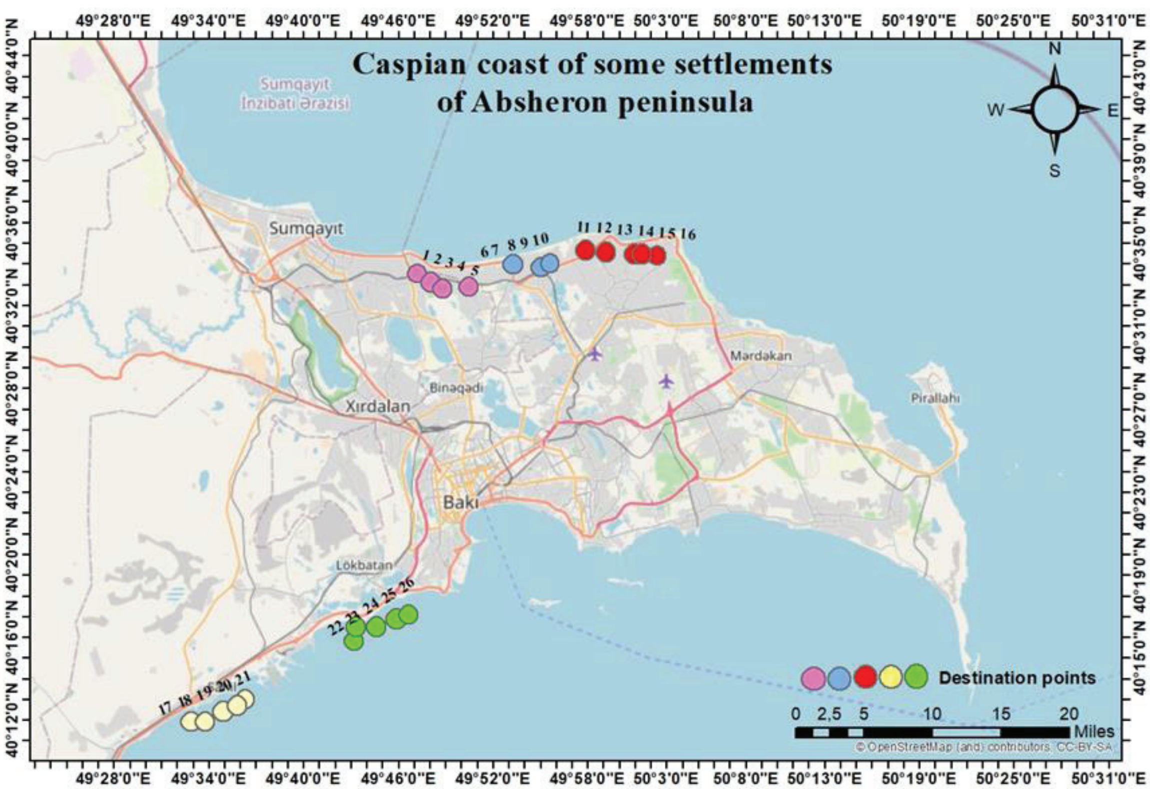

Figure 2. Map of distribution of algae (shown as 1-5, respectively, Pirshagi, 6-10 (Nardaran), 11-16 (Bilgah), 17-21 (Sahil), 22-26 (Shikhov); 1. *Chroococcus turgidus*, (Pirshagi, Sahil), 2. *Cladophora fracta* (Pirshagi, Sahil, Shikhov), 3. *Rhizoclonium riparium* (Pirshagi, Bilgah), 4. *Oscillatoria sancta* (Pirshagi, Nardaran), 5. *Cocconeis placentula*, 6. *Chaetomorpha aerea* (Nardaran, Pirshagi, Bilgah), 7. *Cladophora glomerata* (Pirshagi, Nardaran), 8. *Ulva compressa*, 9. *Spirogyra crassa* (Nardaran, Sahil), 10. *Zygnema stellinum*, 11. *Lyngbya majuscula*, 12. *Ulva prolifera*, 13. *Epithemia parallela* (Bilgah, Nardaran, Sahil, Shikhov), 14. *Hantzschia amphioxys*, 15. *Cladophora ruchingeri* (Pirshagi, Nardaran, Sahil, Shikhov), 16. *Cymbella lanceolata*, 17. *Cladophora laetevirens*, 18. *Chaetomorpha linum*, 19. *Spirogyra majuscula* (Bilgah, Nardaran, Sahil, Shikhov), 20. *Colaconema elegans*, 21. *Amphora pediculus*, 22. *Amphora ovalis* (Pirshagi, Bilgah, Shikhov), 23. *Caloneis silicula*, 24. *Nitzschia denticula* (Pirshagi, Nardaran, Sahil, Shikhov), 25. *Cladophora sericea*, 26. *Nitzschia dissipata*.

benthic species. For a further and detailed study of the materials, 4% formalin was added. Epiphytic algae were collected in plastic containers and 10% formaldehyde was added. To study epilithic diatoms, sediment samples were collected at a distance of 2-3 meters from the shore using a glass tube with a diameter of 8 mm and a length of 1 meter, and the samples were transferred to plastic containers. After the mud samples were sedimented, the water was drained and the mud was transferred to Petri dishes [Van Der Werff, 1999].

Samples containing diatoms were centrifuged and boiled by adding H_2O_2, diatoms were cleaned of acid and organic matter. Diatoms were identified in permanent preparations prepared from them [Tash, Okush, 2006]. A scanning electron microscope (SEM, JSM-35 SEM, JEOL, Japan) was used to determine diatom algae, and an optical microscope (Nikon E100, Nikon ECLIPSE Ci) for algae of other divisions.

Various literature materials were used for morphological characteristics and identification [Zaberzhinskaya, 1968; Williams, 1985; Schmid,1994; Fourtanier, Kociolek, 2009; Seckbach, Kociolek, 2011; Kulikovsky, Kuznetsova 2014; Afanasyev et al., 2016; Nuriyeva, 2019; Afanasyev et al., 2020; Mukhtarova, Jafarova 2020; Nuriyeva, Vinogradova, 2020; Mukhtarova, Muradova 2023; Muradova et al., 2023]. Water temperature was measured with a laboratory thermometer, pH was determined with a portable WTW-3110 pH meter (Germany) (Table 1). AlgaeBase [Guiry, Guiry, 2023], "California Academy" [www.calacademy.org], and "Alga Terra" [www.algaterra.org] websites were used to specify the names of algae species, referring to the latest nomenclature.

RESULTS

Taxonomic analysis. In the study area, 26 species (*Amphora ovalis* (Kützing) Kützing, *A. pediculus* (Kützing) Grunow, *Cladophora fracta* (O.F. Müller ex Vahl) Kützing, *C. laetevirens* (Dillwyn) Kützing, *C. ruchingeri* (C. Agardh) Kützing, *C. glomerata* (Linnaeus) Kützing, *C. sericea* (Hudson) Kützing, *Caloneis silicula* (Ehrenberg) Cleve, *Chaetomorpha aerea* (Dillwyn) Kützing, *Ch. linum* (O.F. Müller) Kützing, *Chroococcus turgidus* (Kützing) Nageli, *Cocconeis placentula* Ehrenberg, *Colaconema elegans* (Ehrenberg) Cleve, *Cymbella lanceolata* (C. Agardh), *Epithemia parallela* (Grunow) Ruck & Nakov, *Hantzschia amphioxys* (Ehrenberg) Grunow, *Lyngbya majuscula* Harvey ex Gomont, *Nitzschia denticula* Grunow, *N. dissipata* (Kützing) Rabenhorst, *Oscillatoria sancta* Kützing ex Gomont, *Rhizoclonium riparium* (Roth) Harvey, *Spirogyra crassa* (Kützing) Kützing, *S. majuscula* Kützing, *Ulva compressa* Linnaeus, *U. prolifera* O.F. Müller, *Zygnema stellinum* (O.F. Müller) C. Agardh) belonging to 15 genera, 10 families, 10 orders and 5 divisions were identified. Among them, 1 species belongs to red, 3 species to Charophyta, 3 species to blue-green, 9 species to diatoms (Fig. 3) and 10 species to green algae. During the studies, it was found that *Amphora ovalis* (Kützing) Kützing, *Amphora pediculus* (Kützing) Grunow, *Epithemia parallela* (Grunow) Ruck & Nakov, *Cladophora ruchingeri* (C. Agardh) Kützing, *Cladophora fracta* (O.F. Müller ex Vahl) Kützing, *Lyngbya majuscula* Harvey ex Gomont species prevailed in different destination points. *Epithemia parallela* was observed in Bilgah, Nardaran, Shikhov, Sahil, *C. ruchingeri* in Pirshaghi, Nardaran, Shikhov, Sahil, *A. ovalis* in Shikhov, Bilgah, Pirshaghi stations.

When analyzing the distribution number of the studied species by seasons, *C. fracta* from Chlorophyta division, diatoms *E. parallela*, *Navicula lanceolata* are observed in four seasons. *Colaconema elegans*, a representative of the Rhodophyta division is found only in winter. Representatives of the Cyanobacteria division are not found in the winter season and representatives of the Charophyta division are not found in the autumn season. Seasonal changes in parameters directly affect the growth of algae and cause changes in their nutritional composition. Some species are noted to have seasonal lifespans. Species diversity predominates in the spring, summer months and the winter season is a period when species are few. Biodiversity and abundance of species were observed on the Caspian coast of Nardaran and Shikhov settlements and the minimum indicator was observed in the Sahil settlement (Table 2, Fig. 2).

Ecological analysis. The results of our research showed that for the algal flora of the Caspian Sea, 1 species belongs to epiphytic, 1 species both to benthic and epiphytic, 1 species to benthic, planktonic, epiphytic, and epilithic, 2 species to planktonic, benthic, and epiphytic, 2 species both to epiphytic, and epilithic, 4 species both to planktonic and benthic, 4 species to planktonic, 11 species to benthic groups. The species are distributed in the temperature range of 10-26ºC and pH 7.9-8.1. As it is well known algae prefer specific pH ranges (6.0-9.0) [Raven et al., 2012]. Changes in pH can affect the availability of nutrients, the chemical forms of certain elements and the general physiology of

Table 1. Ecological indicators of algal species found on coastal areas of the Absheron Peninsula.

Division	Family	Species	Saprob	Ecological group	T., °C	pH	Ecological zone: Littoral zone (intertial)		
							upper	supra	sub
Cyanobacteria	Chroococcaceae	[1]*Chroococcus turgidus*	–	eph.	15	8.1	+	-	-
	Oscillatoriaceae	[2]*Lyngbya majuscula*	–	pl.	19	8.0	+	-	-
		[3]*Oscillatoria sancta*	β-α	pl., ben.	23	8.0	-	+	-
Chlorophyta	Cladophoraceae	[4]*Cladophora fracta*	o-α	pl., ben.	17	7.9	-	-	+
		[5]*C. glomerata*	β-o	pl., ben.	20	7.9	-	-	+
		[6]*C. sericea*	–	ben.	13	8.0	-	-	+
		[7]*C. ruchingeri*	–	pl., ben., eph.	25	7.9	-	-	+
		[8]*C. laetevirens*	–	ben.	15	8.0	-	-	+
		[9]*Chaetomorpha aerea*	–	ben.	26	8.1	-	-	+
		[10]*Ch. linum*	–	ben.	25	8.1	-	+	-
		[11]*Rhizoclonium riparium*	–	pl.	22	7.9	-	-	+
	Ulvaceae	[12]*Ulva compressa*	–	ben.	21	8.1	+	+	-
		[13]*U. prolifera*	–	ben.	13	7.9	+	+	-
Charophyta	Spirogyraceae	[14]*Spirogyra crassa*	β	ben.	25	7.9	+	-	-
		[15]*S. majuscula*	o-α	pl.	14	7.8	+	-	-
	Zygnemataceae	[16]*Zygnema stellinum*	x-β	pl.	18	8.0	+	-	-
Rhodophyta	Colaconemataceae	[17]*Colaconema elegans*	–	pl., ben., eph.	10	7.8	+	-	-
Bacillariophytina (subphylum)	Catenulaceae	[18]*Amphora pediculus*	o-β	ben.	19	8.0	+	-	-
		[19]*Amphora ovalis*	β	eph., ephl.	21	8.0	+	-	-
	Naviculaceae	[20]*Caloneis silicula*	x	ben.	10	7.9	+	-	-
	Cocconeidaceae	[21]*Cocconeis placentula*	–	eph., ephl.	15	7.9	+	-	-
	Rhopalodiaceae	[22]*Epithemia parallela*	–	ben.	19	8.0	+	-	-
	Bacillariaceae	[23]*Hantzschia amphioxys*	α	ben., eph.	16	8.1	+	-	-
		[24]*Nitzschia denticula*	x-β	pl., ben.	13	8.0	+	-	-
		[25]*N. dissipata*	β	pl., ben., eph., ephl.	25	8.1	+	-	-
	Cymbellaceae	[26]*Cymbella lanceolata*	x-β	ben.	22	8.1	+	-	-

Note: Used abbreviations: pl. – plankton, ben.– benthos, eph.– epiphyte, epht.–epilith, α–alphamesosaprobic, β–betamesosaprobic, x–xenosaprobic, x-β–xeno-betasaprobic, o-α–oligo-alphamesosaprobic, o-β–oligobetamesosaprobic, β-α–beta-alphamesosaprobic, β-o–oligo-betamesosaprobic.

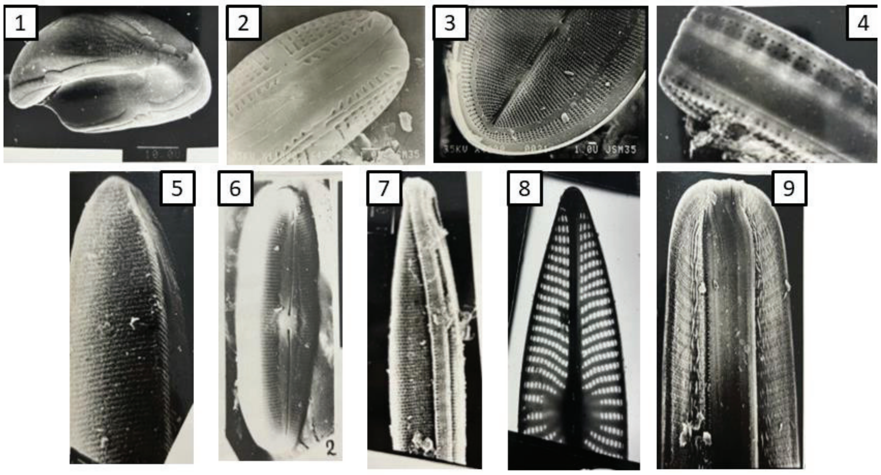

Figure 3. View of species under the scan electron microscope (SEM): 1. *Amphora pediculus*, 2. *Amphora ovalis*, 3. *Cocconeis placentula*, 4. *Nitzschia denticula*, 5. *Hantzschia amphioxys*, 6. *Caloneis silicula*, 7. *Nitzschia dissipata*, 8. *Cymbella lanceolata*, 9. *Epithemia parallela*.

Table 2. Seasonal distribution of algae in the collection sites.

Algae collection sites	Seasons			
	Spring (2023)	Summer (2023)	Autumn (2023)	Winter (2023)
Bilgah	*Chroococcus turgidus* *Amphora ovalis*	*Oscillatoria sancta* *Epithemia parallela* *Chaetomorpha aerea*	*Cladophora glomerata* *Rhizoclonium riparium* *Spirogyra majuscula*	*Cladophora sericea*
Nardaran	*Cladophora fracta* *Zygnema stellinum* *Epithemia parallela*	*Cladophora ruchingeri* *Chaetomorpha aerea* *Spirogyra crassa* *Spirogyra majuscula*	*Lyngbya majuscula* *Amphora pediculus* *Oscillatoria sancta* *Nitzschia denticula*	*Spirogyra majuscula* *Cladophora fracta* *Colaconema elegans*
Pirshagi	*Cladophora laetevirens* *Nitzschia denticula* *Cladophora ruchingeri*	*Cladophora fracta* *Amphora ovalis* *Chaetomorpha aerea* *Nitzschia denticula*	*Cymbella lanceolata* *Epithemia parallela* *Cladophora glomerata*	*Caloneis silicula* *Cymbella lanceolata*
Shikhov	*Ulva prolifera* *Cladophora ruchingeri* *Lyngbya majuscula* *Cladophora fracta* *Spirogyra majuscula*	*Chaetomorpha linum* *Rhizoclonium riparium* *Ulva prolifera* *Amphora ovalis* *Amphora ovalis*	*Ulva compressa* *Cladophora fracta* *Cocconeis placentula* *Hantzschia amphioxys*	*Amphora pediculus* *Epithemia parallela*
Sahil	*Cymbella lanceolata* *Cladophora ruchingeri* *Cladophora glomerata* *Nitzschia denticula*	*Nitzschia dissipata* *Cymbella lanceolata* *Cladophora fracta*	*Epithemia parallela* *Chroococcus turgidus* *Spirogyra crassa*	-

algae. Sensitivity to differences in pH affect growth and survival of algea [Sommer, Lengfellner, 2008].

Our research conducted along the coast of Absheron in the Caspian Sea showed that the number of species differs depending on the degree of water pollution in the saprobic system: 1 species is α-mesosaprobic, 1 species – β-α mesosaprobic, 1 species – β-o-saprobic, 1 species – o-β-mesosaprobic, 1 species – xenosaprobic, 2 species – o-α-mesosaprobic, 3 species – β-mesosaprobic, 3 species – x-β- mesosaprobic (Table 1). As seen, the results of the present study are in line with the earlier findings. In the present study, the pH of sea water was recorded in the range of 7.9-8.1. Despite the slight difference from the previous one (pH 7.5-8.0), the specified pH can be considered normal for algae bloom.

Seaweeds were collected from several ecological zones. These zones include upperlittoral, sublittoral, supralittoral, etc. areas. The richness of algal biodiversity in all three littoral zones is due to the existing vegetation cover and the abundant nutrients brought to the coastal zone by continental waters. [Schwoerbel, 2013]. Of the studied species, 17 were collected from upper-, two species from supra-, seven species from sub- and two species from both supra- and upperlittoral zones (Table 1).

CONCLUSION

The macrophyte algal flora of the Caspian Sea differs from the flora of the Mediterranean and Black seas (especially those with a salinity of 30-35 ppm) in its composition and taxonomic structure. The uniqueness of the Caspian Sea requires taking into account the priorities of the region's economic complex. The algal diversity of the Caspian Sea has been poorly studied. The study of algal diversity in the coastal areas where the research was conducted highlighted the species richness of the sea, revealing previously undocumented species in these ecosystems.

26 species belonging to red, blue-green, diatoms and green algae were identified in the research area. Among them representatives of the Chlorophyta (38.5%) and Bacillariophytina (34.6%) dominate, while Cyanobacteria (11.5%), Charophyta (11.5%), and Rhodophyta (3.9%) occur less frequently. These results show some difference from those of our previous studies (Bacillariophytina – 46.4%, Chlorophyta – 21.4%, Cyanobacteria – 18%, Charophyta – 4.2%) on the northern shores of the Azerbaijani sector of the Caspian Sea [Muradova et al., 2023]. The studies conducted by A.B. Muradova et al. [2023] in the northern part of the Caspian Sea revealed that the species number changed (temperature range of 11-22ºC and pH 7.5-8.0). According to the degree of water pollution in the saprobic system [Barinova et al., 2006], two species are β-mesosaprobic, two species – oligo-α-mesosaprobic, two species – α-betamezosaprobic, one species – oligo-β-mesosaprobic, one species – oligosaprobic, one species – xeno-β-mesosaprobic, one species – β-oligo-mesosaprobic, one species – xeno-oligo-mesosaprobic and one species – oligo-xeno-saprobic.

The reason for the difference in the number of algal species may be related to the direct effect of pollution on the algae. Thus, the density of industrial enterprises causes relatively more pollution on the coasts of the Absheron Peninsula. This is also shown by our analysis of saprobity indices of the collected algal species. Thus, the species identified according to the saprobic system can be considered as indicators of water bodies. Protecting the ecological balance in solving economic problems should be the primary criterion for developing efficient functioning of the ecological-economic system of the Caspian Sea. In the flora of the Caspian Sea, a small number of species of Rhodophyta algae was identified.

Undoubtedly, the difference in the ecological conditions in the coastal areas surrounding the Absheron Peninsula of the Caspian Sea gives reason to assume that the algae inhabiting this part of the Caspian Sea have a different species composition compared to other parts of the sea. However, the algae found on the shores of the Absheron Peninsula of the Caspian Sea together with algae from other parts of the sea make up the taxonomic structure of algae of the Caspian Sea. This, in turn, requires a detailed and comprehensive study of the ecological status of other coastal areas of the Caspian Sea and the algal species inhabiting these areas, the relationships between the species that make up this spectrum, and the role of ecological factors in the distribution of algal species, in order to determine the current state of the taxonomic spectrum of algae in the coastal areas of the Caspian Sea.

Apart from invasive species, the other species of red and brown algae in this water reservoir are considered relicts of the Tertiary period. Studying the role of various factors in the formation of the algal flora of the Caspian Sea has become one of the important regional problems; as a consequence, extensive research is required. Additionally, given the changing and evolving environmental conditions, continuous monitoring and management strategies need to be implemented to maintain the balance of aquatic ecosystems.

ACKNOWLEDGMENT

This work was supported by the Azerbaijan National Academy of Sciences (Grant dated 18.01.2022) and the Ministry of Science and Education of the Republic of Azerbaijan.

REFERENCE

Afanasyev D.F., Kamnev A.N., Sushkova E.G., Steinhagen S. The field guide to *Ulva* species found in the Black, Azov, Caspian Seas and eastern Baltic.Moscow. Publ. house «Pero», 2016, p. 50. [Афанасьев Д.Ф., Камнев А.Н., Сушкова

Е.Г., Штайнхаген С. Полевой определитель водорослей рода *Ulva* Черного, Азовского, Каспийского морей и Восточной Балтики. Москва. Изд-во «Перо», 2016, с. 50.]

Afanasyev D.F., Sushkova E.G., Kamnev A.N. Marine and brackish species of Cladophoraceae and Aegagropila, found in the Ponto-Caspian basin. The field guide. Moscow, Pero Publ. House. 2020, 76 p. [Афанасьев Д.Ф., Сушкова Е.Г., Камнев А.Н. Морские и соленая вода виды Cladophoraceae и Aegagropila, обнаруженные в Понто-Каспийском бассейне. Полевой определитель. М.: Перовское изд-во., 2020, с. 76.]

Alga Terra: www.algaterra.org

Babaev G.V. Composition and distribution of phytoplankton in the Middle and Southern Caspian. In: Biology of the Middle and Southern Caspian. Nauka Publishing House, Moscow, 1968, p. 50-63. [Бабаев Г.В. Состав и распределение фитопланктона в Среднем и Южном Каспии. В кн.: Биология Среднего и Южного Каспия. Изд-во «Наука», М., 1968, с. 50-63.]

Barinova S.S., Medvedeva L.A., Anisimova O.V. Biodiversity of environmental indicator algae. Pilies Studio Tel Aviv. 2006, 498 p. [Баринова С.С., Медведева Л.А., Анисимова О.В. Биоразнообразие водорослей-индикаторов окружающей среды. Студия Пилес Тель-Авив. 2006, с.,498 p.]

Bold H.C., Wynne M.J. Introduction to the algae (second edition). 1985, Chap.2. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

California Academy: www.calacademy.org

Cardinale B.J., Duffy J.E., Gonzalez A. (2012) Biodiversity loss and its impact on humanity. *Nature*, 486(7401): 59-67. https://doi.org/:10.1038/nature11148

Fourtanier E., Kociolek J.P. Catalogue of diatom names. California Academy of Sciences. San Francisco, CA: California Academy of Sciences, 2009, 245 p.

Gaspar R., Fonseca R., Pereira L. Illustrated guide to the macroalgae of Buarcos bay, Figueira da Foz, Portugal, 1st ed.; MARE UC, DCV, FCT: Coimbra, Portugal, 2020, 128 p.

Guiry M.D., Guiry G.M. (2023) AlgaeBase. World-wide Electronic Publication. Galway: National https://doi.org/10.1007/978-94-007-1327-7 Available at: https://www.algaebase.org

Karaeva N.I. (1960) On the biology of benthic diatoms of the Caspian Sea coast. *Bot. Jour.*, 45(5): 767-770. [Караева Н.И. (1960) К биологии бентических диатомовых водо- рослей побережья Каспийского моря. *Бот. журн.*, 45(5): 767-770].

Karaeva N.I. Benthic diatom algae of the Caspian Sea. USSR Academy of Sciences. 1972, 258 p. [Караева Н.И. Диатомовые водоросли бентоса Каспийского моря, "Элм". Баку, 1972, 258 с.].

Kireeva M.S., Shchapova T.F. (1957) Materials on the systematic composition and biomass of algae and higher aquatic vegetation of the Caspian Sea. *Proceedings of the Institute of Oceanology of the USSR Academy of Sciences. Biological studies of the seas*, 23:125-137. [Киреева М.С., Щапова Т.Ф. (1957) Материалы по систе- матическому составу и биомассе водорослей и высшей водной растительности Каспийского моря. *Труды Института океанологии АН СССР. Биологические исследования морей*, 23:125-137].

Kiselev I.A. (1938) On the phytoplankton of the Caspian Sea. In: Materialy po gidrobiologii I litologgii Kaspiyskogo moray (Materials of hydrobiology and lithology of the Caspian Sea). Moscow – Leningrad: *Acad. of Scien. of the USSR Publ.*: 229–254. [Киселев И.А. (1938) О фитопланктоне Каспийского моря. В кн.: Материалы по гидробиологии и литологии Каспийского моря. М. – Л.: *Изд-во АН СССР*: 229–254]

Kulikovsky M.S., Kuznetsova I.V. (2014) Biogeography of freshwater Bacillariophyta L. –Basic concepts and approaches. *Algology,* 2: 125–146. https://doi.org/10.1615/InterJAlgae.v16.i3.10 [Куликовский М.С., Кузнецова И.В. (2014) Биогеография пресноводных Bacillariophyta L. Основные концепции и подходы. *Альгология*, 2: 125-146].

Mukhtarova Sh.C., Jafarova S.K. (2020) Checklist of diatomic algae (Bacillariophyta) of the Continental Reservoirs of Azerbaijan. *Inter. J. Algae*, 22(1): 25-32. https://doi.org/10.1615/InterJAlgae.v22.i1.20

Mukhtarova Sh.C., Muradova A.B. (2023) New rare algae species of the Caspian Sea. International Scientific-Practical Conference "Modern approaches in the study of the plant kingdom" dedicated to the Year of Heydar Aliyev. June 15-16. p. 67-69.

Muradova A.B., Mukhtarova Sh.C., Feyziyev Y.M. (2023) Algoflora of the northern littoral part of the Azerbaijani sector of the Caspian Sea (Siyazan and Shabran districts). *J. Life Sci. Biomed*., 5(78): 34-43. https://doi.org/10.59849/2710-4915.2023.2.34

Norton T.A., Melkonian M., Andersen R.A. (1996) Algal biodiversity. *Phycologia*, 35:308-32.

Nuriyeva M.A. (2019) Diversity and taxonomic structure of Cyanoprokaryota in the Azerbaijani sector of the

Caspian Sea. *Plant & Fungal Research*, 2(2): 2-10. http://dx.doi.org/10.29228/plantfungalres.18

Nuriyeva M.A., Vinogradova O.M. (2020) Caspian cyanobacteria of Azerbaijan: a complete checklist with ecological and geographical characteristics. *Algologia*, 30(4): 325–340. https://doi.org/10.15407/alg30.04.325

Pereira L. (2009) Guia ilustrado das macroalgas. Imprensa da Universidade de Coimbra/Coimbra University Press. http://dx.doi.org/1014195/978-989-26-0397-1

Pereira L., Correia F. (2015) Algas marinhas da costa Portuguesa – *Ecologia*, Biodiversidade e Utilizações, 1st ed.; Nota de Rodapé Editores: Paris, France, 341 pp.

Petrov K.M. Underwater vegetation of the coastal zone of the Caspian Sea near Azerbaijan. In the book: Experience of geological-geomorphological and hydrobiological studies of the coastal zone of the sea. Leningrad: Nauka Publishing House, 1967, 245 p. [Петров К.М. Подводная растительность береговой зоны Каспийского моря у Азербайджана. Опыт геолого-геоморфологических и гидробиологических исследований береговой зоны моря. Ленинград: изд-во «Наука», 1967, 245 с.].

Proshkina-Lavrenko A.I., Makarova I.V. Algae of the Caspian Sea plankton. L. Science, Leningrad Branch, 1968, 291 p. [Прошкина-Лавренко А.И., Макарова И.В. Водоросли планктона Каспийского моря. Л.: Наука, 1968, 291 с.]

Raven J.A., Giordano M., Beardall J., Maberly S.C. (2012) Algal evolution in relation to atmospheric CO2: carboxylases, carbon-concentrating mechanisms and carbon oxidation cycles. *Philos. Trans. R. Soc. B: Biol. Sci.*, 363(1504): 2603-2610. https://doi.org/10.1098/rstb.2011.0212

Schmid A.M.M. (1994). Aspects of morphogenesis and function of diatom cell walls with implications for taxonomy. *Protoplasma*. 181: 43–60. https://doi.org/10.1007/BF01666388

Schwoerbel J. Methods of Hydrobiology (Freshwater Biology). Pergamon Press, London New York, 2013, 200 p.

Seckbach J., Kociolek P. The diatom world. Springer, Dordrecht, 2011, 533 p.

Sommer U., Lengfellner K. (2008). Climate change and the timing, magnitude, and composition of the phytoplankton spring bloom. *Glob. Change Biol.*, 14(6): 1199-1208. doi: 10.1111/j.1365-2486.2008.01571.x

Tash S., Okush E. (2006) Investigation of qualitatively phytoplankton in the Turkish coasts of the Black Sea and a species list. *J. Black Sea Medit. Environ.*, 12: 181-191.

Van Der Werff A. (1999) A new method of concentrating and cleaning diatoms and other orgnanisms, *Verh. Int. Ver. Limnol*, 12: 276-277. https://doi.org/10.1080/03680770.1950.11895297

Williams D.M. (1985) Morphology, taxonomy and ınter-relationships of the ribbed araphid diatoms from the genera Diatoma and Meridion (Diatomaceae: Bacillariophyta). *Bibliotheca Diatomologica*, 8: 1-228.

Zaberzhinskaya E.B. Algae flora of macrophytes of the Caspian Sea. PhD thesisis, Baku, 1968, 234 p. [Забержинская Э.Б. Флора водорослей макрофитов Каспийского моря.Автореф.дисс. на соиск.уч. ст.к.б.н., Баку, 1968, 234 с.].

Zinova A.D. Identifier of green, brown and red algae of the southern seas of the USSR. USSR Academy of Sciences Botanical Institute Publishing House "Nauka" Moscow Leningrad, 1967, 396 p. [Зинова А.Д. Определитель зеленых, бурых и красных водорослей южных морей СССР. Академия Наук СССР Ботанический Институт Издательство «НАУКА» Москва Ленинград, 1967, 396 с.]

Abşeron yarımadasının Xəzər sahili ərazilərinin alqoflorasının sistematik öyrənilməsi və bioekoloji xüsusiyyətləri

Aytac B. Muradova
Şəkər C. Muxtarova
Botanika İnstitutu, Azərbaycan Respublikası Elm və Təhsil Nazirliyi, A. Abbaszadə küç.,1128-ci keçid, Bakı, AZ1004, Azərbaycan

Yaşar M. Feyziyev
Molekulyar Biologiya və Biotexnologiya İnstitutu, Azərbaycan Respublikası Elm və Təhsil Nazirliyi, İzzət Nəbiyev küçəsi 11, Bakı, AZ1073, Azərbaycan

Xəzər dənizinin alqoflorasının öyrənilməsi 1960-cı illərdən başlamışdır, lakin Xəzər dənizinin Azərbaycan hissəsinin yosunlarının öyrənilməsi son iyirmi ildə nəzərəçarpacaq dərəcədə məhdudlaşıb və hal-hazırda bu tədqiqatların genişləndirilməsi, alınmış nəticələrin əvvəlki illərdə əldə olunan məlumatlarla müqayisə edilməsi vacibdir. Xəzər dənizinin alqoflorası taksonomik cəhətdən zəif öyrənilmişdir. Tədqiqatımızın əsas məqsədi Xəzərin alqoflorasının biomüxtəlifliyini aşkar etmək, taksonomik strukturunu öyrənmək, bəzi xarici mühit amillərinin yosunlara təsirini müəyyənləşdirməkdir. Məqalədə Abşeron yarımadasının

Xəzər sahilboyu ərazilərinin dəniz makrofitlərinə və mikroskopik yosun florasınına dair yeni məlumatlar öz əksini tapmışdır. Tədqiqatlarda 26 yosun növü aşkar edilmişdir. Bu növlərin aid olduğu şöbələr: Rhodophyta (1 növ), Charophyta (3 növ), Cyanobacteria (3 növ), Chlorophyta (10 növ), Bacillariophytina (alt şöbə) (9 növ) müəyyən edilmişdir. Chlorophyta şöbəsi Xəzər dənizinin Abşeron sahillərinin yosun florasının tərkibində dominant qrup olub 38.5%, Cyanobacteria şöbəsi 11.5%, Charophyta şöbəsi 11.5%, Rhodophyta şöbəsi 3.9%, Bacillariophytina alt şöbəsi 34.6% ilə təmsil olunmuşdur. Yosun florasında Oscillatoriaceae Engler, Spirogyraceae Bessey, Cladophoraceae Wille və Naviculaceae Kützing aparıcı fəsilələr olaraq müəyyənləşdirilmişdir.

Açar sözlər: *Bacillariophytina, Cyanobacteria, ekoloji qrup, makrofit, növ, taksonomik analiz*

Изучение биоэкологической характеристики и систематики альгофлоры побережья Каспия Апшеронского полуострова

Айтадж. Б. Мурадова
Шакяр. Дж. Мухтарова
Институт ботаники, Министерство Науки и Образования Азербайджанской Республики, ул. А.Аббасзаде, пересечение 1128, Баку, AZ1004, Азербайджан

Яшар. М. Фейзиев
Института Молекулярной Биологии и Биотехнологий, Министерства Науки и Образования Азербайджанской Республики, Иззат Набиев 11, Баку, AZ1073, Азербайджан

Исследование альгофлоры Каспия начато с 1960 годов, но за последние двадцать лет изучение водорослей Каспийского моря (в пределах Азербайджана) заметно ограничилось, в настоящее время требуются новые сведения. В таксономическом отношении альгофлора изучена очень слабо. Основная цель исследования – выявить биоразнообразие альгофлоры Каспия, изучить таксономическую структуру и определить влияние внешних факторов на водоросли. Даны новые сведения о флоре морских макрофитов и микроскопических водорослей побережья Каспия Апшеронского полуострова. В результате исследований выявлены 26 видов водорослей, относящиеся к следующим отделам: Rhodophyta (красные – 1 вид), Charophyta (харовые – 3 вида), Cyanobacteria (синезеленые – 3 вида), Chlorophyta (зеленые – 10 видов), Bacillariophytina (подотдел) (диатомовые – 9 видов). В составе водорослевой флоры отдел Chlorophyta является доминантной группой – 38,5%, отделы Cyanobacteria – 11.5%, Charophyta – 11.5%, Rhodophyta – 3.9%, Bacillariophytina – 34,6%. Ведущие семейства во флоре водорослей – Oscillatoriaceae Engler, Spirogyraceae Bessey, Cladophoraceae Wille и Naviculaceae Kutzing.

Ключевые слова: *Bacillariophytina, Cyanobacteria, экологическая группа, макрофиты, вид, таксономический анализ*