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PHYTOPLANKTON, PHYTOBENTHOS, AND PHYTOPERIPHYTON

Phytoperiphyton of the Samarga River Basin (Primorskii Krai)

L. A. Medvedeva[a] and A. A. Semenchenko[b]

[a] *Institute of Biology and Soil Sciences, Far East Branch, Russian Academy of Sciences, pr. Stoletiya Vladivostoka 159, Vladivostok, 690022 Russia*
e-mail: medvedeva@ibss.dvo.ru
[b] *Far East Federal University, ul. Sukhanova 8, Vladivostok, 690000 Russia*

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Abstract—In the periphyton of the Samarga River basin, 313 species of algae (337, including infraspecific taxa) from eight divisions have been found. The groups of algae from the river main flow, creeks, streams, and the mouth are described. Data on the density and biomass of periphyton algae are presented. A decrease in these parameters after a flood is shown. In algal flora composition, benthic oligohalobic species of algae, preferring a slightly alkaline environment, dominate. At the river mouth a significant amount of mesohalobic species has been observed. A sanitary and biological evaluation of water quality has shown that the mass development of xeno- and oligosaprobic algae defines the excellent quality of the river water. All parts of the main flow correspond to the oligosaprobic purification zone, class II of water purity (saprobic index of 0.95–1.48). The good quality of the Samarga River water is ensured by the absence of pollution sources and the satisfactory condition of its catchment area forests.

Keywords: algae, periphyton, density, biomass, water quality, Samarga river basin

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INTRODUCTION

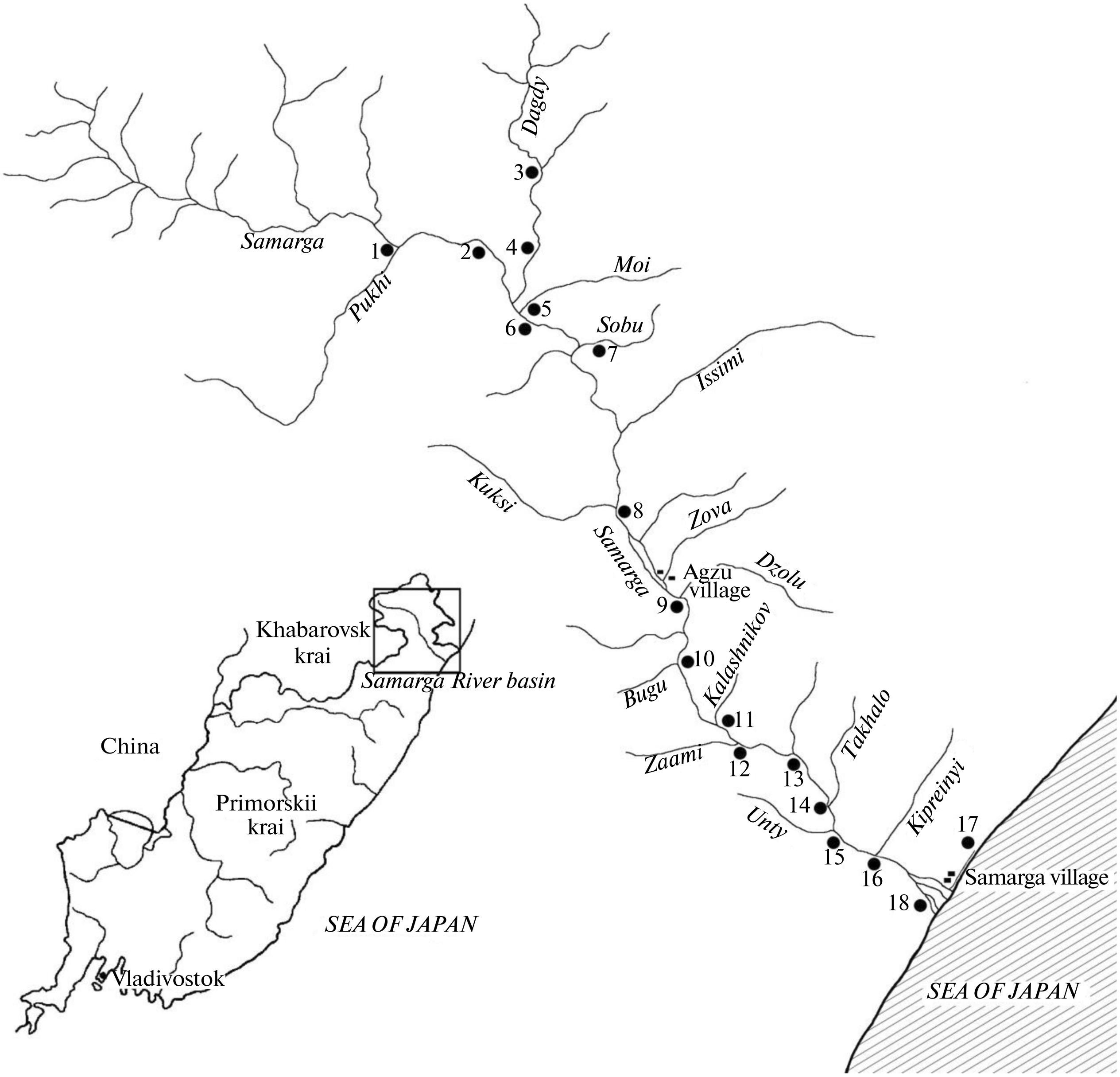
Algae are sensitive indicators of an aquatic environment. The species composition, abundance, and biomass of the organisms are dependent on the qualitative composition and concentrations of substances dissolved in water. The biological analysis of water quality by indicator organisms, in particular by algae, is widely used in the assessment of water bodies and control of their water quality [9, 19, 20]. Getting the background characteristics by studying reservoirs and streams that are not affected by human activity is an urgent aspect of assessing water bodies. One of these water bodies is the Samarga River basin (Primorskii krai), where the largest wild population of Sakhalin taimen, listed in the Red Books of the Russian Federation and Primorskii krai, existed in a relatively healthy state [7, 8, 17].

The purpose of this work is to analyze the qualitative and quantitative composition of phytoperiphyton of the Samarga River and its tributaries in order to assess their ecological status and obtain information on an algal community in the absence of anthropogenic pressure.

MATERIALS AND METHODS

Phytoperiphyton samples were collected in 1998, 2000, 2001, and 2006 at 18 stations along the Samarga River and its tributaries (Dagdy River and Kalashnikov and Unty springs) (see figure). About 180 km of the Samarga River from the mouth to the confluence of the Puhi River and a 30 km stretch of the Dagdy River were examined. The qualitative composition of phytoperiphyton was determined in 54 samples of fouling collected from rocks in the mainstream of the river and from the bottom and higher plants in creeks and streams. Quantitative samples (14) were collected in 2006 at the shoals of the main flow of the river; all algae were washed off a stone with water (100 mL) and fixed with 4% formalin. The biomass was accounted for [3] using an original record chamber. Diatom identification was performed using permanent slides prepared by a peroxide method [1, 21]. The frequency of species was evaluated on S.M. Wyslouch's scale [6]. Established methods were used to assess the water quality [9, 19]; calculations of saprobity indices were carried out on the basis of lists of indicator organisms [2, 4]. Marine red algae were identified by I.R. Levenets (Institute of Marine Biology, Far East Branch, Russian Academy of Sciences), to whom we express our sincere gratitude.

The Samarga River is the northernmost river in Primorskii krai; it extends for 220 km and flows into the Sea of Japan. Its catchment area is 7760 km^2. It is a submountain river; the excess of the source over the mouth is 1080 m [16]. Numerous tributaries form a dense extensive network (see figure). The river is fed mainly by precipitation; floods are common in summer and autumn [5]. The bed in the upper reaches is



Layout of the stations in the Samarga River basin: (1) Samarga River, 80 m upstream of the Pukhi River mouth; (2) Samarga River, 16 km upstream of the Dagdy River mouth; (3) Dagdy River at the Oumi River mouth; (4) Dagdy River, 13 km upstream of the mouth; (5) Dagdy River, mouth; (6) Samarga River, 100 m downstream of the Dagdy River; (7) Samarga River across the Sobu spring; (8) Samarga River, 2.5 km downstream of Kuksi spring (Robinzon stow); (9) Samarga River, 2 km downstream of the Agzu village; (10) Samarga River, 50 m upstream of the Bugu River; (11) Kalashnikov spring, mouth; (12) Samarga River, 1 km downstream of Zaami spring; (13) Samarga River, below the former village of Voznesenovka; (14) Samarga River, in front of A. Chepel's house; (15) Unty spring, mouth; (16) Samarga River, 200 m upstream of the Kipreinyi spring mouth; (17) Samarga duct; and (18) Samarga River, mouth.

narrow with numerous rapids, waterfalls, and blocks; the rocky bottom consists of large boulders and pebbles. The large slope results in a high (up to 2.5 m/s) flow rate. In the middle reaches the stream expands to 30–50 m, but the river is still full of rapids and shoals. The flow rate is ~1.2–2 m/s, reaches 3.6 m/s during a flood, and slows down on stretches. In the lower reaches, the river becomes lowland and the channel widens to 100–150 m and strongly meanders, forming many branches and streams. In the estuary on the seaside border, there is a kind of blind creek extending about 5 km long, called Samarga duct. In the study period, the water temperature in the middle reaches of the river was 10–13°C. In the duct, the surface water layer was warmed to 22°C; salinity ranged from 1 to 5‰, pH 6.9–7.0.

RESULTS

In the Samarga River and its tributaries we found 313 species of algal periphyton (337, including intraspecific taxa) from 121 genera belonging to 8 divisions: 18 species and 13 genera from Cyanoprokaryota, 2 and 2 from Euglenophyta, 1 species from Dinophyta, 2 and 2 from Chrysophyta, 226 (248) and 68 from Bacillariophyta, 8 and 3 from Xanthophyta, 3 and 3 from Rhodophyta, and 53 (55) and 29 from Chlorophyta. Dominant genera totaled a similar number of species: 19 species belong to the largest genus *Navicula* Bory, 18 (21 with varieties) to *Pinnularia* Ehr., 17 to *Nitzschia* Hass., 16 (17) to *Gomphonema* Ehr., and 10 (11) to *Cymbella* Ag. Diatoms were characterized by the maximum species and intraspecific diversity, making up 73.6% of the total number of detected forms. This is genera *Didymosphenia* M. Schmidt, *Hannaea* Patr., *Meridion* C. Ag., *Encyonema* Kütz., *Ulnaria* Kütz., and *Achnanthidium* Kütz. Green algae take second place in algal flora (16.3%). Sterile filaments of *Spirogyra* Link, *Mougeotia* C. Ag., and *Zygnema* C. Ag. dominated in oxbows and channels, and *Ulothrix* Kütz. often overgrow the rocky bottom near the river shore. Cyanoprokaryotes take third place in regards to number of species. *Homoeothrix janthina* (Born. et Flah.) Starm. and *Phormidium uncinatum* (C. Ag.) Gom. developed in fouling of the main channel of the river. From other divisions of algae, large quantities of gold alga *Hydrurus foetidus* (Vill.) Trev. and filamentous yellow-green algae *Tribonema* Derb. et Sol. and *Vaucheria* de Cand. were found.

The composition of algal periphyton was similar at most stations on the Samarga and Dagdy rivers. Fouling contained a complex of rheophilous diatoms: *Hannaea arcus* (Ehr.) Patr., *Meridion circulare* (Grev.) C. Ag., *Encyonema minutum* (Hilse ex Rabenh.) Mann, *E. silesiacum* (Bleisch) Mann, *Ulnaria ulna* (Nitzsch) Compére, *U. inaequalis* (H. Kob.) M. Idei, *Planothidium lanceolatum* (Bréb. ex Kütz.) Round et Bukht., *Achnanthidium minutissimum* (Kütz.) Czarn., and *Didymosphenia geminata* (Lyngb.) M. Schmidt. A similar species composition of algae was also recorded in the surveyed areas of the Kalashnikov and Unty springs. Due to homogeneous environmental conditions, this complex remained practically unchanged on a ~150 km part of the Samarga River and changed greatly only at the lower part of the river, starting with station 14 and further at station 16. This part was dominated by diatoms *Achnanthidium pyrenaicum* (Hust.) Kob. and *Melosira varians* C. Ag. and filamentous yellow-green alga *Vaucheria* sp. ster. Common river diatoms, observed as dominants upstream, appeared as associated species here.

Backwaters and oxbows of the Samarga River and its tributaries were characterized by a high diversity of algocenoses. The composition of dominant species changed radically. Filamentous *Spirogyra*, *Mougeotia*, *Oedogonium* Link, *Ulothrix*, and *Oscillatoria* Vauch. ex Gom. developed massively, forming continuous blankets. Diatoms were diverse: *Diatoma tenuis* C. Ag., *Planothidium lanceolatum*, *Meridion circulare*, *Ulnaria ulna*, *Melosira varians*, *Tabellaria flocculosa* (Roth) Kütz., *T. fenestrata* (Lyngb.) Kütz., *Achnanthidium minutissimum*, and *Eunotia bilunaris* (Ehr.) Mills. Desmids from genera *Closterium* Nitzsch ex Ralfs and *Cosmarium* Corda ex Ralfs were often found in these habitats.

Peculiar algological complexes vegetated in the duct near the village of Samarga (station 17). The massive fouling on higher plants and bottom of the duct consisted of *Zygnema*, *Mougeotia*, and *Tribonema* combined with diatoms *Staurosira construens* var. *venter* (Ehr.) Bukht., *Fragilaria capucina* Desm., *Ctenophora pulchella* (Ralfs ex Kütz.) Will. et Round, *Tabularia fasciculata* (C. Ag.) Will. et Round, *Achnanthidium minutissimum*, and *Encyonema silesiacum*. There were also protococcal algae, desmids, and xanthophytes (species of the genera *Scenedesmus* Meyen, *Closterium*, *Cosmarium*, *Teilingia* Bourr., and *Ophiocytium* Näg.).

At the river mouth, two different complexes of algae have evolved: one in surface fresh waters and one on the bottom under conditions of an inflow of denser salt water from the Sea of Japan. There were freshwater, brackish, and even marine forms. The bottom of the estuary was overgrown with red algae *Pterosiphonia bipinnata* (Rost. et Rupr.) Falk. and *Hyalosiphonia caespitosa* Okam. Some diatoms developed massively: marine *Licmophora paradoxa* (Lyngb.) C. Ag., characteristic for brackish seas and estuaries *Cocconeis scutellum* Ehr., and brackish-water species *Tabularia fasciculate*, *Rhoicosphenia abbreviata* (C. Ag.) Lange-Bert., *Rhabdonema arcuatum* (Lyngb.) Kütz., *Brebissonia boeckii* (Ehr.) Grun., and *Triceratium arcticum* Bright. In the fouling on higher plants at the surface, freshwater filamentous *Spirogyra* and *Ulothrix zonata* (Web. et Mohr) Kütz had evolved.

The abundance and biomass of periphyton were characterized by significant variations over the entire surveyed area of the main flow of the river (Table 1). In the upper section (stations 1 to 7) the total number of algae ranged from 45.9 to 170.1 billion cells/m^2 and biomass ranged from 14.7 to 72.3 g/m^2. The minimum number was recorded at station 5 in the Dagdy river mouth, the minimum biomass was at station 3, and the highest values were at station 7.

Quantitative data for stations 1 to 8 were obtained during the low-water flow, while stations 9 to 16 were sampled after a typhoon on August 12, 2006; as a result there was a critical rise of water and algae fouling was washed away by the flood. The abundance and biomass at stations 9 to 16 significantly decreased to 23.5–35.8 billion cells/m^2 and 1.4–6.9 g/m^2, respectively (Table 1). Golden and yellow-green algae had vanished from the periphyton. However, after a week, an increase in algal films on rocks in the riverbed was noted. Small-celled cyanoprokaryota *Homoeothrix*

Table 1. Abundance (above the line, billion cells/m^2) and biomass (below the line, g/m^2) of periphyton algae of the Samarga River

Station number	Cyanoprokaryota	Chrysophyta	Bacillariophyta	Chlorophyta	Total
1	49.5 / 0.3	10.9 / 3.9	12.9 / 12.6	–	73.3 / 16.8
2	122.6 / 1.7	–	46.7 / 16.0	0.5 / 0.2	169.8 / 17.9
3	46.4 / 0.2	1.9 / 0.7	30.7 / 13.8	–	79.0 / 14.7
4	90.5 / 2.6	–	36.3 / 11.6	5.6 / 1.9	132.4 / 16.1
5	33.5 / 0.5	1.8 / 0.6	10.3 / 18.7	0.2 / 0.1	45.8 / 19.9
6	48.5 / 0.9	–	21.3 / 24.9	–	69.8 / 25.8
7	14.6 / 0.3	–	154.4 / 71.6	1.1 / 0.4	170.1 / 72.3
8	30.6 / 0.6	–	30.0 / 18.5	–	60.6 / 19.1
9	28.9 / 0.6	–	3.6 / 1.7	–	32.5 / 2.3
10	22.3 / 0.4	–	13.5 / 3.0	–	35.8 / 3.4
12	22.9 / 0.4	–	10.2 / 6.5	–	33.1 / 6.9
13	102.0 / 0.8	–	7.5 / 1.6	–	109.5 / 2.4
16	20.0 / 0.4	–	3.5 / 1.0	–	23.5 / 1.4

janthina appeared first, forming the basis abundance, but not reaching high biomass. About 10 days after the flood, the total number of algae on station 13 reached 109.4 billion cells/m^2 (mainly due to *H. janthina*) at a low (2.4 g/m^2) biomass level.

An ecological analysis of the detected species shows that benthic (or sublittoral) and plankton–benthic forms were most widely represented. There were twice as few plankton species. In regard to mineralization, the algal flora was diverse. Indifferents were most numerous, including dominant species *Fragilaria vaucheriae* (Kütz.) Peters., *Ulnaria ulna, Hannaea arcus*, *Achnanthidium minutissimum*, and *Ulothrix zonata*. Halophobe species *Didymosphenia geminata*, *Diatoma mesodon* (Ehr.) Kütz., and *Meridion circulare*, along with indifferents, formed the basis of algal communities in the river and its tributaries. There were a few dominants among halophiles. In ducts near the estuary, there was a mass development of meso- and euhaline species. In regard to pH, indifferents and alkaliphile were most numerous; the number of acidophiles and alkalibionts was significantly lower. The background fouling was created by algae preferring a slightly alkaline environment: *Hannaea arcus*, *Diatoma mesodon*, *Meridion circulare*, *Ulnaria ulna*, and other species along with indifferents *Didymosphenia geminata*, *Achnanthidium minutissimum*, *Encyonema minutum*, *E. silesiacum*, and *Ulothrix zonata* (Table 2).

Of the entire list of algae of the Samarga River basin, 233 species are indicators of organic water pollution (Table 3). Most of them are oligosaprobes (including dominant species *Achnanthidium minutissimum*, *Encyonema minutum*, *E. silesiacum*, *Fragilaria*

Table 2. Environmental groups of periphyton algae of the Samarga River

Factor	Group	Number of species	Share, % of total
Habitats	Plankton	35	10.4
	Plankton–benthos	79	23.4
	Benthos	214	63.5
	No data	9	2.7
Mineralization	Halophiles	28	8.3
	Indifferents	161	47.8
	Halophobes	28	8.3
	Oligohalobes, unspecified	3	0.9
	Mesohalines	19	5.6
	Euhalines	6	1.8
	No data	92	27.3
pH	Alkalibionts	10	3.0
	Alkaliphiles	101	30.0
	Indifferents	73	21.6
	Acidophiles	22	6.5
	No data	131	38.9

Table 3. Saprobity groups of periphyton algae of the Samarga River

Group	Number of species	Group	Number of species
Xenosaprobes	17 (7.3)	Oligo-α-mesosaprobes	16 (6.9)
Xeno-oligosaprobes	22 (9.4)	β-Mesosaprobes	35 (15.0)
Oligo-xenosaprobes	8 (3.4)	β-α-Mesosaprobes	14 (6.0)
Xeno-β-mesosaprobes	16 (6.9)	α-β-Mesosaprobes	9 (3.9)
Oligosaprobes	45 (19.3)	β-Polysaprobes	3 (1.3)
Oligo-β-mesosaprobes	29 (12.4)	α-Mesosaprobes	1 (0.4)
β-Oligosaprobes	17 (7.3)	α-Polysaprobes	1 (0.4)

Percentages of indicator organisms are given in brackets.

capucina, *F. vaucheriae*, *Ulothrix zonata*, *Homoeothrix janthina*, and *Hydrurus foetidus*) and β-mesosaprobes (*Ulnaria ulna* and *Staurosira construens*). The main dominant diatoms on the largest part of the surveyed area—*Hannaea arcus* and *Didymosphenia geminata*—are xenosaprobes. The group of α-mesosaprobes developed massively only in backwaters of the river.

The predominance of xeno- and oligosaprobes indicates the high quality of water of the surveyed area of the river. Saprobity index varies from 0.95 to 1.48, rising slightly in the estuary. All areas of the main flow of the river meet the criteria of the oligosaprobic zone, class II of water purity. The maximum saprobity index 1.61 was recorded in the Samarga duct near the estuary, which corresponds to the lower limit of the β-mesosaprobic zone, class III of water purity.

DISCUSSION

The results on the composition and development of periphyton algae of the Samarga River and its tributaries obtained in 1998, 2000, and 2001 complement the first algological surveys of the river [14, 15]. The basis of the communities is diatoms *Hannaea arcus*, *Meridion circulare*, *Encyonema minutum*, *E. silesiacum*, *Ulnaria ulna*, *U. inaequalis*, *Planothidium lanceolatum*, *Achnanthidium minutissimum*, and *Didymosphenia geminata*. All of them are common river species forming fouling in most rivers of the Far East of Russia. Due to the homogeneity of environmental conditions, this complex remains stable in both the upper and middle parts of the river. In the estuary the surface layer carries fresh river water and the bottom layer contains salty sea water due to seepage or a reverse bottom current, opposite to the river flow. The species complex at the bottom consists of marine and brackish water forms.

The abundance and biomass of periphyton are characterized by significant variations in values. Patchiness of the algal distribution depends on many factors, such as size and stability of substrates, orientation of a stone in the river flow, flow velocity, and light intensity. Development indicators of phytoperiphyton in the Samarga River basin are close to those obtained for other rivers of the Far East of Russia and range within the normal natural background [10–13].

Data obtained during the low-flow period can be considered the background, typical of the normal water level in the river. Primorskii krai is in the monsoon climate, where aquatic biota is heavily impacted by typhoons. Significant changes in the water level essentially alter species composition and have a depressing effect on fouling, reducing its abundance.

The Samarga River is characterized throughout by a high quality of water that belongs to the oligosaprobic zone, class II of water purity. This is due to a lack of pollution sources and a satisfactory condition of forests of the watershed. The algological-complex composition indicates perfect environmental conditions and high biological and production potential of the river [14, 18]. Periphyton is dominated by the xenobiontic diatom *Didymosphenia geminata*.

The results reflect the current state of the river ecosystem, provide a basis for its environmental monitoring, and make it possible to predict changes of natural systems that may occur after a violation of the mountain taiga landscapes.

CONCLUSIONS

In the algal flora of fouling in the Samarga River and its tributaries, we found 313 species (337 species and intraspecific taxa) of algae from 8 divisions. In the main river flow, communities of running water habitats developed, dominated by *Homoeothrix janthina*, *Phormidium uncinatum* (Cyanoprokaryota), *Hydrurus foetidus* (Chrysophyta), *Ulothrix zonata* (Chlorophyta), *Achnanthidium minutissimum*, *Encyonema silesiacum*, *Hannaea arcus*, *Didymosphenia geminata*, *Ulnaria ulna*, and *U. inaequalis* (Bacillariophyta). At the mouth we observed the development of two different complexes: a freshwater one in the surface water and a brackish and marine one at the bottom.

The abundance and biomass of algae ranged widely: from 45.9 to 170.1 billion cells/m^2 and from 14.7 to 72.3 g/m^2, respectively. After the flood, the values decreased significantly.

The algal flora was dominated by benthic oligosaprobe species, preferring a slightly alkaline environment. In the estuary a significant amount of meso- and euhaline species was found. The mass vegetation of xeno- and oligosaprobes reflects the high water quality of the Samarga River, corresponding to the oligosaprobic zone, class II of water purity. Only in the lower reaches of the river is mild natural organic pollution manifested.

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