Folia biologica (Kraków), vol. **56** (2008), No 3-4
doi:10.3409/fb.56_3-4.203-207

# *Paramecium* Species of the Upper and Lower Volga River Basin, Russia*

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*Accepted April 22, 2008*

POTEKHIN A., PRZYBOŚ E., RAUTIAN M. 2008. *Paramecium s*pecies of the upper and lower Volga River basin, Russia. Folia biol. (Kraków) **56**: 203-207.

The Volga, which is the largest river in Europe (3690 km long), flows from the north (Tver' region) to the south (Caspian Sea), and its extensive basin (1380 km$^2$) includes very different biotopes. Thus, analysis of the occurrence of *Paramecium* species along this large river basin may signifcantly enhance our understanding of species distribution according to temperature regime, food richness and other possible factors. The present paper concerns the occurrence of species of the *P. aurelia* complex in the sampling areas of the Upper Volga River, and a comparison with the occurrence of species of the *P. aurelia* complex in the Lower Volga region. In the Upper Volga basin, *P. biaurelia* was the most abundant among species of the complex recorded (among *P. triaurelia, P. decaurelia, P. dodecaurelia*), in the Lower Volga region eight species of the complex were recorded (*P. primaurelia, P. biaurelia, P. triaurelia*, *P. pentaurelia, P. sexaurelia, P. septaurelia, P. novaurelia, P. decaurelia*).

Key words: *Paramecium aurelia* species complex, distribution of species, species expansion.

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Russia, the world-largest country, covers a territory of 17100 km$^2$ with great diversity of climatic and ecological conditions. The total length of rivers in Russia is more than 8 mln km; however, because of the extensive area, this "gold mine of water microorganisms" has not been well-investigated by zoogeographers of Ciliata, and, particularly, of *Paramecium*. The species of this genus can be found almost everywhere around the world except for polar zones (WICHTERMAN 1986). For example, among 15 species of the *Paramecium aurelia* complex known world-wide (SONNEBORN 1975; AUFDERHEIDE *et al*. 1983), some are cosmopolitan, e.g. *P. primaurelia*, *P. biaurelia*, *P. tetraurelia*, and *P. sexaurelia*, while others are limited to certain regions, environments, or even habitats (cf. SONNEBORN 1975; PRZYBOŚ & FOKIN 2000; PRZYBOŚ 2005; PRZYBOŚ *et al*. 2008a).

Until recently, all data on the occurrence of Paramecium species east of the Ural mountains were sparse and random: few places were sampled in Eastern Siberia, and only the presence of *P. primaurelia* and *P. biaurelia* (PREER *et al*. 1974; DAGGETT 1978; KOŚCIUSZKO 1985; PRZYBOŚ & FOKIN 1996) was revealed. Later, the West Siberian Lowland, the Altai Mountains, and the Altai Foreland were representatively sampled, and the presence of *P. primaurelia*, *P. biaurelia*, *P. triaurelia*, and *P. pentaurelia* was recorded (POTEKHIN *et al*. 2006). More studies on the occurrence and distribution of species of the *P. aurelia* complex were carried out in the European part of Russia (cf. PRZYBOŚ *et al*. 2004, 2005; PRZYBOŚ *et al*. 2006; PRZYBOŚ *et al*. 2007a, b; PRZYBOŚ *et al*.2008b), and the presence of the following species was recorded: *P. primaurelia*, *P. biaurelia*, *P. triaurelia*, *P. tetraurelia*, *P. pentaurelia*, *P. sexaurelia*, *P. septaurelia*, *P. novaurelia*, *P. decaurelia*, and *P. dodecaurelia*. Sampling was carried out near Moscow, St. Petersburg, Kaliningrad, Vladimir, in Middle Russia, and in the Black Sea region. However, different regions were unevenly sampled.

*Supported by the Russian Foundation for Basic Research (projects 06-04-49504 and 07-04-01755), and by a grant of the Russian Ministry of Science and Education RNP 148.

Complex studies, when more than a hundred water samples were taken from one discrete geographical territory, were carried out only in the Lower Volga region: in Astrakhan nature reserve and in the Volga-Akhtuba flood lands in the Volgograd region (PRZYBOŚ *et al*. 2004, 2005). The Volga, which is the largest river in Europe (3690 km long), flows from the north (the Tver' region) to the south (Caspian Sea), and its extensive basin (1380 $km^2$) includes very different biotopes. Thus, analysis of the occurrence of *Paramecium* species along this large river basin could potentially contribute much information on species distribution according to temperature regime, food richness and other possible factors. The present paper concerns the occurrence of species of the *P. aurelia* complex in the upper Volga River, and a comparison with the occurrence of species of the *P. aurelia* complex in the lower Volga region; the distribution of other *Paramecium* species is also analyzed.

## Material and Methods

### Material

Water samples with plankton (15-40 ml each) were collected in several dozen sites in the Upper Volga River area and in the Volgograd region of the lower Volga River. As soon as possible (sometimes on the same day that water samples were collected), paramecia were isolated from the whole sample volume, and clones were established. The collecting sites and indexes for newly isolated strains of the *P. aurelia* complex are presented in Table 1 and in Figure 1.

### Methods

Culture and identification of paramecia were performed according to SONNEBORN (1970). Paramecia were cultivated on a lettuce medium inoculated with *Enterobacter aerogenes*. *P. biaurelia*, *P. triaurelia*, and *P. decaurelia* were identified by mating the investigated strains with the mating types of standard strains of the following species:

*P. biaurelia*, strain Rieff from Scotland,

*P. triaurelia*, strain 324 from Florida, USA,

*P. decaurelia*, strains 223 from Florida, USA.

The other species of *Paramecium* were identified by interference light microscopy (POLYVAR microscope, Reichert Yung, 1250X) of vital and whole-mounted preparations stained after Feulgen.

Table 1

New species of the *Paramecium aurelia* complex in Russia, Volga River basin

| Sampling region | Sampling place | Strain index | Species of the *Paramecium aurelia* complex |
|---|---|---|---|
| Tver' region | Seliger lake, Selizharovo | TS 185-1 | *P. biaurelia* |
| | The Volga river, Rzhev | VR 218-6 | *P. biaurelia* |
| | | VR 218-7 | *P. biaurelia* |
| | The Volga river, Staritsa | VS 223-6 | *P. biaurelia* |
| | | VS 223-7 | *P. biaurelia* |
| Moscow region | The Dubna river, Dubna | DD 237-2 | *P. biaurelia* |
| | | DD 237-5 | *P. biaurelia* |
| Yaroslavl' region | Pleshcheevo lake | YP 264-6 | *P. biaurelia* |
| | Pereslavl-Zalesskiy, lake | YPZ 272-2 | *P. biaurelia* |
| | Rybinskoye water reservoir, Nikitinskoye | YR 129-4 | *P. biaurelia* |
| | | YR 129-6 | *P. biaurelia* |
| | | YR 129-8 | *P. biaurelia* |
| | | YR 129-17 | *P. biaurelia* |
| Vologda region | Lake | Vg 56-2 | *P. biaurelia* |
| | | Vg 56-4 | *P. biaurelia* |
| | | Vg 56-8 | *P. biaurelia* |
| | | Vg 56-9 | *P. biaurelia* |
| | Lake | Vg 112-1 | *P. triaurelia* |
| Volgograd region | Pond in Akhtuba flood land | V 9-8 | *P. decaurelia* |

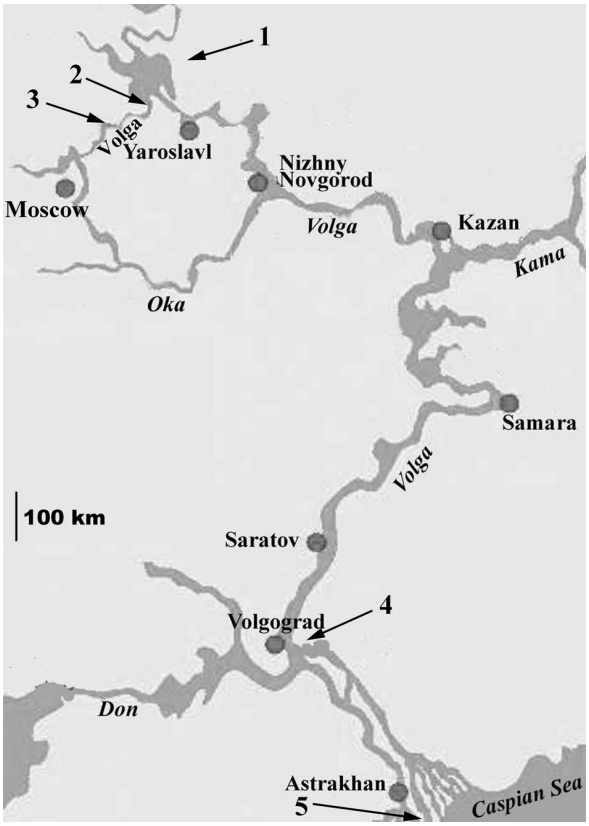


Fig. 1. The map of the sampling territory in the Volga Basin. The sampling sites are marked with arrows. See Table 2 for the list of *Paramecium* species of these regions. 1 – Vologda region; 2 – Yaroslavl region; 3 – Tver' region and Moscow region; 4 – Volgograd region; 5 – Astrakhan' Nature Reserve.

## Results and Discussion

*Paramecium* in the Volga River was previously described as a genus "seldom in plankton and benthic samples, normally not reaching any significant quantity", and only three species – *P. aurelia*, *P. caudatum*, and *P. bursaria* – were recorded (MAMAEVA 1979). In Table 2 data on the occurrence of *Paramecium* species in upper and lower Volga basin are summarized. More than 580 samples of plankton were taken, and 166 of them (approximately 30 %) contained paramecia. The Volga river is mesotrophic, and only in its lower course (from Volgograd down to the delta) it transforms into an eutrophic watercourse (MAMAEVA 1979); *Paramecium*, feeding on bacteria, are common ciliate of eutrophic waters, thus, it is to be expected that the percent of samples containing paramecia was higher in the lower Volga basin (36 %), than in the upper Volga region (25 %). The most frequent species, equally dispersed along the whole basin, was *P. caudatum*. A significant percent of samples contained representatives of the *P. aurelia* complex (see below) and *P. bursaria*; finally, *P. multimicronucleatum*, new for the Volga basin species, was recorded several times in the upper Volga region (but was never observed in the lower Volga region).

As to the species of the *P. aurelia* complex in the upper Volga basin, *P. biaurelia* was the most abundant: its presence was recorded in eight collection sites throughout the whole analyzed area, i.e. in the Tver region (5 strains in the Volga river and Seliger lake, which belongs to the lake system supplying the Volga river with water), Moscow region (2 strains in the Dubna river, which is a tributary of the Volga river), Yaroslavl region (4 strains in Rybinskoye water reservoir on the upper course of the Volga, and two strains in lakes belonging to the Volga system), and the Vologda region (4 strains). *P. biaurelia* is a cosmopolitan species, according to SONNEBORN (1975): "Cosmopolitan, chiefly in moderate to cold climates, where it is commonly found." It is one of the most frequent species in

Table 2

Occurrence of *Paramecium* species in the upper and lower Volga basin

| Region of sampling | No of region, as on Fig. 1 | Number of samples taken | Number of samples containing paramecia | | | | Percent of samples containing paramecia[1] |
|---|---|---|---|---|---|---|---|
| | | | *P. aurelia* complex | *P. caudatum* | *P. bursaria* | *P. multimicronucleatum* | |
| Vologda region | 1 | 115 | 5 | 12 | 8 | 1 | 19 % |
| Yaroslavl', Tver' and Moscow regions | 2+3 | 276 | 15 | 31 | 13 | 4 | 28 % |
| Volgograd region | 4 | 48 | 8 | 8 | 3 | 0 | 49 % |
| Astrakhan' Nature Reserve | 5 | 143 | 24 | 20 | 16 | 0 | 32 % |

[1] The percent of populations was calculated taking into account that some samples contained several *Paramecium* species simultaneously.

Table 3

Species of the *Paramecium aurelia* complex recorded in different regions of the upper and lower Volga basin (the lists of the species are given in accordance with the frequency of records)

| Region of sampling | Species of the *P. aurelia* complex | Reference |
|---|---|---|
| Vologda region | *P. biaurelia*<br>*P. triaurelia*<br>*P. dodecaurelia* | present paper;<br>PRZYBOŚ *et al*. 2008b |
| Yaroslavl', Tver' and Moscow regions | *P. biaurelia*<br>*P. decaurelia*<br>*P. dodecaurelia* | present paper;<br>PRZYBOŚ *et al*. 2007a;<br>PRZYBOŚ *et al*. 2008b |
| Volgograd region | *P. triaurelia*<br>*P. primaurelia*<br>*P. biaurelia*<br>*P. pentaurelia*<br>*P. septaurelia*<br>*P. novaurelia*<br>*P. decaurelia* | present paper;<br>PRZYBOŚ *et al*. 2004, 2005 |
| Astrakhan' Nature Reserve | *P. septaurelia*<br>*P. primaurelia*<br>*P. pentaurelia*<br>*P. sexaurelia*<br>*P. biaurelia*<br>*P. triaurelia*<br>*P. novaurelia* | PRZYBOŚ *et al*. 2004, 2005;<br>KOŚCIUSZKO 1985 |

Europe, where it was recorded in 125 habitats among 483 studied (PRZYBOŚ *et al*. 2008a); it was also registered in the majority of the Russian collection sites (KOMALA & DUBIS 1966; PREER *et al*. 1974; KOŚCIUSZKO 1985; PRZYBOŚ & FOKIN 1996; PRZYBOŚ *et al*. 2004, 2005; PRZYBOŚ *et al*. 2006; POTEKHIN *et al*. 2006), the climate of which is precisely "moderate to cold". However, in the Astrakhan Nature reserve *P. biaurelia* was recorded only once, as well as in the Volgograd region (PRZYBOŚ *et al*. 2005). Thus, *P. biaurelia* seems to preferentially occupy the zone of moderate climatic conditions. *P. biaurelia* is considered a strong competitor, tolerant to less eutrophic waters than the other species of the complex (HAIRSTON & KELLERMANN 1965). This may explain its abundance in the upper Volga basin, but does not resolve why it is less frequent than other species in *Paramecium* populations of the Volga delta.

*P. triaurelia* was found only in the Vologda region (strain Vg 112-1). The species seems to be rather rare in Europe, as it was recorded only in 22 habitats among 483 studied (PRZYBOŚ *et al*. 2008a). Earlier we also recorded this species in several populations in the Volgograd region.

In previous studies we recorded *P. decaurelia* in the upper Volga basin in the Yaroslavl region (the first European record of the species; PRZYBOŚ *et al*. 2007a); now it was recorded in one collecting site, in the lower Volga of the Volgograd region (strain V 9-8). It is a very rare species throughout the world. Previously, it was known only from the USA (SONNEBORN 1975), Japan (PRZYBOŚ & NAKAOKA 2002; PRZYBOŚ *et al*. 2003), and Altai Mountains (Asiatic part of Russia, Western Siberia; PRZYBOŚ *et al*. 2007a). Thus, this species, despite a low frequency of records, seems to be thermotolerant and rather widespread.

Finally, *P. dodecaurelia* was recorded earlier in the Yaroslavl region and in the Vologda region (PRZYBOŚ *et al*. 2008b). This species was known from North America only, but recently it was registered several times in Europe, in Kazakhstan, in Eastern Siberia, in Japan, and in the Hawaiian islands (see TARCZ *et al*. 2006; PRZYBOŚ *et al*. 2008b); thus, this species can now be considered as cosmopolitan.

Summarizing the present data and our previous results (PRZYBOŚ *et al*. 2007a; PRZYBOŚ *et al*. 2008b), four species of the *P. aurelia* complex were found in the upper Volga region – *P. biaurelia*, *P. triaurelia*, *P. decaurelia*, and *P. dodecaurelia* (Table 3). At the same time, eight species of the *P. aurelia* complex were recorded in the lower Volga region (KOŚCIUSZKO 1985; PRZYBOŚ *et al*. 2004, 2005, and the present paper) – *P. primaurelia*, *P. biaurelia*, *P. triaurelia*, *P. pentaurelia*, *P. sexaurelia*, *P. septaurelia*, *P. novaurelia*, *P. decaurelia* (Table 3). The most frequent species in Europe – *P. novaurelia* – was registered in the Volga basin only once (in the Volgograd region, see PRZYBOŚ *et al*. 2004). Three species, which, according to SONNEBORN (1975), are associated with a warm zone – i.e., *P. septaurelia*, *P. sexaurelia*, and *P. pentaurelia* – were registered respectively in 11, 5, and 5 populations of the Volga delta, while they were never found in the northern part of the Volga basin. *P. biaurelia* appeared most abundant in the upper Volga basin, but it was very rare in the lower Volga communities. Finally, in several populations of the upper Volga region we recorded *P. multimicronucleatum* – the largest known *Paramecium* species – for the first time in the Volga basin. This data supports the "protozoogeographical" concept of FOISSNER (2006), according to which most microorganisms exhibit distribution patterns, but these patterns are usually less distinct than those of multicellular organisms mainly due to the lack of data.

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