

The *Paramecium aurelia* Species Complex, Frequency and Co-occurrence across Europe

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In Europe, 10 among the 15 known species of the *Paramecium aurelia* complex have been recorded including *P. primaurelia*, *P. biaurelia*, *P. triaurelia*, *P. tetraurelia*, *P. pentaurelia*, *P. sexaurelia*, *P. septaurelia*, *P. novaurelia*, *P. dodecaurelia*, and *P. tredecaurelia*. The occurrence of species of this complex in Europe has been estimated on the basis of the number of habitats and the ratio value (r.v.), i.e. the number of habitats for a defined species to the total number of habitats with species of the *P. aurelia* complex. The r.v. presents the relative frequency of the particular species to others of the complex. In total, 483 habitats were considered. The dominant species is *P. novaurelia* (r.v. 0.38, found in 186 habitats), followed by *P. biaurelia* (r.v. 0.26 in 125 habitats) and *P. primaurelia* (0.23 in 113 habitats). Other species are less frequent, such as *P. tetraurelia* (r.v. 0.06 found in 29 habitats), *P. triaurelia* (r.v. 0.04 in 22 habitats), or rare such as *P. septaurelia* (r.v. 0.025 found in 12 habitats), as well as *P. pentaurelia* and *P. sexaurelia* (r.v. 0.02 for both, found in 11 and 10 habitats, respectively). *P. dodecaurelia* was found in three localities in Europe (r.v. 0.006) and *P. tredecaurelia* is known from a single habitat (r.v. 0.002). This paper presents new populations, found at present, of species of the *P. aurelia* complex in Europe (Germany, Italy, Spain, Iceland, Poland, Great Britain) and one new from the USA.

Key words: *Paramecium aurelia* species complex, geographical distribution, species occurrence, species identification by mating reaction.

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At present 15 species of the *Paramecium aurelia* complex are known world-wide (SONNEBORN 1975; AUFDERHEIDE *et al.* 1983). Some are cosmopolitan, such as *P. primaurelia*, *P. biaurelia*, *P. tetraurelia*, *P. sexaurelia* (cf SONNEBORN 1975; PRZYBOŚ & FOKIN 2000), others limited to specific territories, e.g. *P. quadecaurelia* (PRZYBOŚ *et al.* 2003) or single populations such as *P. sonneborni* (AUFDERHEIDE *et al.* 1983).

The distribution of species of the *Paramecium aurelia* complex is still little known in spite of many years of intense investigation. The majority of the conclusions reached by SONNEBORN (1957, 1975) have been confirmed, i.e. the existence of cosmopolitan species and temperature zones limiting the occurrence of some species, however, records of new populations of some species may change or modify our understanding of the biogeography of this complex. For instance, *P. novaurelia* was regarded as being restricted to Europe (SONNEBORN

1975), but more recently it was recorded in Asiatic Turkey (Anatolian Upland) (PRZYBOŚ 1998) and in Boston, USA (PRZYBOŚ *et al.* 2007).

The most extensive data on the distribution and frequency of occurrence of particular species of the *P. aurelia* complex concern mainly the territory of the USA (SONNEBORN 1975; AUFDERHEIDE *et al.* 1983) and Europe (cf PRZYBOŚ 2005).

P. primaurelia, *P. biaurelia*, and *P. novaurelia* are common in Europe, while the occurrence of some species, such as *P. triaurelia*, *P. tetraurelia*, *P. pentaurelia*, and *P. sexaurelia* seems to be limited to certain climatic zones; the distribution of other species is confined to certain environments, e.g. *P. septaurelia*, or even to habitats in the case of *P. tredecaurelia* and *P. dodecaurelia* (cf PRZYBOŚ 2005; PRZYBOŚ *et al.* 2005; PRZYBOŚ *et al.* 2006).

The frequency of species occurrence in Europe has been estimated on the basis of the number of

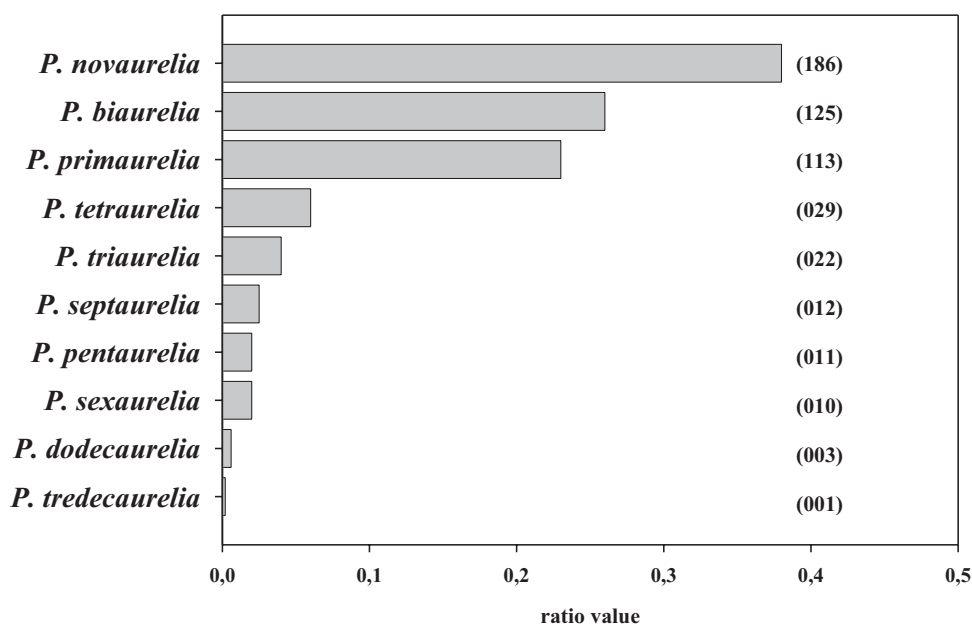


Fig. 1. Diagram presenting the relative frequency of occurrence of the *Paramecium aurelia* species complex in Europe based on the ratio value, i.e. the number of habitats for a defined species to the total number of habitats with the *P. aurelia* species.

habitats with the *P. aurelia* species and the ratio value (r.v.), i.e. the number of habitats for a defined species to the total number of habitats with any of the *P. aurelia* species (PRZYBOŚ & FOKIN 2000; PRZYBOŚ 2005). The current status of *P. aurelia* complex in Europe has been reported by PRZYBOŚ (2005) and new data was presented in PRZYBOŚ *et al.* (2005, 2006). In all, 483 habitats were taken under consideration. The dominant species is *P. novaurelia* (r.v. 0.38, found in 186 habitats), followed by *P. biaurelia* (r.v. 0.26, in 125 habitats) and by *P. primaurelia* (0.23 in 113 habitats). Other species are less frequent, such as *P. tetraurelia* (r.v. 0.06 found in 29 habitats), *P. triaurelia* (r.v. 0.04 in 22 habitats) or rare as in the case of *P. septaurelia* (r.v. 0.025 found in 12 habitats), as well as *P. pentaurelia* and *P. sexaurelia* (for both r.v. 0.02 found in 11 and 10 habitats, respectively). *P. dodecaurelia* was found in three localities in Europe (r.v. 0.006) and *P. tredecaurelia* is known from a single habitat (France, Paris, r.v. 0.002), (Fig. 1).

Conclusions concerning the distribution of particular species of the complex in Europe (483 habitats), especially in the central part of the continent, can be based on data from Poland, as out of 363 central European sampling sites, 254 were located in Poland (Tables 1 & 2, modified from PRZYBOŚ 2005). As different numbers of habitats were studied in different zones of Europe, 65 in the northern, 363 in the central, and 55 in the southern part

of the continent, it seems worthwhile to continue the investigations, especially in zones other than the most studied central zone.

In this paper we present new European populations of the *P. aurelia* complex in Germany, Italy, Spain, Iceland, Poland, Great Britain, and one new from the USA.

Material and Methods

Material

The studied strains are presented in Table 3.

Methods

Culture and identification of paramecia were performed according to SONNEBORN (1970). The paramecia were cultivated on a lettuce medium inoculated with *Enterobacter aerogenes*. The species of the *P. aurelia* complex were identified by mating the investigated strains with mating types of standard strains of the particular species. The following standard strains were used:

P. primaurelia, strain 90; *P. biaurelia*, strain Rieff Scotland; *P. triaurelia*, strain 324; *P. tetraurelia*, strain from Sydney, Australia; *P. pentaurelia*, strain 87; *P. sexaurelia*, strain 159; *P. septaurelia*, strain 38; *P. octaurelia*, strain 138; *P. novaurelia*,

Table 1

Occurrence of species of the *Paramecium aurelia* complex in Europe

Region (temperature zone)	Number of habitats of the particular species of the complex studied in the following countries											Total
	Country	<i>P. primaurelia</i>	<i>P. biaurelia</i>	<i>P. triaurelia</i>	<i>P. tetraurelia</i>	<i>P. pentaurelia</i>	<i>P. sexaurelia</i>	<i>P. septaurelia</i>	<i>P. novaurelia</i>	<i>P. dodecaurelia</i>	<i>P. tredecaurelia</i>	
Northern	Sweden		2						2			3*
	Norway		1									1
	Finland		2		1				2			5
	Russia	15	8	6		7	4	11	12			56*
Central	Great Britain	1	3		1				2			7
	Poland	56	61	3	11				123			254*
	Ukraine	2	4	5					10			21*
	Czech Republic		13	2	1				9			21*
	Slovakia	3			6							7*
	Germany		7	1			2	1	7	1		19*
	France	1	1		1				1		1	5
	Holland				1							1
	Switzerland	1										1
	Hungary	13	5			1			9			27*
Southern	Croatia						2					2
	Italy	4	4		2	1				2		13
	Greece	2					1					3
	Bulgaria	2	3		1				1			5*
	Romania	2	4	2		1			4			12*
	Spain	11	7	3	4	1	2		4			22*
Total		113	125	22	29	11	11	12	186	3	1	483

*Some species appear together in one habitat.
Data from PRZYBOŚ 2005, PRZYBOŚ *et al.* 2005, PRZYBOŚ *et al.* 2006.

Table 2

Occurrence of species of the *P. aurelia* complex in temperature zones in Europe

Zone	Number of studied habitats of species of the <i>Paramecium aurelia</i> complex *										Total
	<i>P. primaurelia</i>	<i>P. biaurelia</i>	<i>P. triaurelia</i>	<i>P. tetraurelia</i>	<i>P. pentaurelia</i>	<i>P. sexaurelia</i>	<i>P. septaurelia</i>	<i>P. novaurelia</i>	<i>P. dodecaurelia</i>	<i>P. tredecaurelia</i>	
Northern	15	13	6	1	7	4	11	16	–	–	65
Central	77	94	11	21	1	2	1	161	1	1	363
Southern	21	18	5	7	3	5	–	9	2	–	55
Total	113	125	22	29	11	11	12	186	3	1	483

*Some species appear together in one habitat.
Data from PRZYBOŚ 2005, PRZYBOŚ *et al.* 2005, PRZYBOŚ *et al.* 2006.

Table 3

New populations of the *Paramecium aurelia* spp.

Species	Origin
<i>P. primaurelia</i>	Iceland, Near Reykjavik
<i>P. biaurelia</i>	Germany, Saxony, Saidenbach Reservoir
<i>P. biaurelia</i>	Germany, Brandenburg, Brandenburg, Havel
<i>P. biaurelia</i>	Germany, Thuringia, Marlishausen
<i>P. triaurelia</i>	Germany, Lower Saxony, Hannover
<i>P. triaurelia</i>	USA, Washington, D.C.
<i>P. pentaurelia</i>	Poland, Kraków
<i>P. pentaurelia</i>	Italy, Naples
<i>P. pentaurelia</i>	Spain, Rivas, Vaciamadrid
<i>P. novaurelia</i>	UK, Scotland, Edinburgh
<i>P. novaurelia</i>	Germany, Hessen/Rhön, Geisfeld

lia, strain 510; *P. decaurelia*, strain 223; *P. undecaurelia*, strain 219; *P. dodecaurelia*, strain 246; *P. tredecaurelia*, strains 209 and 321; *P. quadecaurelia*, strain 328; *P. sonneborni*, strain Texas, USA.

The recently studied strains were identified as *P. primaurelia*, *P. biaurelia*, *P. triaurelia*, *P. pentaurelia*, and *P. novaurelia* on the basis of conjugation between the complementary mating types of the strains under examination with the corresponding ones of the particular species.

Results and Discussion

New populations of the *Paramecium aurelia* species are presented in Table 3.

Paramecium primaurelia was found in Iceland, which is the first record of any species of the *P. aurelia* complex in this country and the most northern population in Europe. In northern Europe only 65 habitats were studied and the majority were located in Russia. The species is considered cosmopolitan, known from North, Central, and South America, Hawaii, Asia, and Europe (cf SONNEBORN 1975; PRZYBOŚ & FOKIN 2000). In Europe it was recorded in 113 out of 483 habitats with the *P. aurelia* species.

New strains of *P. biaurelia* were found in Germany, the identified strains originated from different federal states, i.e. Saxony, Brandenburg, Thuringia. Previously, the species was identified in samples collected in Baden-Württemberg and Westphalia (PRZYBOŚ & FOKIN 1997). *P. biaurelia* is another cosmopolitan species known from North and South America, New Zealand, Asia, and

Europe. In Europe it is very common, recorded in 125 habitats out of 483.

A *P. triaurelia* population was recorded in Germany in Lower Saxony. Previously (PRZYBOŚ & FOKIN 1997), the species was found in Germany in Stuttgart and its vicinities (Baden-Württemberg). A new population of this species was also identified in Washington, USA. The species was known from North America from Alaska to Florida (SONNEBORN 1975), and was later found in Spain, Romania, Germany, Czech Republic, Ukraine, Poland, and Russia, altogether in 22 out of 483 habitats.

New strains of *P. pentaurelia* were recorded in Italy (Naples), Spain (Madrid region), and Poland (Kraków). The species was known before from North America and Australia (SONNEBORN 1975), and was later found in 11 European habitats including Spain, Romania, Italy, Hungary, and Russia (only in the Lower Volga Basin and the Belgorodsky region), so it seemed to be limited to the warm zone of Europe. The occurrence of some species may be bounded by climatic zones as already suggested by SONNEBORN (1975). The detection of a new stand of this species in Kraków is surprising because Poland is one of the most extensively sampled countries (254 habitats out of 483 in all of Europe) and has been studied since 1959. Until now, the checklist of Polish species included *P. primaurelia* in 56 habitats, *P. biaurelia* in 61, *P. triaurelia* in 3, *P. tetraurelia* in 11, and the most frequent species, *P. novaurelia*, in 123 habitats. The new finding of *P. pentaurelia* also raises the question of transport of paramecium strains between different water bodies, as cysts are unknown in *Paramecium*. Perhaps waterfowl or water insects serve as ciliate transmitters, or the *P. pentaurelia* strain found in Kraków may have been transferred by water borne plants as the water sample with the species was collected from artificial pond in park.

P. novaurelia populations were found in Germany, Hessen/Rhön and in Edinburgh, Scotland. The species was recorded previously in Germany in Westphalia and Baden-Württemberg (PRZYBOŚ & FOKIN 1997) and in Great Britain in the same collecting site as at present, i.e. in St. Margaret's Lake, Edinburgh, Scotland (collected in 1952 by G. H. BEALE, cf BEALE & SCHNELLER 1954; SONNEBORN 1974). *P. novaurelia* is the most common in Europe, recorded in 186 habitats among 483, and was thought to be restricted to this continent only (SONNEBORN 1975), however, single populations were later found in Asia and North America.

We agree with the statement that "... although many free-living protists may be globally distributed, geographical patterns and local distribution also occur" (SCHLEGEL & MEISTERFELD 2003).

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