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## SYMBIONT FAUNA OF FRESHWATER ZOOPLANKTON IN SEVERAL WATER BODIES OF THE DNIPRO RIVER BASIN

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**Symbiont Fauna of Freshwater Zooplankton in Several Water Bodies of the Dnipro River Basin.**  
**Rybka, T. S., Yuryshynets, V. I.** — In several water bodies of the Dnipro river Basin, parasitological studies of the representatives of main taxonomic groups of freshwater zooplankton (Rotifera, Copepoda and Cladocera) were conducted. Altogether 22 species of different taxonomic groups (bacteria, flagellates, algae, fungi, ciliates, etc.) of symbionts of zooplankters were found. The data on the symbiofauna of zooplankters and on the aspects of biology of certain epibiotic and parasitic species were summarized. The study showed the peculiarities of symbionts distribution by host species in different taxonomic groups of zooplankton. The number of symbiotic species increased in following order: Rotifera → Cladocera → Copepoda. Copepoda had high species richness of epibiotic ciliates and the highest rates of colonization by epibiotic algae.

Key words: zooplankton, symbionts, infection parameters, Rotifera, Cladocera, Copepoda.

### Introduction

Zooplankton is one of the most dynamic components of aquatic biota, sensitive to the impact of natural and anthropogenic factors. The ecological indices of zooplankton communities (diversity, the abundance ratio of certain taxonomic groups and species, quantitative indicators, saprobity characteristics of edicator species) are used to assess the ecological status of aquatic ecosystems and to monitor the quality of the aquatic environment (Pashkova, 2013). The zooplankters are hosts of a number of symbionts, with highly varying relationships depending on the localization (epi- and endobiosis) and the peculiarities of metabolic interactions (commensalism, parasitism, etc.).

Although the composition of the symbiofauna in a particular water body depends primarily on the composition of the host species, it should be borne in mind that the symbiotic communities in the ecosystems of present-day water bodies are subject of the constant influence of destabilizing abiotic and biotic factors. Changes in hydrobiont symbiocoenoses can be used in biological indication (Yuryshynets, 2013, 2017).

Overall, there is very few information about the symbionts of plankton organisms (Rotifera, Cladocera, Copepoda). Freshwater zooplankters act as hosts for symbionts of various taxonomic groups: bacteria, fungi, microsporidia, algae, heterotrophic flagellates, ciliates, trematodes, cestodes and nematodes (Green, 1974; Gaiser & Bachmann, 1993; Vávra et al., 2005; Zalocar et al., 2011; Banina, 1984; Monchenko, 2003; Dubovskaya et al., 2005; Gorbunov, 2008; Dovgal, 2013; Boshko, 2013; Rybka & Jurishinets, 2013, et al.).

The first descriptions of organisms attached to the surfaces of zooplankton bodies were made by K. Ehrenberg (Ehrenberg, 1838), who noted the presence of sessile ciliates and algae on planktonic crustaceans. The active study of zooplankton epibionts began in the 19th century; these findings later reflected in large-scale reviews on peritrichia (Keiser, 1921; Kahl, 1935; Stiller, 1971). Epibionts of other taxonomic groups were hardly ever studied. The species composition of zooplankton symbionts is best studied for Copepoda (Alikin, 1992; Monchenko, 2003; Dubovskaya et al., 2005, and others). First information on symbionts of Cladocera appeared at the end of the 19th century. Green later summarized these studies in a well-known review (Green, 1974) with a list of parasites and epibionts of Cladocera. There are some fragmentary data on rotifer parasites (Decksbach, 1928; Miracle, 1977; Barron, 1980; Cohn, 1902; Glockling, 1998; Mierinho et al., 2013; Gorbunov, 2008).

Such Ukrainian scientists as V. I. Monchenko, I. V. Dovgal and Y. G. Boshko significantly contributed to the study of obligate epibionts of zooplankton (Dovgal, 1984; Dovgal, 1988, 2013; Monchenko, 2003; Boshko, 2013). Foreign studies of zooplankton symbionts are very few, and mainly focus on the taxonomy and biology of certain species of hosts and symbionts (Evans et al., 1979; Gaiser & Bachmann, 1993; Carman & Dobbs, 1997; Fernandes-Leborans & Tato-Porto, 2000; Barea-Arco et al., 2001; Bittner et al., 2002; Duncan et al., 2009; Lohr et al., 2010; Bickel et al., 2012; Wolska & Mazurkiewicz-Zapalowicz, 2013; Bielecka & Boehnke, 2014; and others).

However, the influence of symbionts (including parasites) on the diversity of planktonic organisms is poorly investigated. Likewise, the role of many symbiotic groups in aquatic ecosystems and the nature of their interactions with invertebrate hosts have not been studied yet.

The purpose of our research was to study the species diversity of symbionts of zooplankters of various taxonomic groups, their infection parameters and specifics of localization, depending on the type of water body and species composition of zooplankton.

## Material and methods

The zooplankton samples were collected in different types of water bodies of the Dnipro River Basin during the vegetation periods of 2012–2013. River-type water bodies include different parts of the Kanevsky reservoir (near the “Sobach’e Girlo” Bay, the area of the Novodnitsky Park, and the areas in the upper part of Kanivsky Reservoir, located above and below the Bortnitsa aeration station); various parts of the Desenka branch (near the Desna River, the area of Rusanivski Gardens, and near the Paton Bridge); the Upper Pripyat basin and its right-bank tributaries (the Tsir River and the Stokhid River). Lake-type water bodies were located within Kyiv (Jordan Lake (Opechen Lake System), Verbne Lake, Redkino Lake and two reservoirs of the Troeschyna meliorative system). Totally 65 samples of zooplankton were collected and processed, from the coastal and deep parts of water bodies.

Plankton samples were collected using conventional techniques (Romanenko, 2006; Trokhymets, 2011). From each biotope, two samples were taken: a sample with live material and a fixed sample. For each sample, 100 liters of water were filtered through the medium plankton Apstein net (gas No. 68), the residue was either placed in a portable refrigerator and transported to a laboratory for microscopy, or fixed with 4 % formaldehyde solution. The fixed sample was examined later, taking into account the species composition of the symbionts found in the non-fixed sample. The collected material was processed in a laboratory by the method of sequential partial comparison under a microscope. For species identification of zooplankton, several keys were used: L. A. Kutikova (1970) for Rotifera, E. F. Manuilova (1964) for Cladocera, V. I. Monchenko (1974) for Copepoda.

The symbiotic organisms were studied both live and fixed under the Axio Imager A1 (Carl Zeiss) microscope using various methods of light and differential-interference contrast microscopy. Zooplankters and their symbionts were prepared for laboratory analysis according to the manuals (Markevich, 1961; Asaul, 1975; Shalapenok & Zapolskaya, 1988).

Algae were identified in temporary and permanent (in Canada balsam) microscope slides (Asaul, 1975). Fungi were studied in temporary slides according to the structure of mycelia and zoosporangia (Khulbe, 2001). Peritrichia and Suctoria were studied in vivo using oil immersion (Boshko, 2009; Dovgal, 2013).

Species identification was carried out using the appropriate papers (Kahl, 1935; Zabelina & Kiselev, 1951; Banina, 1984; Dovgal, 1988; Monchenko, 2003; etc.). To reveal the specifics of the symbiotic colonization of zooplankton hosts, we estimated the prevalence of infection EI (EC), % and intensity of infection (colonization) II (IC), ind./host.

## Results and discussion

In total, 22 symbiotic species or supraspecific taxa of different taxonomic groups were found on zooplankters (table 1): bacteria (not identified up to a species or group); parasitic fungi of the genera *Catenaria* Sorokin, 1889 (one species), *Saprolegnia* Nees, 1823 (one species), *Lagenidium* Schenk, 1857 (one species) and *Olpidium* A. Braun, 1886 (one species); parasitic euglenozoa of the genus *Dinema* Perty, 1852 (one species); epibiontic euglenozoa and diatom algae of the genera *Colacium* Ehrenberg, 1883 (one species) and *Epithemia* Brébisson,

**Table 1.** Distribution of symbionts by host species of various taxonomic groups of zooplankton in the studied water bodies

Symbionts	Zooplankton species																																															
	Rotifera					Cladocera											Copepoda																															
	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	10	11																					
Bacteria	+																																															
Fungi																																																
<i>Catenaria anguillulae</i> Sorokin, 1876	+	+				+	+	+	+		+						+			+		+																										
<i>Lagenidium giganteum</i> Couch, 1935						+		+																		+																						
<i>Saprolegnia</i> sp.																										+																						
<i>Olpidium gregarium</i> Schroter, 1886	+				+																																											
Euglenozoa (= Euglenophyta)																																																
<i>Dinema unduliflagellatum</i> Monchenko, 1969																							+																							+		
Euglenophyta (= Euglenozoa)																																																
<i>Colacium vesiculosum</i> Ehrenberg, 1834		+		+																								+	+																	+		
Bacillariophyta																																																
<i>Epithemia adnata</i> Brébisson, 1838																							+																									
Ciliophora																																																
<i>Epistylis digitalis</i> Ehrenberg, 1838																							+																								+	
<i>E. lacustris</i> Imhoff, 1884																							+																								+	
<i>E.</i> sp.																							+	+	+	+	+																					
<i>Opercularia</i> sp.																																																
<i>Vorticella lutea</i> Stiller, 1932																							+																									
<i>V. cyclopicola</i> Kahl, 1935																																																
<i>V.</i> sp.																																																
<i>Haplocaulus kahlII</i> (Stiller, 1931)																																																
<i>H. epizoicus</i> (Sramek-Husek, 1948)																																																
<i>Rhabdostyla cyclopicis</i> Kahl, 1935																																																
<i>Zoothamnium</i> sp.		+																																														
<i>Cothurnia</i> sp.																																													+			
<i>Acineta nitocrae</i> Dovgal, 1984																																													+			
<i>Tokophrya actinostyla</i> Collin, 1912																																													+			
Uncertain systematic position																																																
<i>Coelosporidium chydoricola</i> Mesnil et Marchoux, 1897																																													+			

Note: **Rotifera**: 1 — *Brachionus calyciflorus* Pallas, 1766; 2 — *Filinia longiseta* (Ehrenberg, 1834); 3 — *Polyarthra vulgaris* Carlin, 1934; 4 — *Keratella quadrata* (Müller, 1786); 5 — *Euchlanis dilatata* Ehrenberg, 1832; **Cladocera**: 1 — *Sida crystallina* (O. F. Müller, 1776); 2 — *Diaphanosoma brachyurum* (Liévin, 1848); 3 — *Daphnia cucullata* Sars, 1862, 4 — *Moina micrura* Hellich, 1877, 5 — *Streblocerus serricaudatus* (Fischer, 1849); 6 — *Scapholeberis mucronata* (O. F. Müller, 1785); 7 — *Chydorus sphaericus* (O. F. Müller, 1785); 8 — *Ceriodaphnia quadrangula* (O. F. Müller, 1785); 9 — *C. laticaudata* P.E. Müller, 1867; 10 — *Simocephalus vetulus* (O. F. Müller, 1776); 11 — *Bosmina longirostris* (O. F. Müller, 1785); **Copepoda**: 1 — *Eucyclops serrulatus* (Fischer, 1853); 2 — *E. macrurus* (Sars, 1863); 3 — *Cyclops vicinus* (Uljanin, 1875); 4 — *Acanthocyclops americanus* (Marsh, 1893); 5 — *A. viridis* (Jurine, 1820); 6 — *Microcyclops bicolor* (Sars, 1863); 7 — *Mesocyclops leuckarti* (Claus, 1857); 8 — *Thermocyclops oithonoides* (Sars, 1863); 9 — *Th. crassus* (Fischer, 1853); 10 — *Cyclopoida* juv.; 11 — Harpacticoida.

1838 (one species); epibiotic ciliates (*Peritrichia* Stein, 1859) of the genera *Rhabdostyla* Kent, 1881 (one species), *Epistylis* Ehrenberg, 1830 (three species), *Opercularia* Stein, 1854 (one species), *Zoothamnium* Ehrenberg, 1838 (one species), *Haplocaulus* Precht, 1935 (two species), *Vorticella* Linnaeus, 1767 (three species), *Cothurnia* Ehrenberg, 1834 (one species); sucking ciliates (Cl. Suctorea Claparede et Lachmann, 1859) of the genus *Acineta* Ehrenberg, 1834 (one species) and *Tokophrya* Butschli, 1889 (one species). Also in the intestine and body cavity of *Bosmina longirostris* (O. F. Müller, 1785), parasitic flagellates of the genus *Coelosporidium* (*C. chydoricola* Mesnil et Marchoux, 1897) were found. The latter remains a systematically unspecified group of protists (Lange, 1993; Adl et al. 2012).

Hence, of the 96 recorded zooplankton species, only 25 species (25 %) were infected with different species of symbionts, as well as the naupliar and juvenile stages of Copepoda and Harpacticoida G. O. Sars, 1903 (table 1).

Fungi. The microbiota of hydrobionts, formed as a result of the contact with the environment, includes fungi of different systematic groups. A common type of interaction between lower fungi and invertebrates is parasitism (Sychev et al., 2008). Parasitic fungi are pathogens with which zooplankters contact in water. In the organism of planktonic crustaceans, fungi produce enzymes and toxins capable of destroying various tissues and organs of the host. Susceptibility of the latter depends on a number of factors. First, these are the properties of the pathogen itself, which determine its aggressiveness. There is also the minimal infective dose, i.e. the amount of pathogen necessary for successful infection of the crustaceans.

Four parasitic fungi species of the genera *Catenaria*, *Saprolegnia*, *Lagenidium* and *Olpidium* were found in the studied water bodies. Only six species of observed zooplankton, as well as juvenile and naupliar stages of copepods, were infected by those fungi. The hosts included Cladocera (*S. crystallina*, *D. brachyurum*, *D. cucullata*, *M. micrura*), Rotifera (*B. calyciflorus*) and Copepoda (*A. viridis*, *T. oithonoides*).

*Catenaria anguillulae* Sorokin, 1876 is a widespread fungal parasite of nematodes, rotifers and other microscopic animals (Sychev et al., 2008). V. I. Monchenko (Monchenko, 2003) first discovered and described this cavity fungus parasitizing crustaceans, particularly copepods. The parasitic fungus has a tubular thallus with rhizoids and zoosporangia immersed in the substrate. Zoosporangia form necks for the exit of zoospores (fig. 1, A).

During our studies *C. anguillulae* was recorded in all types of water bodies, and mostly affected the juvenile and naupliar stages of copepods. About 250 to 300 zoosporangia were found in the body cavity of each infected copepod. Hyphae with sporangia were observed even in furcal branches and antennal segments. In infected copepods, chitin became transparent and soft. Sporadically this fungus was found in the body cavity of the crustaceans *D. brachyurum*, *M. micrura*, *S. crystallina*, *A. viridis*, and *T. oithonoides*. The maximum abundance of *C. anguillulae* was recorded in the lake-type water bodies in the warm period of the year. In the late spring in Verbne Lake, the infection rates of the copepods of all life stages were 70 %. In summer this index reached 95 % in the reservoirs of the Troieschyna meliorative system. Taking into account the literature data and the results of our studies, we can confirm that this cavity fungus parasitizes copepods, and assume that *C. anguillulae* does not have narrow host specificity.

The fungi of the genera *Lagenidium* and *Saprolegnia* were less common than *C. anguillulae* in zooplankters. *Lagenidium giganteum* Couch, 1935 is the usual parasite of mosquito larvae and crustaceans (Sychev et al., 2008). We first found this parasite in the body cavity of Cladocera *S. crystallina* and *D. cucullata* (fig. 1, B), and V. I. Monchenko (Monchenko, 2003) reported it in Copepoda. *Saprolegnia* sp. was found in the body cavity of juvenile Copepoda. A well-developed mycelium filled the entire body cavity of the crustacean, and the hyphae grew freely to the sides of the substrate (fig. 1, C). Previously *Saprolegnia* fungi were found in the body cavity of Cladocera *C. sphaericus* (Wolska & Mazurkiewicz-Zapalowicz, 2013).

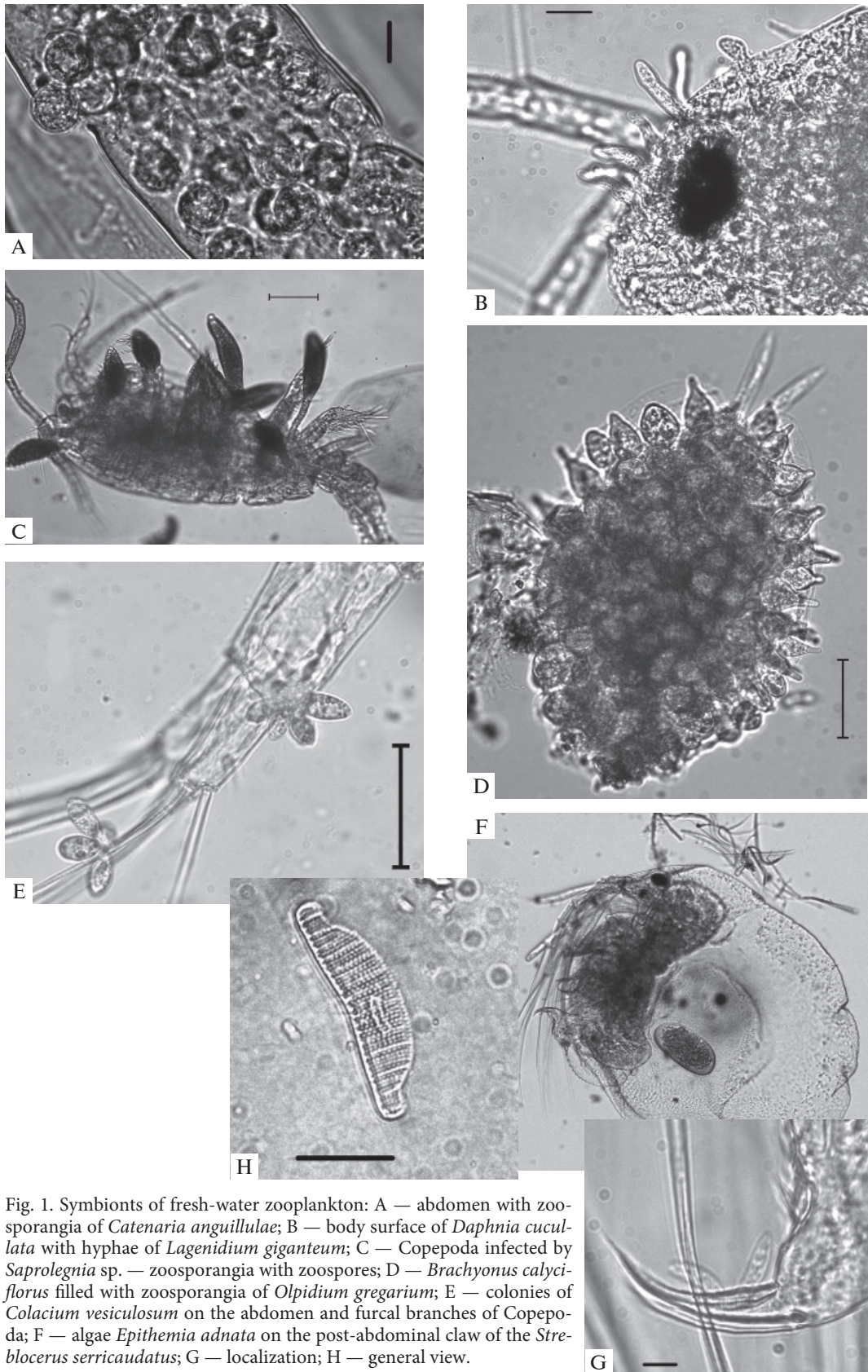


Fig. 1. Symbionts of fresh-water zooplankton: A — abdomen with zoosporangia of *Catenaria anguillulae*; B — body surface of *Daphnia cucullata* with hyphae of *Lagenidium giganteum*; C — Copepoda infected by *Saprolegnia* sp. — zoosporangia with zoospores; D — *Brachyonus calyciflorus* filled with zoosporangia of *Olpidium gregarium*; E — colonies of *Colacium vesiculosum* on the abdomen and furcal branches of Copepoda; F — algae *Epithemia adnata* on the post-abdominal claw of the *Strebloceris serricaudatus*; G — localization; H — general view.

*Olpidium gregarium* Schroter, 1886 belongs to holocarpic fungi which parasitize mainly the freshwater algae, mosses, flowering plants and microscopic animals such as rotifers (Mierinho et al., 2013). This endoparasitic fungus has unicellular vegetative body, which during reproduction develops into zoosporangium with uniflagellate zoospores inside. We found this species in the summer in the coastal zone of Verbne Lake. Moreover, only one species of rotifers (*B. calyciflorus*) was infected by *O. gregarium*, the prevalence was 1.3 % (fig. 1, D). In this case, a parasitic fungus reveals certain selectivity when choosing a host. In known papers on parasitic fungi in water bodies of Poland and the Volga delta, this fungus was noted as infecting only loricate rotifers with specific shape of lorica (Mierinho et al., 2013; Gorbunov, 2008).

During infection, *O. gregarium* can absorb the hostal organism (the content of the rotifers) in 24 hours, causing its death. As a result of the pathogenic effect, only lorica remains, filled with zoosporangia with special excretory tubules plugged with mucus before the time of maturation and release of zoospores (Barron, 1980).

All species of fungi that we found are highly pathogenic for zooplankters. They can infect eggs, embryos and adults. High plasticity of parasitic fungi to environmental conditions allows them to colonize all types of aquatic ecosystems. However, our studies have shown that they had reached the maximum diversity and abundance in lake-type water bodies, with the largest values of zooplankton quantitative indicators (Rybka, 2018).

Algae. The outer cover of plankton organisms are a stable and accessible substrate for epibiotic algae. Representatives of algal flora prefer to settle on the exoskeleton of actively moving crustaceans, using them as the most effective environment for survival, thus forming a kind of community of the host and its epibiont (Carman & Dobbs, 1997).

The relationship between crustaceans and algae covers a wide spectrum from parasitism to mutualism (Dubovskaya et al., 2005). The high intensity of epibiotic colonization increases the specific surface area of the crustacean body, thus hampering its movement in the water column. Reduced mobility of epibiont hosts can lead to the elimination of zooplankters due to predation, as well as excessive energy waste and a decrease in the fertility of crustaceans (Allen et al., 1993; Willey et al., 1993; Barea-Arco et al., 2001).

The found epibiont algae belonged to two species, euglenoid algae of the genus *Colacium* (*C. vesiculosum* Ehrenberg, 1834), and diatom algae of the genus *Epithemia* (*E. adnata* (Kützing, 1833) Brébisson, 1838). Among the total diversity of zooplankton, only nine species, as well as juvenile stages of copepods, served as the hosts of epibiont algae. They include Rotifera (*F. longiseta*), Cladocera (*S. serricaudatus*) and Copepoda (*A. americanus*, *A. viridis*, *E. macrurus*, *E. serrulatus*, *T. oithonoides*, *T. crassus*, *M. bicolor*).

Intensity of colonization by epibionts varied, the largest abundance was noted for the *C. vesiculosum* (more than 350 specimens per host). The latter species was recorded in the majority of studied water bodies (fig. 1, E). The highest rates of EC were found in the Pripyat River and Redkino Lake in the summer (79 and 75 %, respectively).

These algae mainly chose the body surface of Copepoda as the substrate for attachment, probably due to the complex segmentation of their body, as well as the fact that mature copepods do not shed. The microalgae attach to the body of aquatic animals using mucous feet or pads. The main place of algae attachment is the cephalothorax and the thoracic legs of the crustaceans, less often they attach to the antennules and the furcal branches.

*C. vesiculosum* reached the greatest abundance on the plankton crustacean *A. viridis*, probably due to the large size of its body (1470–2700  $\mu$ ) compared with other copepods (650–1600  $\mu$ ). The maximum fouling of copepods by algae occurred in the summer period.

In the tributary of the Pripyat (Tsir River), the diatom alga *E. adnata* was found on the bristles of the post-abdomen claw of Cladocera *S. serricaudatus* (fig. 1, F, G, H). The single cells of this microalgae did not create a significant abundance and did not dominate on planktonic crustaceans (EC 0.5 %, IC 2 specimens per host). It should be noted that *E. adnata* is an epiphyte of aquatic plants (Zabelina & Kiselev, 1951), and it is first found on the body of Cladocera.

The fouling of Cladocera by epibiotic algae was less intensive. There are several possible causes: first, the peculiarities of their body structure, which is less segmented, compared with the body of copepods; second, frequent molts of Cladocera, when they shed epibionts and are not immediately re-infected (Dubovskaya et al., 2005). Algae were located mostly on the crustacean abdominal claws, thoracic limbs and antennae.

It is clear that the abundance, diversity and localization of the epibiont algae are affected by the potential availability of the substrate, the quality and quantity of food, as well as the hydrological regime of the water body (Dubovskaya et al., 2005). Because of the specific attachment and adaptation to the existence at the boundary of solid (host body) and liquid (water) phases, microalgae primarily settle on the moving parts of the crustacean body such as abdomen, antennae and thoracic legs.

Ciliates (Ciliophora). Ciliates play an important ecosystem role as the first-order consumers, due to their ability to consume particles suspended in water (seston), as well as being predators actively feeding on bacteria, flagellates and algae. Attached species of ciliates are a common component of fouling, which makes them convenient objects for biological indication. Various species of ciliates are included in the lists of indicator organisms by many authors (Foissner, 1988; Banina, 1984; Konstantinenko, 2007; Dementeva & Lihachev, 2010). All species of ciliates found during the study are epibiont commensals of freshwater plankton crustaceans and rotifers.

On zooplankters, ciliates of two systematic groups were found: sucking ciliates of the subclass Suctorina (class Phyllopharyngea) and ciliates of the subclass Peritrichia (class Oligohymenophorea), which colonize the surface of plankton crustaceans in different parts of the body and swimming limbs. The carriers of epibiotic ciliates included Rotifera (*P. vulgaris*), Cladocera (*D. cucullata*, *C. sphaericus*, *C. quadrangula*, *C. laticaudata*, *S. mucronata*, *S. vetulus*), Copepoda of the family Cyclopidae (*E. serrulatus*, *Th. oithonoides*, *A. americanus*, *A. viridis*, *M. leuckarti*, *C. vicinus*) and the family Harpacticoidae.

Peritrichia is a small group of sessile ciliate species that are widespread in freshwater bodies. The sessile Peritrichia (order Sessilida) lead an attached life, and therefore their structure is adapted for attachment and resettlement. Ciliates of this group colonize various substrates of inorganic and organic origin. As an organic substrate (carrier) in freshwaters, these ciliates prefer the body surface of the freshwater crustaceans belonging to the family Cyclopidae (Banina, 1984; Alikin, 1992; Monchenko, 2003), which are a significant part of zooplankton and zoobenthos of freshwater bodies.

In the studied water bodies, 12 Peritrichia species belonging to the genera *Rhabdostyla*, *Epistylis*, *Opercularia*, *Zoothamnium*, *Haplocaulus*, *Vorticella* and *Cothurnia* were found. Among peritrichs, both by the number of species and the number of specimens, ciliates of the genus *Epistylis* (three species) prevailed, the genus *Vorticella* was also represented by three species, the genus *Haplocaulus* was represented by two species, the rest of the genera were represented each by one species. Peritrichia with different contractility of the stalk had different intensity of colonization: from one specimen per host (*Vorticella lutea* Stiller, 1932) to 90 and 150 specimens per host (*Epistylis digitalis* Ehrenberg, 1838 and *Epistylis* sp.).

Ciliates of the genus *Vorticella* are single-cell species attached to the crustaceans of the family Cyclopidae, with long contractile stalk, which, when contracted, twist into a spiral and press the body of the ciliate to the attachment surface (Kankaala & Eloranta, 1987). The ciliates were localized predominantly on the genital segment and the copepod cephalothorax; their prevalence of colonization of crustaceans ranged from 0.5 to 33 %, the intensity ranged from one to three specimens per host (fig. 2, N).

Ciliates of the genus *Epistylis* were the most common Peritrichia found in almost all studied water bodies. Colonies of ciliates of this genus are tree-like, with stalks that are not contractile, densely branched and terminate in zooids. The most common species were two representatives of the genus, *E. digitalis* and *E. lacustris* Imhoff, 1884 (fig. 2, L), the IC of which ranged from 6 to 120 specimen per host (the EC reached 30 %). Among the carriers,

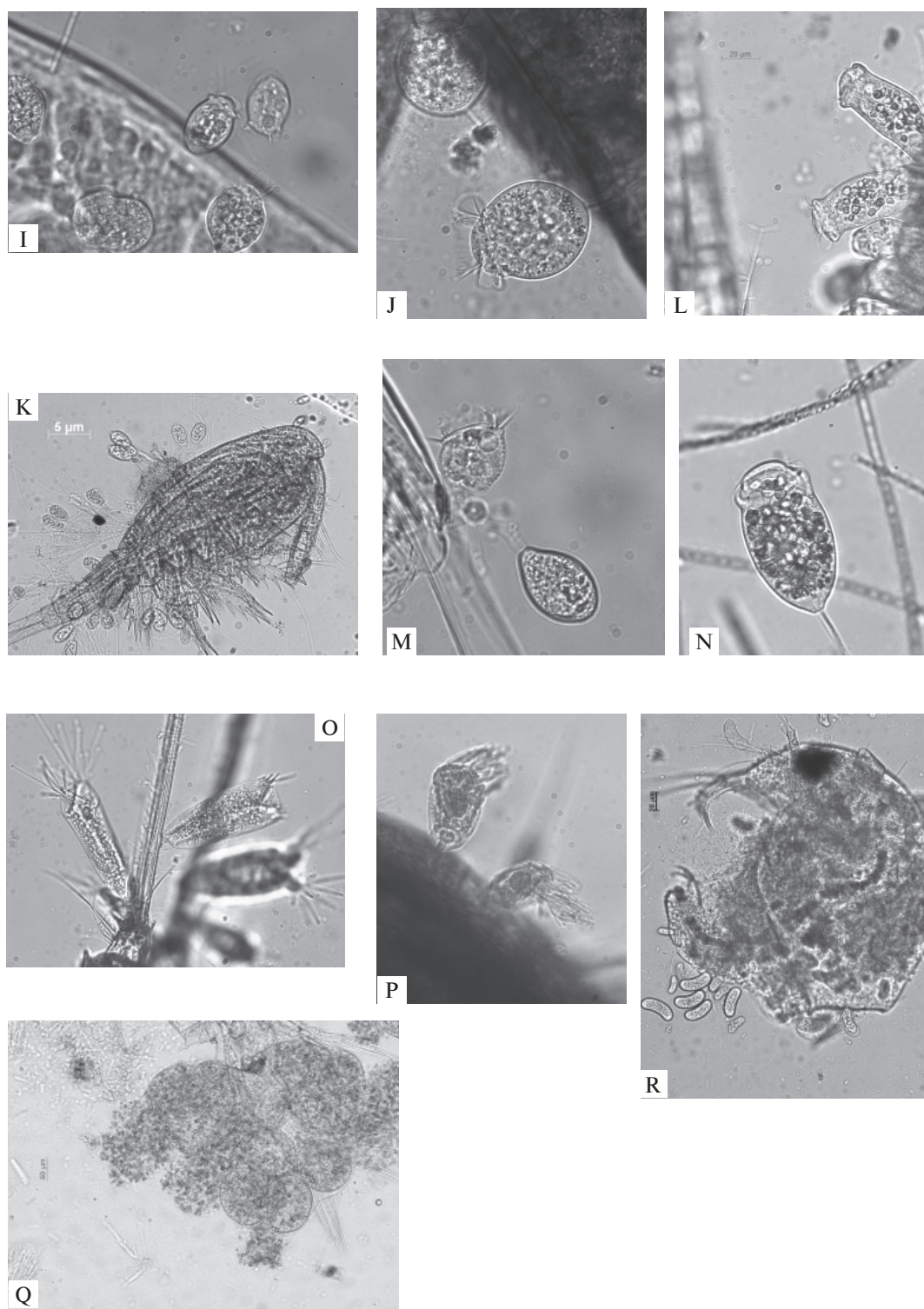


Fig. 2. Symbionts of fresh-water zooplankton: I — *Haplocaulus kahlii*; J — *Haplocaulus epizoicus*; K — *Rhabdostyla cyclopis*; L — *Epistylis digitalis*; M — *Zoothamnium* sp.; N — *Vorticella lutea*; O — *Acineta nitocrae*; P — *Tokophrya actinostyla*; Q — eggs of *Thermocyclops oithonoides* infected by parasitic flagellates *Dinema undulaflagellatum*; R — *Bosmina longirostris* filled by *Coelosporidium chydoricola*.



there were Copepoda *E. serrulatus*, *M. leuckarti*, *A. viridis*, *A. americanus*, *T. oitonoides*, with complex body segmentation which provides various places for the attachment of epibionts (antennulae, cephalothorax, genital segment, etc.).

The stalks of ciliates of this genus are unable to contract, but this is compensated by the diversity and variability in their structure. The stalks are flexible, easily bent and straightened. In some cases, the ciliates of the same species may change the structure of stalks depending on the placement on the host body (the stalk length changes, transverse and annular striation appears).

Ciliates of the genus *Haplocaulus*, *H. kahlii* (Stiller, 1931) (EI 0.9 %, II 13 specimen per host) and *H. epizoicus* (Sramek-Husek, 1948) (EI 0.3 and 20 %, II 5 and 8 specimen per host) were found on the body surface of Cladocera (*D. cucullata*, *S. mucronata* and *C. laticaudata*) in the Jordan lake, Troyeschinsky reservoirs and the mouth of the river Tsir (fig. 2, I, J). In the Redchino lake and Obolonsky Bay, *Rhabdostyla cyclopis* Kahl, 1935 (EI 33 and 3 %; II 31 and 6 specimen per host) was found on the cephalothorax of the planktonic crustacean *E. serrulatus* (fig. 2, K).

Ciliates of the genus *Zoothamnium*, with bending stalk, were found in Obolonsky Bay on illoricate rotifer *P. vulgaris* (EI 3.3 %; II 3 specimen per host) (fig. 2, M). Ciliates of the genus *Cothurnia* were found on the antennae of freshwater harpacticoida (EI 5 %; II 4 specimen per host). The tectinlorica of *Cothurnia sp.* completely covers the zooid and attaches to the substrate with a small stalk.

Most cases of interaction between Peritrichia and their carriers have one-sided benefit, and interactions between separate species of ciliates are neutral. Antagonistic interactions are also sometimes noted between certain Peritrichia species, as well as between some ciliates and their carrier. Antagonism between different commensal ciliates occurs when they occupy the same microniche on the carrier body and the mass development of one species inhibits the development of another and vice versa (Boshko, 2009).

Single ciliate settlements on zooplankton do not cause noticeable harm to their owners. However, the mass development of some Peritrichia species can lead to a decrease in the mobility of the crustacean-carrier, and hence to a decrease in trophic activity, fertility and lifespan.

Suctorina is one of the most ecologically diverse groups of ciliates, rich in species that inhabit almost all types of water bodies, colonize a variety of substrates and hosts. The majority of these ciliates at the trophont stage are attached forms (Dovgal, 2002). The ecology of the group is almost not studied, and special studies on tentacle ciliates are quite rare (Dovgal, 2002, 2013).

Two species of Suctorina belonging to the genera *Acineta* and *Tokophrya* were found in the studied water bodies. Trophonts of these species are stalked zooids, characterized by the presence of one or several tentacles with distal spherical extensions.

In the environs of Kyiv (Obolonsky Bay), *Acineta nitocrae* Dovgal, 1984 was found on the furcal setae of benthic crustacean *Nitocra sp.* (EI 5%; II 4 specimen per host) (fig. 2, O). This species is a specific commensal of freshwater Harpacticoida. It has an elongated lorica and straight club-shaped retractable tentacles, and short and dense stalk with striation (Dovgal, 1984).

Notably, a rare predatory ciliate *Tokophrya actinostyla* Collin, 1912 was found in the Pripyat River. We first found it on the cephalothorax of a crustacean *A. viridis* (EC 0.6 %, IC 4 specimen per host) (Rybka & Dovgal, 2014). Previously, this species was recorded on only one host species, copepod *E. serrulatus*. This suctorina has a flattened elongated body, and two bundles of tentacles for catching prey. A distinctive feature of the ciliate is the connection between stalk and zooid: the stalk is immersed deep into the body in a special cavity, and is connected to the pellicle by a system of fibrils (fig. 2, P).

Parasitic flagellates (Euglenozoa). For the first time parasitic flagellates were discovered by F. Stein in crustaceans of the family Cyclopidae (Stein, 1848). A great contribution to the study of euglenoid flagellates was made by the Polish parasitologist V. Mikhailov, who, after many years of study, erected a separate genus *Parastasia* (Michajlov,

1972). Later, as a result of electron microscopic studies, the genus *Sophienseia* was isolated from the genus *Parastasia* (Lihachev, 1998). But to date, this group of euglenoid flagellates remains poorly studied. There is little data about their ecological characteristics and adaptability to the parasitic way of life. The range of hosts of these parasites, as well as the nature of interaction with them, have not been sufficiently studied (Montina, 2009).

During our research, mature individuals of flagellates of the genus *Dinema*, *D. undulaflagellatum* Monchenko, 1969 (fig. 2, Q), were found in the river part of the Desenka branch (near the Desna River). These parasites infected the eggs of the copepod *T. oithonoides*, EI was insignificant (0.2 %). Parasites completely destroy the contents of the egg and occupy its entire cavity faster than the development of nauplii passes in the neighboring uninfected eggs. V. I. Monchenko first identified this species of flagellates in egg-bearing females of *A. viridis*, *A. vernalis*, *C. strenuus* in the vicinity of Kyiv (Monchenko, 2003). Our research has expanded the host range of this parasite, because infection of *T. oithonoides* was observed for the first time.

During the study, several symbionts were found which required further identification. Thus, in the Troyeshchinsky reservoirs and the river part of the Desenka branch, in the body cavity of Cladocera *B. longirostris*, a large number of single-celled organisms similar to the *Coelosporidium chydoricola* were noted, EI ranged from 4.5 to 22.5 % (fig. 2, R). Ultrastructural studies are necessary for their accurate identification, and the genus *Coelosporidium* is classified as *incertaesedis* in eukaryotes, with uncertain affiliation within protists (Adl et al., 2012).

Bacteria (putatively) were found in the body cavity of the loricated rotifers *K. quadrata* and *E. dilatata* (EI 1.3 and 5 %) in Jordan Lake. Most of the bacterial species known in hydrobionts are not pathogenic or show their pathogenicity only when the host immunity is inhibited and at conditions favoring the development of microorganisms: the optimum temperature, excessive eutrophication of the environment, etc.

## Conclusions

During the parasitological studies of the main taxonomic groups of freshwater zooplankton (Rotifera, Copepoda, Cladocera), 22 species of symbionts were found that belong to several taxonomic groups (bacteria, flagellates, algae, fungi, ciliates etc.). Epibionts prevailed (16 species), endobionts were mainly represented by fungi (four species).

We established that some taxonomic and ecological groups of symbionts are confined to certain taxonomic groups of zooplankters, demonstrating different degrees of host specificity.

Thus, the parasitic fungus *Catenaria anguillulae* was found in all three groups of zooplankters. Epibiont alga *Colacium vesiculosum* was found in Rotifera and Copepoda, with the highest indices of colonization on copepods. The greatest diversity of peritrichia was recorded on Copepoda, representatives of the genera *Epistylis* and *Opercularia* were observed only on this group of crustaceans.

According to the comparative analysis of the species richness of zooplankton symbionts, the greatest number of symbiotic species was noted for the Copepoda crustaceans, with the predominance of epibiotic ciliates and algae. Parasitic flagellates and sucking ciliates were found only in copepods.

Cladocera have the peculiar epibiont peritrichia, representatives of the genus *Haplocaulus* that did not inhabit the copepods.

Rotifers have the least number of symbiotic species. Fungi, algae, and ciliates found in rotifers were also found in other zooplankton hosts.

The attractiveness of Copepoda for colonization by epibionts is probably due to the specifics of their biology: the lack of adult molting and the diversity of attachment sites, due to the developed segmentation.

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