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Occurrence of *Paramecium* Species in Western Siberia, Russia

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Paramecium strains collected in Central Russia, Western Siberia (the West Siberian Lowland and the Altai Mountains in the south) were studied. The presence of *P. caudatum*, *P. bursaria*, *P. multimicronucleatum*, *P. polycaryum*, and four species of the *P. aurelia* complex, i.e. *P. primaurelia* (in Omsk), *P. biaurelia* (in Krasnoyarsk and the Altai Mountains), *P. triaurelia* (in Krasnoyarsk), and *P. pentaurelia* (in Novosibirsk, Altai Foreland, and Altai Mountains) was revealed. *P. triaurelia* and *P. pentaurelia* were found for the first time in Asia.

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

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The key question of understanding the structure of species in Protozoa is the problem of occurrence and distribution of the particular species. The occurrence of protist species in geographic zones is a currently debated topic (FINLAY & FENCHEL 1999; FOISSNER 1999; FINLAY 2004). *Paramecium* (Ciliophora) is one of the best studied protists. Not all *Paramecium* species have a world-wide distribution (WICHTERMAN 1986); the most data on distribution and frequency of occurrence concerns the *P. aurelia* species complex (PRZYBOŚ & FOKIN 2000; PRZYBOŚ 2005). The *Paramecium* aurelia complex is composed of 15 species (SONNEBORN 1975; AUFDERHEIDE *et al*. 1983). Some of them are cosmopolitan (*P. primaurelia*, *P. biaurelia*, *P. tetraurelia*, *P. sexaurelia*), others known from single habitats only (e.g. *P. undecaurelia*, SONNEBORN 1975). Thus, one could expect interesting results from sampling in territories which have not yet been examined.

Studies carried out in Asia revealed the presence of cosmopolitan species of the complex (*P. primaurelia*, *P. biaurelia*, *P. tetraurelia*, *P. sexaurelia*) and also *P. novaurelia* (PRZYBOŚ & FOKIN 2000), as well as *P. decaurelia* and *P. dodecaurelia* (PRZYBOŚ *et al*. 2003). The mentioned species were recorded in single localities, i.e. *P. novaurelia* in Beysechir, Turkey for the first time outside Europe (PRZYBOŚ 1998), *P. decaurelia* in Tousenjiousen, Japan, and *P. dodecaurelia* in Ube, Japan (PRZYBOŚ *et al*. 2003). Studies in Asia were conducted mainly in Japan (SONNEBORN 1950, 1974; KOŚCIUSZKO & KOIZUMI 1984; PRZYBOŚ & FOKIN 2001; PRZYBOŚ *et al*. 2003), while some places were studied in Central Asia (India, Turkmenistan), the Near East (Israel, Lebanon, Turkey), and again the Far East (Russian Far East, Vietnam, Thailand), (PRZYBOŚ & FOKIN 2000). A broad area of Asia is still *terra incognita* as far as the occurrence of species of the *Paramecium aurelia* complex is concerned.

Here strains collected in Central Russia, Western Siberia (the West Siberian Lowland and the Altai Mts in the south – geographical nomenclature after ZIERHOFFER 1967) have been studied. Previously, the greater part of Russia from Ural Mountains (the border between Europe and Asia) up to Baikal Lake was left completely unexplored, and data on *Paramecium* distribution farther to the East are fragmentary. Sampling was carried out only in a few places in the Asian part of Russia, in Eastern Siberia. The mentioned studies revealed the presence of *P. primaurelia* in the Kamchatka peninsula (DAGGETT 1978), *P. biaurelia* on Sakhalin Island (PREER *et al.* 1974), in Nakhodka (KOŚCIUSZKO 1985), and in Irkutsk (PRZYBOŚ & FOKIN 1996).

Material and Methods

Material

160 water samples (15-40 ml each) were collected during summer field expeditions from a number of localities situated on the West Siberian Lowland and from water reservoirs in the Altai Foreland and the Altai Mts. Sampling was performed in this vast area with significant altitude drop between sampling places (see Fig. 1, Tables 1 and 2). Each sample was considered as a separate population, though some samples were taken from one and the same water reservoir. The same day that water samples were collected, some paramecia were isolated from the whole sample volume, and clones were established. Clones from the samples taken in Omsk were isolated later in the laboratory.

Methods

Culture and identification of paramecia

Paramecia cultivation and identification were performed according to SONNEBORN's (1970) methods. 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. pentaurelia, strain 87.

Results and Discussion

The western and central part of Northern Asia has not yet been investigated by ciliatologists, so the data on occurrence of different *Paramecium* species in this territory are absent. *Paramecium* species structure was analyzed in five regions of Western Siberia separated from each other by significant distances (see Fig. 1). 160 water samples were collected, and paramecia were found in 52 of them (Table 2). Several other genera of ciliates – *Dileptus*, *Stentor*, *Spirostomum*, *Stylonychia*, *Vorticella*, *Climacostomum*, *Oxytricha*, *Loxodes* – were registered frequently in all samples.

Paramecia belonging to five morphological species were found: the *P. aurelia* complex, *P. caudatum*, *P. bursaria*, *P. multimicronucleatum*, *P. polycaryum* (Table 1). Representatives of the *P. aurelia* species complex and *P. caudatum* were registered in the most often, in 14 and 19 samples respectively. Interesting, *P. caudatum* dominated only in the Altai Mts, where environments are rela-

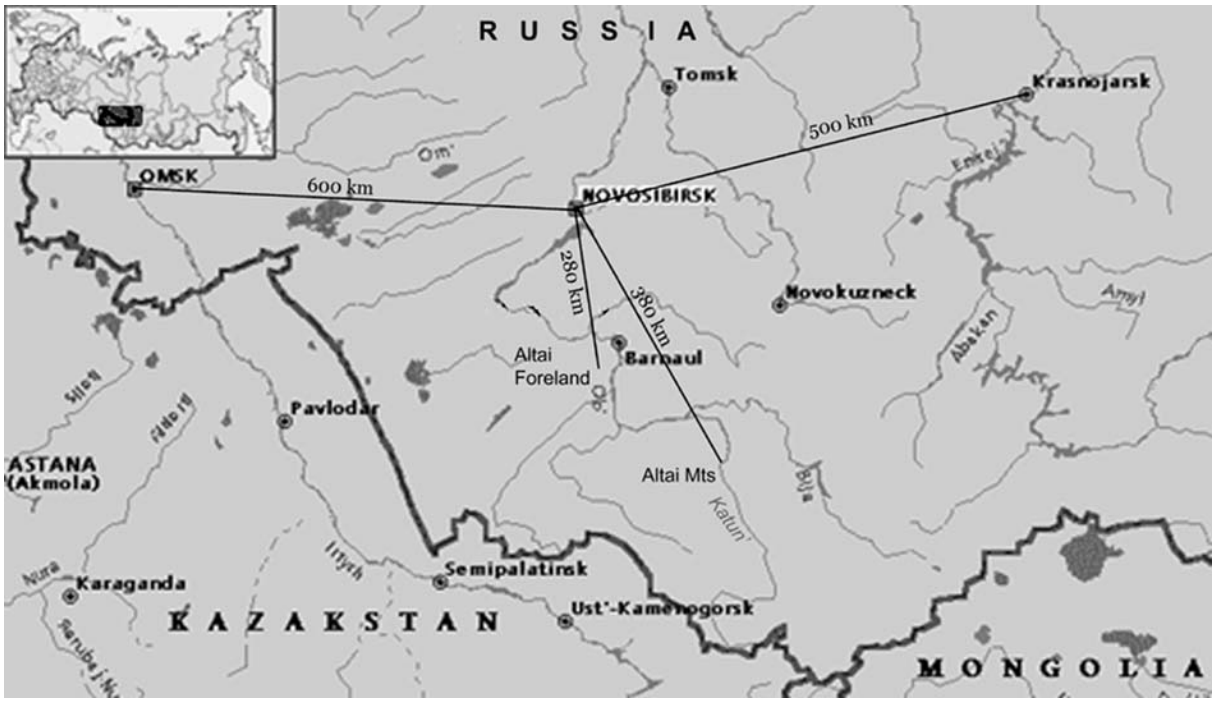

Fig. 1. The map of the sampling territory in the Western Siberia Lowland and Altai Mts. In the upper left corner – a map of Russia; the sampling territory is shaded. The distances from Novosibirsk to the other sampling grounds (Omsk, Krasnoyarsk, Altai Mts, Altai Foreland) are shown. The altitude of Novosibirsk and Omsk is 200 ma.s.l.; of Krasnoyarsk and Altai Foreland – 500 ma.s.l.; Altai Mts (Chemal region) – 2000 m a.s.l.

Table 1

Occurrence of *Paramecium* species in Western Siberia

Region of sampling	Number of samples taken	Number of samples containing paramecia						
		P. aurelia complex	*P. caudatum*	*P. bursaria*	*P. multimicro-nucleatum*	*P. polycaryum*	Not identified paramecia[1]	Total[2]
Omsk	4	2	0	0	1	0	0	2
Novosibirsk	12	1	1	0	1	0	1	4
Krasnoyarsk	58	6	6	2	7	2	2	16
Altai Foreland	29	2	3	2	0	0	5	10
Altai Mts	57	3	9	0	0	0	8	19
Total[2]	160	14	19	4	9	1	16	522

[1] Paramecia were observed in the sample but the clones were not established afterwards

[2] The total was calculated taking into account that:

P. caudatum was observed together with species of the *P. aurelia* complex in one sample from Altai Mts, and in one sample from the Altai Foreland;

P. caudatum was observed together with *P. multimicronucleatum* in two samples from Krasnoyarsk;

P. multimicronucleatum was observed together with species of the *P. aurelia* complex in two samples from Krasnoyarsk and in one sample from Omsk;

P. caudatum was observed together with species of the *P. aurelia* complex, and *P. multimicronucleatum* in one sample from Krasnoyarsk;

P. multimicronucleatum was observed together with species of the *P. aurelia* complex and *P. polycaryum* in one sample from Krasnoyarsk;

P. bursaria was observed together with non-identified *Paramecium* sp. in one sample from Altai Foreland.

Table 2

Occurrence of species of the *Paramecium aurelia* complex in Western Siberia and characteristics of examined habitats

Geographical place	No. of sample	*Paramecium aurelia* species	Number of isolated strains	Other *Paramecium* species	Habitat
Omsk	159	*P. primaurelia*	6	*P. multimicronucleatum*	The Irtysh river
	160	*P. primaurelia*	2		The Irtysh river
Krasnoyarsk	128	*P. biaurelia* *P. triaurelia*	1 1	*P. caudatum*	Pond near meat-packing factory
	133	*P. biaurelia*	2	*P. caudatum*	Pond on outskirts, grass
	149	*P. triaurelia*	1	*P. bursaria*	Pond belonging to the Yenisei river system; grass
	153 155 156	*P. triaurelia*	3 4 1	*P. caudatum*, *P. polycaryum*, *P. multimicronucleatum*	The Kacha river, foul water
Novosibirsk	7	*P. pentaurelia*	1	*P. caudatum*	Small pond in the Ob' river system
Altai Foreland	81	*P. pentaurelia*	2	*P. caudatum*	Permanent pool, cattail
	87	*P. pentaurelia*	4		Permanent pool, water grass
Altai Mts	67	*P. biaurelia*	3	*P. caudatum*	Stream in a farmyard
	62	*P. biaurelia*	1	*P. caudatum*	Isolated pond near the Katun river
	20	*P. pentaurelia*	1		Lake at the foot of Babyrgon mountain

tively poor in nutrition sources; in all other regions they were represented equally with species of the *P. aurelia* complex. *P. bursaria*, which is a cosmopolitan and common species (LANDIS 1988), was registered only in two populations in the Altai Foreland and in two populations in Krasnoyarsk; thus, this species appeared to be rare in Western Siberia. *P. multimicronucleatum* was found in Novosibirsk and Krasnoyarsk, but only in samples taken from habitats rich in organics – a pond near a meat-packing factory in Krasnoyarsk and in small rivers with foul waters running through the cities – Zayeltsovka in Novosibirsk and Kacha in Krasnoyarsk. Such polluted water with organic waste is, probably, rich in bacteria, and, thus, it is appropriate habitat for *P. multimicronucleatum*. It is worth noting that the Kacha river is extremely rich with different *Paramecium* species – *P. triaurelia*, *P. caudatum*, *P. multimicronucleatum*, and *P. polycaryum* were isolated from 6 samples taken from it; in a single locality *P. polycaryum* was revealed. Four species were aslo recorded in the pond near the meat-packing factory in Krasnoyarsk – *P. biaurelia*, *P. triaurelia*, *P. caudatum*, *P. multimicronucleatum*.

The presence of four species of the *P. aurelia* complex, i.e. *P. primaurelia*, *P. biaurelia*, *P. triaurelia*, and *P. pentaurelia* was revealed in the studied regions (Table 2).

P. primaurelia was found only in Omsk – all eight isolated strains collected from two populations in the Irtysh River belonged to this species.

P. biaurelia was revealed in Krasnoyarsk in two samples, both taken from ponds in the outskirts of the town. This species was also detected in two samples taken in the Altai Mts. *P. biaurelia* is cosmopolitan (SONNEBORN 1975), and it seems to be a common species in Eastern Siberia and in the Russian Far East, it was also found in Japan (PREER *et al*. 1974; KOŚCIUSZKO 1985; PRZYBOŚ & FOKIN 1996; PRZYBOŚ & FOKIN 2000).

P. triaurelia was found in Krasnoyarsk in five samples, although three of them were collected close to each other in the same small polluted river Kacha (see Table 2). The species was revealed for the first time in Asia. In Europe it seems to be rather rare (PRZYBOŚ 2005) and is known also from Northern America (SONNEBORN 1975).

P. pentaurelia was revealed in Novosibirsk, in two collecting localities from the Altai Foreland, and one strain was isolated from the sample from the Altai Mts. The species was recorded for the first time in Asia, in Europe it is rare (PRZYBOŚ 2005, PRZYBOŚ *et al*. 2004, 2005) and is known also from North America and Australia (SONNEBORN 1975).

Some environmental variables may be important for determining the natural distribution of species. The occurrence of some species of the *P. aurelia* complex is limited by climatic zones, already suggested by SONNEBORN (1975). This is true certainly in the case of *P. quadecaurelia*, known from two localities only, both situated in hot regions, one in Central Australia (SONNEBORN 1975), the second in Namibia, Africa (PRZYBOŚ *et al*. 2003). This seems to be true also for *P. pentaurelia*, which had been recorded before only in the warm zone (USA, Australia, Hungary, Romania, Spain, and Italy – see SONNEBORN 1975; PRZYBOŚ 2005, PRZYBOŚ *et al*. 2005). The presented data on Siberian species of the *P. aurelia* complex are inconsistent with this assertion – Western Siberia is characterized by a very continental climate, which means hot, but relatively short summers, long and cold autumns and springs, and severe winters, when the temperature may fall to -40°C. *P. pentaurelia* was registered in three different territories, so it seems to be a common species in Siberia. The three other detected species have already been registered in the northern region of Europe (PRZYBOŚ 2005), thus their ability to survive in cold areas is not surprising.

Paramecium is considered to be an eurythermal organism (SUKHANOVA 1968), and it was demonstrated that *P. caudatum* can survive for years when cultivated at a temperature of 0°C (POLJANSKY & POZNANSKAYA 1964). However, *Paramecium* can not stay freezen, unlike Tetrahymena (WANG & MARQUARDT 1966), though it can survive temperatures below zero for a short time when allowed to adapt gradually (POLJANSKY 1963). It is never found in samples taken from under ice in their usual habitats (LANDIS 1988), though one can not exclude the survival of ciliates in silt. Under conditions of the Siberian winter many water reservoirs, which serve as a habitat for *Paramecium* in the warm season, may be frozen down to the bottom. According to the literature, cysts, which enable Colpoda to survive in ice, are unknown in *Paramecium* (GUTIERREZ *et al*. 1998). It is possible that the paramecia population is renovated each year after the cold season in the completely freezing habitats; for example, waterfowl may serve as ciliate transmitters from reservoirs with permanent populations. Nonetheless, the problem of *Paramecium* survival in extremely low temperature still remains enigmatic. Extensive sampling in winter in the frozen reservoirs rich with paramecia in warm season may shed light on this question.

Generally, according FINLAY (2004) "Most biologists probably believe that the sympatric sibling species will eventually be shown to occupy differentiated niches. One important task for the

future will be to discover if there is any discernible correspondence between biological species, ecotypes and DNA sequence clusters". However, sibling species of the *P. aurelia* complex are not just differentiated by ecological niches, but also may compete in the same environment. Usually, only one species of the *P. aurelia* complex is present in a single population; all exceptions from this rule were reported from habitats rich with nutrition sources. For example, in the Volga delta, which is especially eutrophic, often two or three species of the *P. aurelia* complex were registered sharing a habitat and not out-competing each other (PRZYBOŚ *et al*. 2005). Two species of the *P. aurelia* complex in one population were also registered in Spanish habitats (PRZYBOŚ 1993). In Siberia each habitat was occupied by a single species of the *P. aurelia* complex. The only case in the present study when two species of the *P. aurelia* complex (namely, *P. biaurelia* and *P. triaurelia*) were found in one population was the sample taken from the organics-enriched pond near the meat-packing factory in Krasnoyarsk. Interestingly, HAIRSTON and KELLERMANN (1965) demonstrated that *P. triaurelia* can survive and even outcompete *P. biaurelia* only in rich waters. Food excess is necessary to overcome interspecies competition, otherwise stronger competitors would drive another species in the same habitat to extinction when food resources are relatively scarce (LANDIS 1988).

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References

AUFDERHEIDE K. J., DAGGETT P.-M., NERAD T. A. 1983. *Paramecium sonneborni* n. sp., a new member of the *Paramecium aurelia* species-complex. J. Protozool. **30**: 128-131.

DAGGETT P.-M. ed. 1978. Protozoa and Algae. (In : Catalogue of Strains. I. Thirteenth edition, the American Type Culture Collection, Rockville, Maryland): 1-18.

FINLAY B. J. 2004. Protist taxonomy: an ecological perspective. Phil. Trans. R. Soc. Lond. B **359**: 599-610.

FINLAY B. J., FENCHEL T. 1999. Divergent perspectives on protist species richness. Protist **150**: 229-233.

FOISSNER W. 1999. Protist diversity: estimates of the near-imponderable. Protist **150**: 363-368.

GUTIERREZ J. C., MARTIN-GONZALES A., CALLEJAS S. 1998. Nuclear changes, macronuclear chromatin reorganization and DNA modifications during ciliate encystment. Europ. J. Protistol. **34**: 97-103.

HAIRSTON N. G., KELLERMANN S. I. 1965. Competition between varieties 2 and 3 of *Paramecium aurelia*: the influence of temperature in a food-limited system. Ecology **46**: 134-139.

KOŚCIUSZKO H. 1985. Species of the *Paramecium* aurelia complex in some regions of the USSR. Folia biol. (Kraków) **33**: 117-122.

KOŚCIUSZKO H., KOIZUMI S. 1984. Habitats of the *Paramecium aurelia* complex in Japan. Folia biol. (Kraków) **32**: 57-62.

LANDIS W.G. 1988. Ecology. (In: *Paramecium* H.-D. Görtz ed., Springer-Verlag, Berlin): 419-436.

POLJANSKY J. I. 1963. On ability of *Paramecium caudatum* to withstand temperatures below zero. Acta Protozool. **1**: 165-175.

POLJANSKY J. I., POZNANSKAJA T. M. 1964. Long-term cultivation of *Paramecium caudatum* at 0°C. Acta Protozool. **2**: 271-278.

PREER J. R. Jr., PREER L. B., JURAND A. 1974. Kappa and other endosymbionts in *Paramecium aurelia*. Bact. Rev. **38**: 113-163.

PRZYBOŚ E. 1993. Species of the *Paramecium aurelia* complex in Spain. Microbiologia SEM **9**: 113-117.

PRZYBOŚ E. 1998. The first habitat of *Paramecium novaurelia* of the *P. aurelia* spp. complex in Asia (Turkey). Folia biol. (Kraków) **46**: 91-95.

PRZYBOŚ E. 2005. Recent data on the occurrence of species of the *Paramecium aurelia* in Europe. Folia biol. (Kraków) **53**: 61-63.

PRZYBOŚ E., FOKIN S. 1996. New habitats of species of the *Paramecium aurelia* complex in Russia and Vietnam. Folia biol. (Kraków) **44**: 105-106.

PRZYBOŚ E., FOKIN S. 2000. Data on the occurrence of species of the *Paramecium aurelia* complex world-wide. Protistology **1**: 179-184.

PRZYBOŚ E., FOKIN S. 2001. Species of the *Paramecium aurelia* complex in Japan. Folia biol. (Kraków) **49**: 105-106.

PRZYBOŚ E., FUJISHMA M., NAKAOKA Y. 2003. *Paramecium decaurelia* and *Paramecium dodecaurelia* from the *P. aurelia* spp. complex in Japan. Folia biol. (Kraków) **51**: 223-224.

PRZYBOŚ E., HORI M., FOKIN S. I. 2003. Strain of *Paramecium quadecaurelia* from Namibia, Africa: Genetic and molecular studies. Acta Protozool. **42**: 357-360.

PRZYBOŚ E., RAUTIAN M., POTEKHIN A. 2004. First European record of *Paramecium* septaurelia and the discovery of new European habitats of *P. pentaurelia* and P. sexaurelia in Russia (Astrakhan and Volgograd Region). Folia biol. (Kraków) **52**: 87-90.

PRZYBOŚ E., RAUTIAN M., POTEKHIN A. 2005. Species of the *Paramecium aurelia* complex in Russia, Lower Volga Basin. Protistology **4**: 129-134.

SONNEBORN T. M. 1950. Methods in the general biology and genetics of *Paramecium aurelia* . J. exp. Zool. **113**: 87-148.

SONNEBORN T. M. 1970. Methods in *Paramecium* research. (In: Methods in Cell Physiology, vol. 4. D. M. Prescott ed. Academic Press, New York, London): 241-339.

SONNEBORN T. M. 1974. *Paramecium aurelia*. (In: Handbook of Genetics, vol. 2 . R. C.King ed., Plenum Press, New York): 469-594.

SONNEBORN T. M. 1975. The *Paramecium aurelia* complex of fourteen sibling species. Trans. Amer. Micros. Soc. **94**: 155-178.

SUKHANOVA K. M. 1968. Temperature adaptations in Protozoa. Nauka, Leningrad. (In Russian).

WANG G.-T., MARQUARDT W. C. 1966. Survival of Tetrahymena pyriformis and *Paramecium aurelia* following freezing. J. Protozool. **13**: 123-128.

WICHTERMAN R. 1986. The Biology of *Paramecium*, Plenum, New York London.

ZIERHOFFER A. ed. 1967. General Geography, vol. 4, PWN, Warszawa (In Polish).