Far Eastern Entomologist

Number 446: 13-23 ISSN 1026-051X (print edition) ISSN 2713-2196 (online edition) January 2022

https://doi.org/10.25221/fee.446.3
http://zoobank.org/References/AC799029-6D9F-4D8B-94A3-0618E92F9AD1

NEW DATA ON THE MAYFLIES (EPHEMEROPTERA) OF NORTH-WESTERN YAKUTIA

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Summary. New data on the fauna of mayflies in the Anabar River basin are given. A total of eight species of Ephemeroptera have been identified in the fauna of North-Western Yakutia for the first time. Though the mayfly fauna in this region consists mainly of East Palaearctic species, the only seven of them are characterized by arctic-alpine distribution. In general, mayfly species richness of the studied subarctic and southern rivers of Yakutia is similar.

Key words: mayflies, Ephemeroptera, fauna, Anabar River basin, Subarctic, Russia.

Л. В. Яныгина, Н. К. Потапова. Новые сведения о поденках (Ephemeroptera) Северо-Западной Якутии // Дальневосточный энтомолог. 2022. N 446. С. 13-23.

Резюме. Представлены новые данные по фауне поденок бассейна р. Анабар. Впервые для Северо-Западной Якутии указываются 8 видов Ephemeroptera. Хотя фауна поденок исследуемого региона слагается преимущественно из восточнопалеарктических видов, но только семь из них характеризуются как аркто-альпийские. В целом видовое разнообразие поденок в субартических и южных реках Якутии сходно.

INTRODUCTION

The Arctic water bodies are among the least explored in the world because of inaccessibility of its vast and poorly populated territory, remoteness from major scientific centers and long-lasting freeze-up periods. Moreover, freshwater communities exist in extreme climate of the Arctic that makes studying the features of their structural, phylogenetic and ecological characteristics of great interest. A short cold summer limits the imago flight, frequent rapid floods create unstable habitat conditions for larvae, a long-lasting and powerful ice cover forms bad oxygen regime. All these factors are particularly unfavorable for aquatic amphibiotic insects. In addition, the Arctic watercourses are usually characterized by low nutrient levels and scanty primary productivity responsible for adverse trophic conditions and limited development of aquatic insects (Lento *et al.*, 2013). Among common adaptive features of macroinvertebrates are the use of widely available trophic resources, the extension of the

food range, and the prolongation of the development period of aquatic larvae (Danks, 2007). As compared to temperate latitudes, the basins of various Arctic rivers are distinguished by much worse taxonomic richness with predominance of the community taxa tolerant to extreme conditions (Lento *et al.*, 2013).

Harsh climate conditions of the Arctic make its aquatic ecosystems highly vulnerable (Brittain *et al*., 2020). The most significant threat to freshwater ecosystems here is climate warming, which induces permafrost melting accompanied by an increase in water turbidity, changes in nutrient amounts and chemical composition of waters (Chin *et al.*, 2016; Lento *et al.*, 2013; Brittain *et al.*, 2020). Being more determined by physical factors than biotic interactions, freshwater communities from the Arctic rivers are more sensitive indicators of environmental changes in contrast to riverine communities from temperate latitudes (Blaen, 2013).

The growing pace of the Arctic development, increased anthropogenic impacts on its rivers and their catchments pose additional threats to aquatic communities. North-Western Yakutia refers to the regions with high proven reserves of placer diamonds, the extraction of which brings to increased turbidity, mineralization and concentration of some heavy metals in river waters (Ksenofontova & Legostaeva, 2015). An important stage in the development of effective measures for managing water resources in the region and preserving biodiversity is bioindication of the ecological state of streams. It is based on studying the composition and structure of macroinvertebrate communities – a promising and most frequently used indicator of environmental changes. The purpose of this work is to analyze the taxonomic composition of mayflies from small rivers of the Anabar River basin (North-Western Yakutia) to assess the features of benthic community formation in Arctic rivers and forecast their transformation under changing environmental conditions.

STUDY AREA

The study area is located in the middle course of the Anabar River (Fig. 1), the transition area of the Central Siberian Plateau to the North-Eastern Lowland to be exact. It is a low plateau composed of carbonate formations of the Anabar set of the Middle Cambrian (Yelovskaya *et al*., 1979). The climate of the region is severe, sharply continental with strong fluctuations in average monthly and average daily temperatures, high atmospheric pressure and low precipitation. The proximity to the Arctic Ocean and low availability of warm and humid air masses from east and south is the major driven factor in climate formation.

The Anabar River basin is situated beyond the Arctic Circle; by water regime and alimentation (mainly due to spring snowmelt and summer-autumn rainfalls combined with intensive melting of permafrost rocks) it belongs to the East Siberian type of rivers. The onset of a free-ice period is usually June 1, freeze-up one – October 4, open water duration – 112 days (Chistyakov *et al.*, 1971).

The Anabar River waters are characterized by high transparency (to the bottom). In the upper reaches, after its confluence with the Ebelyakh River, this indicator (up to 0.4 m) sharply decreases. The surface waters in the middle course of the Anabar River and its large tributaries have limited biogenic and organic substances; they refer to the bicarbonate class of a calcium or magnesium group being soft (by general hardness) and low mineralized (by salts amount) (Zhirkov *et al.*, 2014; Ksenofontova & Legostaeva, 2015). According to a set of controlled indicators, the waters in the upper reaches of this river are "clean", whereas in the lower parts are "moderately polluted" (Gabyshev & Gabysheva, 2010).

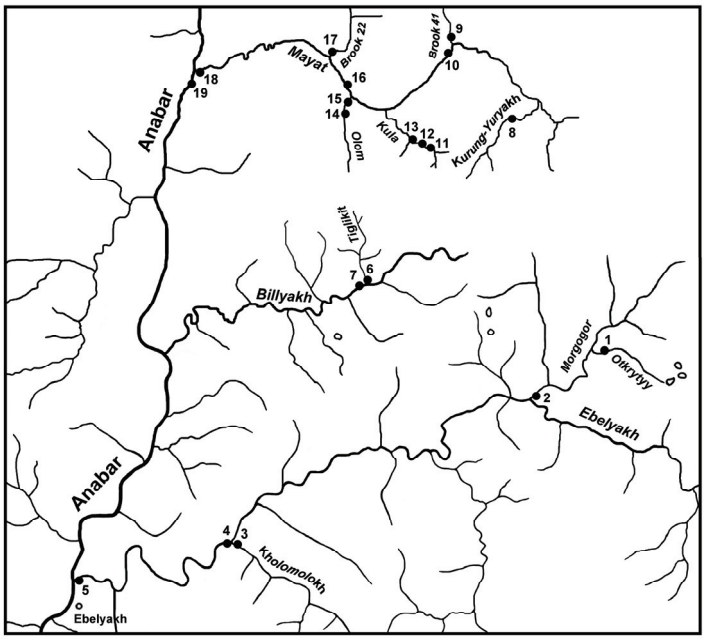

Fig. 1. Location of sampling sites in the Anabar River basin.

Table 1. Geographical coordinates of the sampling sites in the Anabar River basin.

N	River	Locality	Latitude/Longitude
1	Otkrytyy	8 km upstream of the mouth	71°03'57" N, 114°44'45" E
2	Morgogor	near the mouth	71°02'05" N, 114°33'55" E
3	Kholomolokh	2 km upstream of the mouth	70°56'17" N, 113°53'06" E
4	Ebelyakh	near the Kholomolokh River mouth	70°56′18″ N, 113°52′57″ E
5	Ebelyakh	near the mouth	70°54'53" N, 113°31'57" E
6	Tiglikit	near the mouth	71°06'36" N, 114°09'60" E
7	Billyakh	near the Tiglikit River mouth	71°11'52" N, 114°33'36" E
8	Kurung-Yuryakh	7 km upstream of the mouth	71°16'07" N, 114°53'59" E
9	Brook 41	near the mouth	71°21'11" N, 114°40'52" E
10	Mayat	the middle course of the river	71°19'15" N, 114°36'10" E
11	Kula	the pond near the Kula River	71°15'32" N, 114°38'49" E
12	Kula	left branch of the river	71°15'55" N, 114°38'57" E
13	Kula	right branch of the river	71°15'44" N, 114°32'21" E
14	Olom	the pond near the Olom River	71°15'54" N, 114°24'34" E
15	Olom	2 km upstream of the mouth	71°16'25" N, 114°27'30" E
16	Mayat	10 km upstream of the mouth	71°18'36" N, 114°19'26" E
17	Brook 22	near the mouth	71°20'04" N, 113°50'56" E
18	Mayat	near the mouth	71°19'57" N, 113°50'56" E
19	Anabar	near the Mayat River mouth	71°20'03" N, 113°50'25" E

MATERIAL AND METHODS

The investigations were carried out on August 16–26, 2015 at 19 sections of the middle course of the Anabar River and its right tributaries, i.e. the Ebelyakh, Billyakh and Mayat (Table 1). The samples were repeated on July 10–12, 2016 at 3 sites (3, 5, 19). In different years, most of the selected sites (except for the Anabar and the source of the Ebelyakh River) were subject to man-made impacts caused by mining activities.

Almost all the surveyed rivers and streams have a rocky bed formed of stones of different size, pebbles and boulders. In large Anabar and Ebelyakh rivers, narrow loamy-silty substrates are met along the coastal edge. At each site, 20–25 stones were collected, washed in a hand net and measured. In sedimentation tanks and shallow waters of larger rivers with loamy soils, a 20 cm scraper and a hand net were used to collect macroinvertebrates. All macroinvertebrates were picked up fr silty om wash-offs with tweezers and fixed with 75% ethanol. In total, more than 450 samples of macroinvertebrates were sampled. Specimen was identified using available keys (Kluge, 1997; Zaika, 2000) and current scientific literature. The system of families, genera and subgenera is given according to Kluge (2021).

LIST OF THE MAYFLIES SPECIES IN THE ANABAR RIVER BASIN

Family Ameletidae

***Ameletus procerus* Bajkova, 1976**

REMARKS. In 1985–1987, *Ameletus procerus* was recorded from Anabar River (Kirillov *et al*., 2007). Currently, *Ameletus procerus* is a synonym of *Ameletus montanus* Imanishi, 1930 (Kluge, 2007). At the same time, *Ameletus montanus* is divided into three subspecies, one of them (*Ameletus montanus rossicus*) is widely distributed in Altay, East Siberia and Russian Far East (Kluge, 2007).

***Ameletus* sp.**

MATERIAL EXAMINED. Ebelyakh River: station N 4, 10.VII 2016, 1 larva.

REMARKS. The larvae have not been identified to the species level.

Family Baetidae

***Acentrella sibirica* (Kazlauskas, 1963)**

REMARKS. This species was recorded from Anabar, Billyakh and Ebelyakh rivers (Kirillov *et al*., 2007).

Acentrella* gr. *lapponica

MATERIAL EXAMINED. Mayat River: station N 16, 17.VIII 2015, 1 larva; Kholomolokh River: station N 3, 24.VIII 2015, 3 larvae.

REMARKS. The larvae have not been identified to the species level.

***Baetis* (*Baetis*) *fuscatus* (Linnaeus, 1761)**

MATERIAL EXAMINED. Billyakh River: station N 7, 16.VIII 2015, 1 larva; Mayat River: station N 16, 17.VIII 2015, 2 larvae, station N 10, 20.VIII 2015, 2 larvae; Kula River: station N 12, 18.VIII 2015, 1 larva.

REMARKS. This species was previously recorded from Anabar, Billyakh and Ebelyakh rivers by A.F. Kirillov *et al*. (2007).

***Baetis* (*Baetis*) *feles* Kluge, 1980**

MATERIAL EXAMINED. Billyakh River: station N 7, 16.VIII 2015, 2 larvae; Kula River: station N 13, 16.VIII 2015, 8 larvae, station N 12, 16.VIII 2015, 11 larvae, 18.VIII 2015, 116 larvae, station N 11, 25.VIII 2015, 1 larva, 26.VIII 2015, 4 larvae; Tiglikit River: station N 6, 18.VIII 2015, 25 larvae.

REMARKS. In Anabar River basin, it is one of the most widespread species.

***Baetis* (*Tenuibaetis*) *ursinus* Kazlauskas, 1963**

MATERIAL EXAMINED. Anabar River: station N 19, 10.VII 2016, 4 larvae.

REMARKS. In the Anabar River basin, it is a rare species.

***Baetis* sp.**

MATERIAL EXAMINED. Mayat River: station N 16, 17.VIII 2015, 1 larva; Kula River: station N 13, 16.VIII 2015, 1 larva, station N 11, 26.VIII 2015, 2 larvae; Tiglikit River: station N 6, 18.VIII 2015, 3 larvae.

REMARKS. The larvae have not been identified to the species level.

***Cloeon* sp.**

MATERIAL EXAMINED. Kula River: station N 11, 16.VIII 2015, 2 larvae, 25.VIII 2015, 1 larva.

REMARKS. The larvae have not been identified to the species level.

***Similicloeon spiniventre* Kluge et Novikova, 1992**

MATERIAL EXAMINED. Kurung-Yuryakh River: station N 8, 18.VIII 2015, 1 larva; Tiglikit River: station N 6, 18.VIII 2015, 1 larva; Kula River: station N 11, 25.VIII 2015, 3 larvae; Brook 41: station N 9, 26.VIII 2015, 5 larvae.

REMARKS. In Anabar River basin, it is one of the most widespread species.

***Procloeon pennulatum* (Eaton, 1870)**

MATERIAL EXAMINED. Billyakh River: station N 7, 16.VIII 2015, 4 larvae; Kula River: station N 12, 16.VIII 2015, 1 larva, station N 23, 26.VIII 2015, 1 larva, station N 11, 25.VIII 2015, 4 larvae.

REMARKS. This species was previously recorded from Anabar, Billyakh and Ebelyakh rivers by A.F. Kirillov *et al*. (2007).

Family Heptageniidae

***Cinygmula cavum* (Ulmer, 1927)**

REMARKS. In 1985–1987, this species was recorded from Ebelyakh River (Kirillov *et al*., 2007).

***Cinygmula* sp.**

MATERIAL EXAMINED. Mayat River: station N 16, 17.VIII 2015, 1 larva; Olom River: station N 15, 26.VIII 2015, 1 larva.

REMARKS. In the Anabar River basin, it is a rare species.

***Ecdyonurus* (*Atopopus*) *abracadabrus* Kluge, 1983**

REMARKS. *Ecdyonurus abracadabrus* was recorded from Anabar River (Kirillov *et al*., 2007).

***Ecdyonurus* (*Atopopus*) *aurarius* Kluge, 1983**

REMARKS. In 1985–1987, this species was recorded from Billyakh and Ebelyakh rivers (Kirillov *et al*., 2007).

***Ecdyonurus* (*Afghanurus*) *aspersus* (Kluge, 1980)**

MATERIAL EXAMINED. Ebelyakh River: station N 4, 24.VIII 2015, 1 larva; Kula River: station N 13, 16.VIII 2015, 1 larva; Mayat River: station N 16, 17.VIII 2015, 21 larvae, station N 10, 20.VIII 2015, 14 larvae, station N 18, 21.VIII 2015, 2 larvae; Kholomolokh River: station N 3, 24.VIII 2015, 8 larvae; Morgogor River: station N 2, 24.VIII 2015, 1 larva; Olom River: station N 15, 26.VIII 2015, 8 larvae; Brook 22: station N 17, 21.VIII 2015, 3 larvae.

REMARKS. In the Anabar River basin, it is one of the most widespread species.

***Ecdyonurus* (*Afghanurus*) *joernensis* (Bengtsson, 1909)**

MATERIAL EXAMINED. Ebelyakh River: station N 5, 19.VIII 2015, 4 larvae; Mayat River: station N 16, 17.VIII 2015, 2 larvae.

REMARKS. This species was previously recorded from Anabar, Billyakh and Ebelyakh rivers by A.F. Kirillov *et al*. (2007).

***Ecdyonurus* sp.**

MATERIAL EXAMINED. Ebelyakh River: station N 5, 24.VIII 2015, 4 larvae.

REMARKS. The larvae have not been identified to the species level.

***Epeorus* (*Belovius*) sp.**

MATERIAL EXAMINED. Ebelyakh River: station N 4, 10.VII 2016, 1 larva; Kholomolokh River: station N 3, 24.VIII 2015, 1 larva.

REMARKS. The larvae have not been identified to the species level.

***Heptagenia sulphurea* (Müller, 1776)**

MATERIAL EXAMINED. Anabar River: station N 19, 21.VIII 2015, 1 larva.

REMARKS. This species was previously recorded from Anabar and Billyakh rivers by A.F. Kirillov *et al*. (2007).

***Heptagenia dalecarlica* Bengtsson, 1912**

MATERIAL EXAMINED. Anabar River: station N 19, 21.VIII 2015, 1 larva, 10.VII 2016, 1 larva.

REMARKS. In the Anabar River basin, it is a rare species.

***Sibirigena sibirica* (Brodsky, 1930)**

MATERIAL EXAMINED. Kholomolokh River: station N 3, 24.VIII 2015, 1 larva.

REMARKS. This species was previously recorded as *Rhithrogena sibirica* Brodsky, 1930 from Anabar and Ebelyakh rivers by A.F. Kirillov *et al.* (2007).

Family Leptophlebiidae

***Leptophlebia* sp.**

MATERIAL EXAMINED. Ebelyakh River: station N 4, 10.VII 2016, 1 larva.

REMARKS. The larvae have not been identified to the species level.

Family Metretopodidae

***Metretopus borealis* (Eaton, 1871)**

REMARKS. In 1985–1987, this species was recorded from Billyakh River (Kirillov *et al*., 2007).

***Metretopus* sp.**

MATERIAL EXAMINED. Billyakh River: station N 7, 16.VIII 2015, 6 larvae; Kula River: station N 12, 16.VIII 2015, 14 larvae, 18.VIII 2015, 4 larvae; Olom River: station N 14, 26.VIII 2015, 1 larva; Otkrytyy Brook: station N 1, 17.VIII 2015, 2 larvae.

REMARKS. The larvae have not been identified to the species level.

Family Ephemerellidae

***Ephemerella aurivillii* (Bengtsson, 1909)**

MATERIAL EXAMINED. Anabar River: station N 19, 21.VIII 2015, 1 larva.

REMARKS. This species was previously recorded from Anabar and Ebelyakh rivers by A.F. Kirillov *et al*. (2007).

***Ephemerella mucronata* (Bengtsson, 1909)**

REMARKS. In 1985–1987, this species was recorded from Billyakh and Ebelyakh rivers (Kirillov *et al*., 2007).

***Torleya nuda* Tshernova, 1949**

MATERIAL EXAMINED. Mayat River: station N 16, 17.VIII 2015, 2 larvae, station N 10, 20.VIII 2015, 1 larva; Olom River: station N 15, 26.VIII 2015, 2 larvae.

REMARKS. The larvae belong to *Torleya nuda* f. *nuda*.

***Torleya ignita* (Poda, 1761)**

MATERIAL EXAMINED. Anabar River: station N 19, 21.VIII 2015, 2 larvae; Mayat River: station N 18, 21.VIII 2015, 3 larvae; Kholomolokh River: station N 3, 24.VIII 2015, 2 larvae.

REMARKS. This species was previously recorded from Anabar, Billyakh and Ebelyakh rivers by A.F. Kirillov *et al*. (2007).

Family Leptophlebiidae

***Paraleptophlebia cincta* (Retzius, 1783)**

REMARKS. In 1985–1987, this species was recorded from Anabar, Billyakh and Ebelyakh rivers (Kirillov *et al*., 2007).

Family Siphlonuridae

***Parameletus* sp.**

REMARKS. In 1985–1987, this species was recorded from Anabar River (Kirillov *et al*., 2007).

Family Caenidae

***Caenis macrura* Stephens, 1835**

REMARKS. In 1985–1987, this species was recorded from Anabar, Billyakh and Ebelyakh rivers (Kirillov *et al*., 2007).

DISCUSSION

In 2015, a total of 22 species and forms of mayflies were found in watercourses of the Anabar River basin. Maximum number of the species falls on the families Heptageniidae and Baetidae (8 species each); the family Ephemerellidae is represented by 3 species, the families Leptophlebiidae, Metretopodidae and Ameletidae – by 1 species each. Mayflies were discovered most frequently (in 84 % of samples) than other groups of macroinvertebrates. The highest occurrence was noted for *Baetis feles* (36%), *Ecdyonurus aspersus* (23%) and *Metretopus* sp. (16%). About half of species (45%) are rare for the basin (they were identified only in one sample). Our incomplete list of species just reflects the current state of the faunistic research in the region. Further studies will allow supplementing this list with new species substantially.

Pioneer studies of the macroinvertebrate fauna of the Anabar River basin were made in 1985–1987 before the start of mining activities in this region (Kirillov *et al*., 2007). In the largest surveyed rivers (Anabar, Ebelyakh, Billyakh) 17 species of mayflies were detected. Our studies allowed to identify among mayflies six more species and group of species, i.e. *B. feles*, *B. ursinus*, *Acentrella* gr. *lapponica*, *Similicloeon spiniventre*, *Cinygmula* sp., *Torleya nuda* for the first time here. Taxonomic identification of 8 species (*Epeorus* (*Belovius*) sp., *Ameletus* sp., *Baetis* sp., *Cloeon* sp., *Ecdyonurus* sp., *Leptophlebia* sp., *Metretopus* sp., *Parameletus* sp.) requires further research. Two newly found (for this region) taxa have a generic rank (*Epeorus* and *Cloeon*). Thus, the mayfly fauna of the basin currently includes 31 species and forms from the eight families and 19 genera. By and large, the new data on species richness of mayflies in rivers of the study basin correspond to the previously obtained ones that is evidence of insignificant transformations in the fauna of the region influenced by mining activities.

Half (50%) of mayfly species of the Anabar River basin with a known distribution area belonged to the Eastern Palearctic fauna. This group includes *Ameletus montanus* Imanishi, 1930, *B. feles*, *B. ursinus*, *B. sibiricus*, *Similicloeon spiniventre*, *Cinygmula cavum* (Ulmer, 1927), *Ecdyonurus abracadabrus*, *E. aurarius*, *E. aspersus*, *Eph. nuda*, *Sibirigena sibirica*.

Among Eastern Palearctic species, 2 ones (*B. feles, S. spiniventre*) are characterized by an arctic-alpine distribution. The group of transpalearcts involves 6 species, i.e *B. fuscatus, Heptagenia sulphurea, H. dalecarlica, E. joernensis, Torleya ignita*, and *Caenis macrura*. Among them, *H. dalecarlica* has an arctic-alpine distribution. Holarcts are represented by four species (*Procloeon pennulatum, Metretopus borealis*, *Ephemerella aurivillii, Eph. mucronata*), among them *M. borealis* are found mainly in the northern part of the range. Only *Paraleptophlebia cincta* is Western Palearctic species. Thus, most of the discovered species are widely spread both in temperate and high latitudes being, probably, adapted to the existence in a wide temperature range. Therefore, these species are assumed to be most resistant to temperature growth in the event of further climate changes. Apparently, the arctic-alpine elements of the fauna represented in the Anabar basin rivers by 5 species (*B. feles, S. spiniventre, H. dalecarlica, E. joernensis, M. borealis*) should be considered as most threatened taxa in case of temperature growth.

It is believed that harsh conditions of the northern reservoirs provide low fauna diversity since only a few species are able to survive there (Blaen *et al.*, 2013). In some regions, a temperature fall (from south to north) is accompanied by decreased species richness of macroinvertebrates (Friberg *et al.*, 2013; Blaen *et al.*, 2014; Brittain *et al.*, 2020). The latitudinal gradient of biodiversity is reported in the studies of macroinvertebrates from Europe, North and South America (Vinson & Hawkins, 2003; Scott *et al.*, 2011; Shah *et al.*, 2013; Culp *et al.*, 2019). This trend is marked for both aquatic and terrestrial ecosystems, however, not for all groups of hydrobionts and river basins. Studies of the northern territories all over the world indicate that the composition and structure of Arctic communities depend as on climatic and local conditions as on species-specific responses of the biota to environmental changes (Brittain *et al.*, 2020). Species richness of mayflies in the Aldan River basin (41 species) (Tiunova *et al.*, 2009) and the Anabar River basin (32 species and forms) is comparable. The former is located at a similar longitude, but 1500 km farther to the south (South Yakutia). Besides water temperature and latitude, a river alimentation type is an important factor affecting biodiversity of riverine communities (Blaen *et al.*, 2013). Obviously, the Arctic rivers of a glacial-fed type support lower diversity of macroinvertebrate communities as compared to those with largely precipitation and groundwater alimentation (Castella *et al.*, 2001; Blaen *et al.*, 2013). Predominantly snow-fed alimentation of the studied Anabar Rivers basin, probably, provides a relatively high diversity of the fauna.

CONCLUSION

The mayfly fauna of watercourses of the Anabar River basin is characterized by relatively high species richness. Most of the species have an Eastern Palearctic distribution and occur in both high and moderate latitudes. Intensive mining in the basins of the considered rivers has not brought to degradation of the fauna.

ACKNOWLEDGEMENTS

This study was carried out as a part of State Task (registration no. 121020500194-9 and 121031200178-8). The authors are grateful to Dr. A.P. Burnasheva (Yakutsk, Russia) for the drawing design. Two anonymous reviewers kindly commented on earlier drafts of the manuscript.

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