Spatial and temporal dynamics of phytoplankton community in the Sviyaga River, the Volga River basin, Russia

N G Tarasova
Samara Federal Research Center RAS, Institute of the Ecology of the Volga Basin RAS, Togliatti, Russia

E-mail: tnatag@mail.ru

Abstract. The phytoplankton communities of the Sviyaga River, the right-bank tributary of the Volga River, were studied. It was characterized by high taxonomic diversity. In total, 365 taxa of microalgae with a rank below genus were registered during the study period. Green algae and diatoms were the most diverse groups. The data obtained in 1984 and 2016 were compared; by the XXI century, the role of Planktotrichet-type algae has increased, as well as their share in the total species richness (by 10%). The distribution of the Ponto-Caspian invading diatom species Skeletonema subsalsum and Actinocyclus variabilis within the Volga River basin has been checked. These species were found in the estuarine phytoplankton communities of the Sviyaga River.

1. Introduction
Any large riverine system depends strongly on small rivers, which are the indispensable tributaries bringing their waters to the main reverbed. The chemical composition of the waters of larger rivers and reservoirs, their water content, hydrological regime, and hydrobiological characteristics depend largely on these tributaries. People have been settling on the banks of watercourses since ancient times. Small settlements grow into large cities, which have a significant impact on the water quality of streams. Often, due to the specificity of local conditions, specific biota develops there. New species, getting into large rivers or reservoirs, may either naturalize or collapse. Therefore, without understanding the processes occurring in the tributaries, it is often difficult to explain the phenomena observed in large watercourses.

In total, 284 watercourses flow into the Volga River [1]. However, much attention is usually paid for the artificial reservoirs practically from the moment of their establishing, but the ecosystems of small rivers have been insufficiently studied.

The study aims to analyze the plankton algal flora of the Sviyaga River (the right-bank tributary of the Volga River), to search for the features of its development in different years, different seasons, and in different ecotopes (along the coast and in riverbed).

2. Materials and Methods
The material for the study was collected in 1984 by the employees of the Institute of the Ecology of the Volga Basin, Academy of Sciences of the USSR. Samples were processed by the author. The Sviyaga River is a watercourse with a high degree of development of the catchment area [2]. In addition, in 2016, the river was surveyed from the source to mouth, the flora of microalgae developing
in different ecotopes (along the coast and on the riverbed) have been studied. Some hydrological and hydrochemical indicators for the study period are presented in table 1.

**Table 1.** Some hydrochemicals and hydrological characteristics of the Sviyaga River in 2016 (FV – flow velocity)

| Site                  | Parameter | T (°C) | pH | FV (m s⁻¹) | Width (m) | Depth (m) | O₂ (mg%) | Transparency (m) |
|-----------------------|-----------|--------|----|-------------|-----------|-----------|----------|-----------------|
| Kuzovatovo upstream   |           | 26     | 7  | 0.4         | 2         | 0.1       | 3.2/43   | 0.1ᵃ           |
| Chirkovo              |           | 18.6   | 7.7| 0.3         | 7         | 0.7       | 5.4/58   | 0.7ᵃ           |
| Stogovka              |           | 18.7   | 7.7| 0.3         | 9         | 1.5       | 4.7/50   | 1.5ᵃ           |
| Ulyanovsk, 1 km       |           | 20.9   | 7.9| 0.2         | 7         | 1.7       | 5.2/58   | 0.3            |
| Ulyanovsk, 1 km       |           | 24.4   | 7.5| <0.01       | 300       | 1.5       | 4.5/55   | 0.7            |
| Ulyanovsk, 1 km       |           | 25.4   | 7.5| 0.1         | 25        | 3.5       | 4.0/50   | 1.1            |
| Vozzi                 |           | 23     | 7.7| 0.4         | 30        | 0.9       | 4.6/55   | 0.7            |
| Buinsk                |           | 23.2   | 7.7| 0.3         | 30        | 0.7       | 4.6/55   | 0.4            |
| Sviyazsky             |           | 23.3   | 7.9| 0.2         | 30        | 1.8       | 5.1/61   | 0.6            |
| Burunduki             |           | 28.9   | 7.9| 0.2         | 50        | 3.0       | 3.4/58   | 0.4            |
| Kayna                 |           | 24.7   | 8.0| reverse     | 5         | 4.0       | 6.1/72   | 0.8            |

ᵃ - indicates water transparency of entire water column, from surface to the bottom

Samples were taken from the water surface, preserved with a 4% formaldehyde solution, and processed according to standard hydrobiological methods [3]. The dominant species were assigned as comprising 10% or more of the total abundance/biomass.

The Sviyaga River is a right-bank first-order tributary of the Volga River. The river originates in the Kuzovatovsky District of the Ulyanovsk Oblast. It has three sources: (1) near the Kuzovatovo village, (2) near the Krasnaya Polyana village, and (3) near the Baevka village. The river stretches from north to south parallel to the Volga River and flows into the Kuibyshev Reservoir on the territory of the Republic of Tatarstan, forming the Sviyazhsky Bay at the confluence (figure 1).

The watercourse passes through Ulyanovsk city and Buinsk town. The river is 375 km long, 20–30-m wide, the catchment area is 16.7 thousand km². The depth at the rifts is about 0.5 m, at the reaches, down to 1.5 m. The river is mainly snow-fed [1].

3. Results and Discussion

3.1. Taxonomic composition.

The phytoplankton of the Sviyaga River is very diverse; during the entire study period, 365 taxa of algae were registered (rank below genus). At the same time, in 2016, the species richness of algal flora exceeded by 20% that observed in 1984. In 2016, 242 species and intraspecific taxa of algae were recorded, but only 192, in 1984. In addition, the taxonomic structure of planktonic algal flora varied significantly in different periods of study (figure 2).

Green algae was the most diverse group of microalgae in the Sviyaga River in 1984, accounting for 36% of the total number of species and intraspecific taxa, followed by diatoms (33% of the total species richness). In 2016, diatoms were the most diverse group (40%), followed by green algae (31%). This difference was probably due to the fact that deep-water part of the river was studied in 1984, and mainly its mouth section, in the backwater zone of the Kuibyshev Reservoir, where green algae almost always prevailed by species richness [2, 4].
In 2016, the entire watercourse, from source to mouth, has been studied, both deep-water and coastal areas. The diatoms usually prefer the fast flow, so they have been registered abundantly in the upper reaches of the river. When studying coastal and shallow-water areas, there is a high probability that benthic and periphyton forms will be included in the samples, where the share of Bacillariophyta representatives is usually also high. In 1984, Euglenophyta took the third place by the species richness, but in 2016, these were Cyanophyta. Most likely, this difference was due to seasonal peculiarities in
the phytoplankton development. In 1984, studies were performed throughout the entire productive season, but only in the summer in 2016, when blue-green algae developed actively, often causing the phenomenon of water blooming.

In 1984, the relative number of algal species per sample was 1.3 times higher than that in 2016. Most likely, seasonal changes in the phytoplankton composition were more pronounced than that between different ecotopes. In addition, Sørensen similarity index was 74% when comparing riverbed and coastal sections of the river in 2016; i.e. the differences between ecotopes were insignificant.

In 2016, the microalgae species richness increased from the source to the mouth of the river. The maximum number of species and intraspecific taxa was recorded in the Sviyazhsk Bay of the Kuibyshev Reservoir.

3.2. Quantitative parameters.
The abundance and biomass of phytoplankton in the Sviyaga River during the study period varied within a fairly wide range (table 2).

| Table 2. Quantitative parameters of phytoplankton of the Sviyaga River in different years |
|-----------------------------------------------|--------|-------|--------|--------|--------|--------|
| Parameter                                      | Abundance | Biomass | $H_N$  | $H_B$  | $E_N$  | $E_B$  |
| 1984                                          | 18.4$^a$ | 3.9    | 3.4    | 3.7    | 0.5    | 0.58   |
|                                               | 2.7-41.6 | 0.6-6.7 | 1.3-4.5 | 2.6-4.4 | 0.21-0.73 | 0.41-0.67 |
| 2016                                          | 7.7     | 4.8    | 4.0    | 3.2    | 0.70   | 0.56   |
|                                               | 0.5-58.7 | 0.4-20.7 | 0.9-4.6 | 0.5-4.7 | 0.16-0.84 | 0.09-0.81 |

$^a$ - Values above the line indicate mean, below the line, min-max.

In 1984, the wide range of parameters depended on the season, when minimum values were recorded in autumn (October), maximum, at the river mouth, in summer (July).

In 1984, the maximum phytoplankton abundance was recorded in July, in the marginal backwater zone, reaching $41.6 \times 10^6$ cells L$^{-1}$. An active development of *Aphanizomenon flos-aquae* (L.) Ralfs, blooming Cyanophyta species, was also registered during that period, when its share reached 85% of the total phytoplankton abundance and 66% of the total biomass (table 3). Representatives of this division of algae dominated by abundance until the end of October.

| Table 3. Dominant species of phytoplankton in the Sviyaga River in 1984, the relative abundance/biomass (%) is indicated in the brackets |
|--------------------------------------------------|------------------|------------------|
| Dominants by abundance                          | Dominants by biomass |
| June 22, 1984                                    | *Stephanodiscus hantzschii* (38%), *Euglena tripteris* (Duj.) Hubner (17%) |
| July 28, 1984                                    | *Aphanizomenon flos-aquae* (66%) |
| August 26, 1984                                  | *Stephanodiscus hantzschii* (17%), *Euglena tripteris* (Duj.) Hubner (14%), *Cyclotella meneghingiana* Kütz. (11%) |
| October 26, 1984                                 | *Cyclotella meneghingiana* Kütz. (27%), *Stephanodiscus hantzschii* (21%), *Peridinium umbonatum* Stein (17) |

Diatoms were a significant part of the dominant complex of algal species, except for July 1984. Along with representatives of this division, Euglenophyta and Dinophyta dominated episodically. The species of Euglenophyta and Dinophyta divisions are able to be mixotrophs and may develop in water
bodies at a high content of organic matter [6]. The composition of the dominant complex of algal species at different stations in 2016 was significantly different. In terms of abundance, blue-green and diatoms dominated, and in terms of biomass, diatoms, with rare exceptions, prevailed (table 4).

Regard should be paid to increasing share of the Planktotrichet-type algae in the riverine phytoplankton communities. In 1984, these microalgae accounted for 27% of the total species richness of the algal flora, but 37%, in 2016. In addition, in 1984, these algae did not contribute to the dominant complex, but in 2016, they dominated by abundance at 7 out of 15 stations.

Among diatoms, benthic forms were often dominant, especially at the coastal stations. The dominant algae, both in terms of abundance and biomass, often included species invasive for the Volga River basin, Skeletonema subsalsum and Actinocyclus variabilis. Moreover, the development of these two species in phytoplankton communities was observed along the entire river, practically from the source.

Table 4. Dominant species of phytoplankton in the Sviyaga River in 2016; the relative abundance/biomass (%) is indicated in the brackets

| Location | Dominants by abundance | Dominants by biomass |
|----------|------------------------|----------------------|
| Kuzovatovo | Microcystis pulverea (22%) | Carteria globosa Korsch. (25%), Scenedesmus ellipticus Corda (14%) |
| Chirikovo, along the shore | Microcystis aeruginosa (Kütz.) Kütz. (37%), M. wesenbergii Kom. (21%) | Melosira undulata (Ehr.) Grun. (14%), Microcystis wesenbergii (10%) |
| Riverbed | Leptolyngbya foveolarum (Rabenhorst ex Gomont) Anagnostidis et Komárek (56%) | Actinocyclus variabilis (Makar.) Makar. (29%), Cymbella amphycephylla var. subsolina (11%) |
| Stogovka, along the shore | Cocconeis placentula Ehr. | Melosira undulata (Ehr.) Grun. (22%), Amphora ovalis Kütz/ (20%), Cocconeis placentula (20%), Opephora martji (11%) |
| Riverbed | Cocconeis placentula (30%), Opephora martji (11%) | Melosira undulata (Ehr.) Grun. (25%), Amphora ovalis Kütz/ (15%) |
| 1 km upstream Ulyanovsk city, along the shore | Actinocyclus variabilis (Makar.) Makar. (31%), Planktothrix agardii Gomont (25%) | Actinocyclus variabilis (94%) |
| Riverbed | Actinocyclus variabilis (19%), Planktothrix agardii (11%), Oscillatoria tenuis Ag. (10%) | Actinocyclus variabilis (85%) |
| Ulyanovsk city, along the shore | Limnothrix planctonica (Wołosz.) Meffert (29%), Nitzschia pusilla Grun. (19) | Amphora ovalis (42%), Nitzschia pusilla Grun. (11%) |
| Riverbed | Skeletonema subsalsum (Cl.-Euler) Bethge (89%) | Skeletonema subsalsum (88%) |
| 1 km downstream Ulyanovsk city, along the shore | Cocconeis placentula (14%), Skeletonema subsalsum (13%) | Cyclotella meneghenginiana (12%), Cocconeis placentula (12%) |
| Riverbed | Skeletonema subsalsum (22%), Aphanizomenon. flos-aquae (19%), Jaaginema geminensis (Meneghini ex Gomon) Anagnostidis et Komárek (12%) | Actinocyclus variabilis (10%) |
| Vozzino, along the shore | Oscillatoria tenuis (20%), Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová et Cronberg | Scenedesmus ellipticus Corda (13%), Cyclotella meneghenginiana (12%), Cocconeis placentula (11%), |
| Dominants by abundance | Dominants by biomass |
|------------------------|----------------------|
| Cymbella tumida (Brèb.) V. H. (11%) | Cymbella tumida (Brèb.) V. H. (11%) |
| Dominants by biomass | |
| Leptolyngbia foveolarum (19%), Planktolyngbia limnetica (12%) | Cyclotella meneghenginiana (27%), Caloneis amphysbaena (Bory) Cl. (17%) |
| Buinsk, along the shore | |
| Coelastrium microporum Näg. in A. Br. (18%), Planktothrix agardii (11%) | Amphora ovalis (40%), Rhopalodia gibba (10), Cyclotella meneghenginiana (10%) |
| Riverbed | |
| Chroomonas acuta Uterm. (31%) | Cyclotella meneghenginiana (26%), Amphora ovalis (18%) |
| Sviyazhsky, along the shore | |
| Microcystis wesenbergii (22%), Leptolyngbia foveolarum (17%) | Cyclotella meneghenginiana (37%) |
| Burunduki, riverbed | |
| Cyclotella meneghenginiana (34%), Chroomonas acuta (12%) | Cyclotella meneghenginiana (76%) |
| Kayna, along the shore | |
| Microcystis aeruginosa (25%) | Cyclotella meneghenginiana (10%) |
| Kuibyshev Reservoir | |
| Cyclotella meneghenginiana (32%) | Cyclotella pseudostelligera (69%) |
| Microcystis pulverea (22%), Anabaena flos-aquae Bréb. (15%), Anabaena flos-aquae Bréb. (15%), Anabaena flos-aquae Bréb. (15%) | Bisocoea lanctonica (28%), Anabaena flos-aquae Bréb. (11%) |

4. Conclusions
The phytoplankton of the Sviyaga River was characterized by high taxonomic diversity. It comprises 365 taxa of algae with a rank below genus. Chlorophyta and Bacillariophyta was the most diverse groups.

The number of species and intraspecific taxa of algae was higher in 2016 comparing to 1984. However, the relative number of species per sample was 1.3 times higher in 1984. Seasonal differences in the phytoplankton composition of the Sviyaga River were more pronounced than that between the ecotopes.

By 2016, the share of Planktotrichet-type algae in the phytoplankton of the Sviyaga River increased. Compared to 1984, they were regularly found in the dominant complex of microalgae.

In 2016, invasive Bacillariophyta species, namely, Skeletonema subsalsum and Actinocyclus variabilis, were regularly registered in the dominant complex of microalgae throughout almost entire Sviyaga River, starting from the source.

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