

First records of Cladocera and Copepoda from Chukchagir Lake and its basin (Khabarovsk Territory, Far East of Russia)

Первые данные о Cladocera и Copepoda из Чукчагирского озера и его бассейна (Хабаровский край, Дальний Восток России)

P.G. Garibian¹, E.S. Chertoprud^{1,2*}
П.Г. Гарибян¹, Е.С. Чертопруд^{1,2*}

¹ A.N. Severtsov Institute of Ecology and Evolution, Leninsky Prospect, 33, Moscow 119071, Russia.

¹ Институт проблем экологии и эволюции им. А.Н. Северцова РАН, Ленинский проспект, 33, Москва 119071, Россия.

² Department of Hydrobiology, Biological Faculty, M.V. Lomonosov Moscow State University, Leninskie Gory, Moscow 119991, Russia.

² Кафедра гидробиологии, Московский Государственный Университет им. М.В. Ломоносова, Ленинские горы, Москва 119991, Россия.

*Corresponding author: horsax@yandex.ru

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КЛЮЧЕВЫЕ СЛОВА: Crustacea, Cladocera, Copepoda, фауна, биоразнообразие.

ABSTRACT. We conducted an initial study of the microcrustacean species diversity of Chukchagir Lake and its basin (Khabarovsk Territory, Far East of Russia). In total, 29 Cladocera taxa and 14 Copepoda taxa were found. Two of these species, *Disparalona ikarus* Kotov et Sinev, 2011 and *Thermocyclops asiaticus* (Kiefer, 1932) are endemic to the Far East. In the investigated region, the cladocerans were more species-rich than the copepods. The species richness of Chukchagir Lake fauna was lower than that of Bolon Lake. This fact is probably explained by the anoxic bottom layer of Chukchagir Lake.

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РЕЗЮМЕ. Изучена фауна микроракообразных Чукчагирского озера и его бассейна (Хабаровский край). В общей сложности обнаружено 29 таксонов Cladocera и 14 таксонов Copepoda. Два вида *Disparalona ikarus* Kotov et Sinev, 2011 и *Thermocyclops asiaticus* (Kiefer, 1932) являются эндемиками Дальнего Востока. В озере по видовому составу и типу ареала более разнообразны Cladocera, чем Copepoda. Для избранных таксонов Cladocera приведены морфологические описания. Видовое богатство фауны Чукчагирского озера ниже чем в озере Болонь, что, вероятно, связано с заморными условиями формирующимися на дне водоема.

Introduction

The fauna of Cladocera and Copepoda of the inland water bodies of the southern part of the Russian Far

East is relatively poorly studied [Streletskaia, 1975a, b]. Active studies in Primorye and Khabarovsk Territory began with a series of expeditions at the beginning of the 20th century and primarily focused on large lakes and basins of large rivers [Borutsky, 1952; Manuilova, 1964; Borutsky *et al.*, 1991]. Among the lacustrine systems, the fauna of Khanka and Bolon Lakes are the best known [Barabanshikov, Kozhevnikov, 1998; Barabanshikov, 2000, 2004; Garibian *et al.*, 2019]. Among the river basins — the Amur, Ussuri and Zeya are adequately studied [Mikulich, 1948; Kotov *et al.*, 2006, 2011a, b, 2021; Kotov, Sinev, 2011; Barabanshikov, 2014]. The microcrustacean fauna of this region has unusually high endemicity [Korovchinsky, 2000, 2009, 2010; Korovchinsky, Sheveleva, 2009; Smirnov, Sheveleva, 2010; Kotov, Sinev, 2011]. However, the composition of the fauna of planktonic microcrustaceans of the Far East is not completely known.

One of the largest water bodies of the Khabarovsk Territory without records of planktonic crustaceans is Chukchagir Lake with a water-surface area of more than 350 km². It is located in the Amgun River basin [Grigoriev, 1964], and belongs now to the Oldzhikansky State Nature Reserve. The lake is shallow (with a maximum depth of 6 m), its bottom covered with a thick layer of detritus formed by dead macrophytes. Previously, this sapropel layer was mined in the lake for use in agriculture [Shabalin, 1966]. The reservoir is low-flow, several large rivers flow into it, and the only outflow is the Oldzhikan River. Lake Chukchagir appears to be an oxbow formation and a remnant of an ancient channel of the Amgun River [Prokhorov, 1978].

The aim of the present study is to make an inventory of the Cladocera and Copepoda fauna of Chukchagir Lake and its basin.

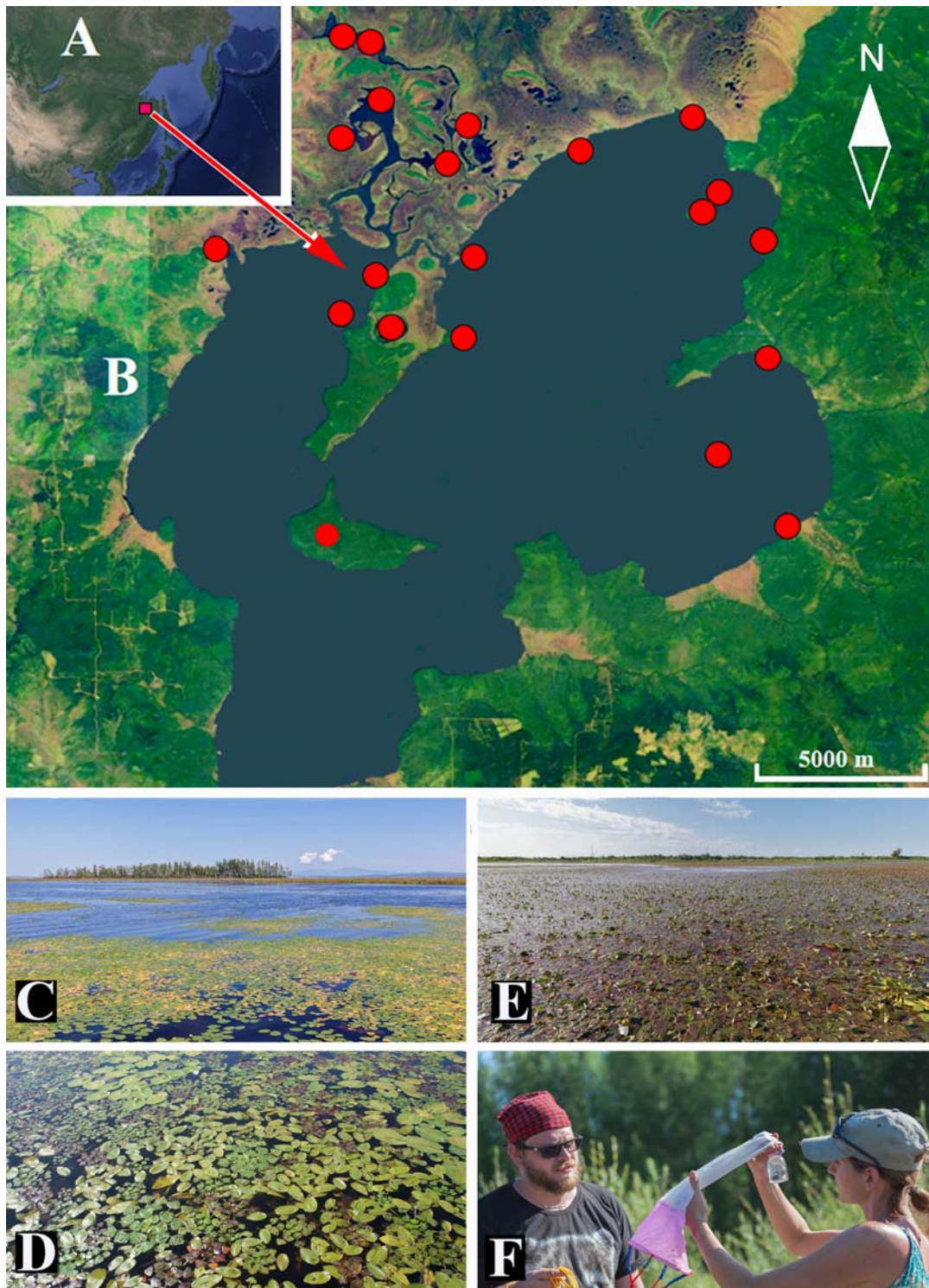


Fig. 1. Map of the investigated water bodies, main aquatic biotopes and researchers at work. A — location of the Chukchagir Lake on Far East of Russia. B — map of the Chukchagir Lake with marked sampling points. The base maps is the Google planet and available at <https://www.google.com/earth/>. C — water area covered with spatterdock (*Nuphar* sp.). D — water area with thickets of floating heart (*N. peltata*) and pondgrass (*Potamogeton* sp.). E — water area covered with water nut (*Trapa* sp.). F — sampling. (Photos authors: I.N. Nikonova — C, D; N.A. Aseev — E, F).

Рис. 1. Карта исследуемого водоема, основные водные биотопы и исследователи за работой. А — положение озера Чукчагирское на Дальнем Востоке России. В — карта озера Чукчагирское с отмеченными местами отбора проб. Карты взяты с портала Google planet и доступна по адресу <https://www.google.com/earth/>. С — акватория покрытая болотоцветником (*Nuphar* sp.). D — акватория с зарослями кувшинки (*N. peltata*) и рдеста (*Potamogeton* sp.). E — акватория заросшая водяным орехом (*Trapa* sp.). F — sampling. (Авторы фотографий: И.Н. Никонова — C, D; Н.А. Асеев — E, F).

Material and methods

We collected zooplankton samples during August 2018 in the territory of the Oldzhikansky State Nature Reserve with special permission of the Reserve authority. Sampling was conducted at 27 localities in 21 “sites” (Fig. 1B) mainly in the northern part of the Chukchagir Lake, inflow areas of the rivers flowing into it, and at the Selgon River source. The shallow bays of the lake were densely covered by different aquatic plants. The most numerous macrophytes were: several species of the water nut (*Trapa* sp.) (Fig. 1E), the floating heart (*Nymphoides peltata* (S.G. Gmel.) Kuntze) (Fig. 1D), the spatterdock (*Nuphar* sp.) (Fig. 1C), the pondgrass (*Potamogeton* sp.) (Fig. 1D) and reed (*Phragmites* sp.). All these plants formed dense thickets in the lake.

The sampling (Fig. 1f) was performed both from the shore and from the boat so that the open water zones could be sampled. At each locality, some qualitative samples were collected by hauling a plankton net (Apstein, diameter 0.1 m, mesh size 0.05 mm). Samples were preserved with 96% ethanol. All samples were provisionally investigated under stereoscopic microscopes using standard techniques. The general morphology of all found individuals was studied *in toto* under an Olympus BX41 compound microscope. Then some individuals were dissected using tungsten needles electrolytically sharpened in 10% NaOH [Frey, 1986]. Each dissected body part was transferred individually by the afore-

mentioned needles to a new drop of glycerol on a separate slide, covered by a cover-slip and investigated in detail under an immersion lens at magnification x 100. Drawings were prepared with a drawing tube attached to the light microscope Olympus BX 41 or Olympus CX 41.

The computer package EstimateS used [Colwell, 2013] was used to estimate species richness of the cladocerans and copepods in the region.

Abbreviations: IDL — inner-distal lobe of limb I; ODL — outer-distal lobe of limb I.

Results

A. GENERAL

In total, 29 taxa of Cladocera and 14 taxa of Copepoda were recorded in our material (Table 1). *Daphnia* (*Daphnia*) sp. and *Diaphanosoma* sp. were identified only to the genus level. Their species identification was not possible because the samples contained juvenile specimens only. A single juvenile specimen of *Ilyocryptus* cf. *agilis* Kurz, 1878, with weakly expressed morphological features, was also found. The majority of cladoceran taxa were widely distributed in Eurasia and belonged to the so-called “cosmopolitan” taxa. However, many of these cladoceran taxa are in need of revision. Only *Disparalona ikarus* Kotov et Sinev, 2011

Table 1. Cladocera and Copepoda species from the Chukchagir Lake Basin, their ranges and frequencies at stations. Таблица 1. Виды Cladocera и Copepoda, найденные в бассейне Озера Чукчагирское, их ареалы и встречаемость в пробах.

Taxon	Faunistic complex	Frequency at stations
Cladocera		
<i>Acroperus angustatus</i> Sars, 1863	EUR	11
<i>A. harpae</i> (Baird, 1834)	EUR	5
<i>Biapertura affinis</i> (Leydig, 1860)	EUR	6
<i>B. sibirica</i> (Sinev, Karabanov et Kotov, 2020)	EUR	3
<i>Alonella excisa</i> (Fischer, 1854)	COS	1
<i>Bosmina longirostris</i> (O.F. Müller, 1785)	COS	21
<i>Camptocercus fennicus</i> Stenroos, 1898	EUR	1
<i>C. cf. lilljeborgi</i> Schödler, 1862	EUR	2
<i>C. uncinatus</i> Smirnov, 1971	EEUR	2
<i>Ceriodaphnia pulchella</i> Sars, 1862	COS	1
<i>C. quadrangula</i> (O.F. Müller 1785)	COS	1
<i>Chydorus</i> cf. <i>sphaericus</i> (O.F. Müller 1776)	COS	22
<i>Coronatella rectangula</i> (Sars, 1962)	COS	3
<i>Daphnia</i> (<i>Daphnia</i>) sp.	-	2
<i>Diaphanosoma dubium</i> Manujlova, 1964	THE	1
<i>Diaphanosoma</i> sp.	-	1
<i>Disparalona ikarus</i> Kotov et Sinev, 2011	END	1
<i>Eurycercus macracanthus</i> Frey, 1973	EEUR	9

Table 1 (continued).
Таблица 1 (продолжение).

Taxon	Faunistic complex	Frequency at stations
Cladocera		
<i>Flavalona costata</i> (Sars 1862)	COS	8
<i>Graptoleberis testudinaria</i> (Fischer, 1851)	COS	3
<i>Holopedium gibberum</i> Zaddach, 1855	EUR	1
<i>Ilyocryptus</i> cf. <i>agilis</i> Kurz, 1878	EUR	1
<i>Limnosida frontosa</i> Sars 1862	EUR	2
<i>Pleuroxus truncatus</i> (O.F. Müller, 1785)	EUR	17
<i>Polyphemus pediculus</i> (Linnaeus, 1761)	COS	3
<i>Scapholeberis mucronata</i> (O.F. Müller 1776)	EUR	20
<i>Sida crystallina</i> (O.F. Müller 1776)	EUR	16
<i>Simocephalus mixtus</i> . Sars, 1903	COS	5
<i>S. vetuloides</i> Sars, 1899	EEUR	1
Copepoda		
<i>Acanthocyclops vernalis</i> (Fisher, 1853)	COS	3
<i>Cyclops vicinus vicinus</i> Uljanin, 1875	EUR	2
<i>Eucyclops macruroides denticulatus</i> (Lilljeborg, 1901)	EUR	5
<i>E. serrulatus</i> (Fischer, 1851)	COS	15
<i>Eudiaptomus vulgaris</i> (Schmeil, 1898)	EUR	1
<i>Macrocyclus albidus</i> (Jurine, 1820)	COS	3
<i>Megacyclus viridis</i> (Jurine, 1820)	COS	5
<i>Mesocyclops leuckarti</i> (Claus, 1857)	COS	15
<i>Microcyclus varians</i> (Sars, 1863)	COS	1
<i>Paracyclus fimbriatus orientalis</i> (Alekseev, 1995)	EUR	13
<i>Platycyclops phaleratus</i> (Koch, 1883)	COS	2
<i>Thermocyclops asiaticus</i> (Kiefer, 1932)	END	1
<i>T. crassus</i> (Fisher, 1953)	COS	7
<i>Tropocyclops prasinus</i> (Fischer, 1860)	COS	2
Total species richness of locality		43

END — endemic of Far East; EUR — widely distributed in Eurasia or even in Holarctic and needs a revision; EEUR — distributed in eastern portion of Eurasia; COS — so-called “cosmopolitan” taxon needs a revision; THE — taxon of the southern thermophilic complex for which the Amur River Basin is its northernmost region of occurrence.

END — эндемик Дальнего Востока; EUR — таксон, широко распространен в Евразии или даже в Голарктике, который должен быть подвергнут ревизии; EEUR — распространен в восточной части Евразии; COS — так называемый «космополит», который должен быть подвергнут ревизии; THE — таксон южного теплолюбивого комплекса, для которого бассейн Амура — наиболее северный регион обитания.

are considered to be Far East endemics. Most of the representatives of the copepod crustaceans had wide Holarctic or Palaearctic ranges or were cosmopolitan. Only one species *Thermocyclops asiaticus* (Kiefer, 1932) was specific for the Far East.

All Cladocera and Copepoda species found in the Chukchagir Lake were already recorded in waterbodies of the Russian Far East.

Some remarkable taxa of Cladocera are briefly described below.

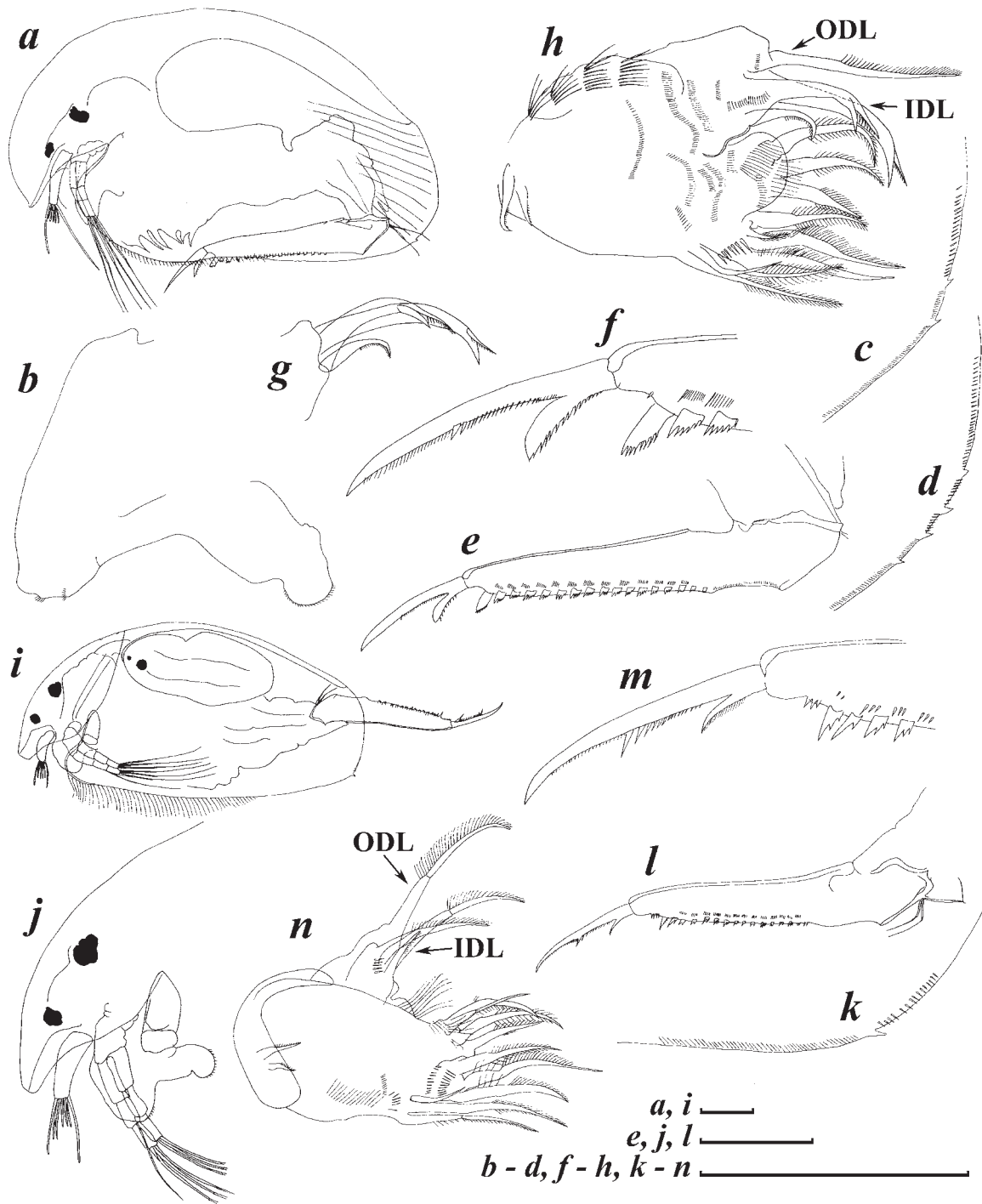


Fig. 2. Parthenogenetic females of *Camptocercus fennicus* (a-h) from Chukchagir Lake, 300 m from mouth of the Bikkitkan River: a — lateral view; b — labrum; c-d — postero-ventral margin of valves; e-f — postabdomen and postabdominal claw; g-h — IDL of limb I and limb I; *C. liljeborgi* (i-n) from Chukchagir Lake, Tavkit Bay apex part: i — lateral view; j — head; k — postero-ventral margin of valves; l, m — postabdomen and postabdominal claw; n — limb I. Scale bars: 0.1 mm.

Рис. 2. Партеногенетические самки *Camptocercus fennicus* (a-h) из озера Чукчагирское, 300 м от устья реки Биккиткан: a — вид сбоку; b — лярбрум; c-d — задне-нижний край створки. e-f — постабдомен и постабдоминальный коготь; g-h — внешняя дистальная доля торакопода I и торакопод I; *C. liljeborgi* (i-n) из озера Чукчагирское, залив Тавкит кутовая часть: i — вид сбоку; b — голова; k — задне-нижний край створки; l, m — постабдомен и постабдоминальный коготь; n — торакопод I. Масштабная линейка: 0,1 мм.

B. TAXONOMIC NOTE OF SOME CLADOCERAN SPECIES

Order Anomopoda Sars, 1865
 Family Chydoridae Dybowski et Grochowski, 1894
 emend. Frey, 1967
 Subfamily Aloninae Dybowski et Grochowski, 1894
 emend. Frey, 1967

Camptocercus fennicus Stenroos, 1898
 Fig. 2a–h.

PARTHENOGENETIC FEMALE. Length of examined individual 0.77 mm, height 0.45 mm. Body (Fig. 2a) ovoid, elongated in lateral view, strongly compressed laterally. Head and carapace with a well-expressed dorsal keel. Dorsal margin convex, postero-dorsal and postero-ventral angles rounded. Ventral margin slightly convex with a row of setae. Labrum with a sub-triangular keel, its posterior margin with two rows of short setules (Fig. 2b). Postero-ventral angle of valves with 2–3 pointed denticles (Fig. 2c–d). Postabdomen very long, without defined distal margin, its length about 6 heights. Dorsal margin almost straight, preanal margin concave. Postanal margin straight with 17 subrectangular saw toothed denticles. Postanal portion with 13 lateral fascicles (Fig. 2e). Postabdominal claw slightly curved very long. Basal spine broad with lancet-like shape (Fig. 2e–f). Limb I with ODL bearing long seta, armed with long setules. IDL with three seta, seta 1 moderate size 1/3 length of ODL seta. Seta 2 and 3 hook-like with setulated distal portion (Fig. 2g–h).

COMMENTS. *C. fennicus* is regarded as a rare species, it is distributed in Germany, Poland, Scandinavia, North European part of Russia and Yakutia [Sinev, 2014]. Previously it was recorded in the Zeya River basin [Kotov *et al.*, 2011a] and the Kolyma River [Smirnov, 1971]. This is a rare species in the Far East also.

Camptocercus cf. lilljeborgi Schödler, 1862
 Fig. 2i–n.

PARTHENOGENETIC FEMALE. Length of examined individual 0.62 mm, height 0.29 mm. Body (Fig. 2i) ovoid, elongated in lateral view, strongly compressed laterally and having a dorsal keel. Head rostrum pointed down, its tip broadly rounded (Fig. 2j). Dorsal margin convex, ventral margin slightly concave. Postero-dorsal and postero-ventral angles rounded. Ventral part of valves bearing setae, which covered more than half of margin. Postero-ventral angles of valves with denticle (Fig. 2k). Postabdomen very long, narrowing distally, its length about five heights. Anal margin almost straight, preanal portion slightly concave, postanal margin slightly concave to straight with 14-clustered postanal denticles with fused bases. Preanal angle well-developed, a postanal angle not defined (Fig. 2l). Postabdominal claw long with curved tip. Basal spine slightly bent, shorter than claw about 4.2X (Fig. 2m). Limb I with ODL bearing long seta, armed with long setules. IDL with three seta, seta 1 large, seta 2 and 3 thick, curved with setulated distal portion (Fig. 2n).

COMMENTS. It is the second record of *C. lilljeborgi* from the Amur River basin. This population is located more northwest as compared to previous record from Bolon Lake basin. *C. lilljeborgi* is, probably, widely distributed in North-

ern Eurasia, but this is a relatively rare species.

Biapertura sibirica (Sinev, Karabanov et Kotov, 2020)
 Fig. 3a–g.

PARTHENOGENETIC FEMALE. Length of examined individual 0.84 mm, height 0.47 mm. Body (Fig. 3a) ovoid, moderately compressed laterally, maximum height approximately at middle. Dorsal and posterior margin of valves convex, ventral margin weakly convex. Anteroventral, Postero-dorsal and postero-ventral angles broadly rounded. Postero-dorsal angle with two denticles (Fig. 3c–d), ventral margin with row of setae. Head relatively small, with ocellus and eye, rostrum pointed down, relatively narrow. Head shield with two connected major head pores and two lateral head pores (Fig. 3b). Postabdomen (Fig. 3e) large, subrectangular, moderately high. Ventral margin straight, distal margin almost straight, distal angle rounded. Dorsal margin slightly convex, straight in postanal portion and weakly concave in anal portion. Postanal angle not defined, preanal angle well expressed. Postanal margin with 13 well-developed denticles, lateral portion with 14 clusters of setules. Postabdominal claw moderately long, basal spine long and slender. Limb I with IDL with three seta, seta 1 large and broad, claw-like, seta 2 and 3 with thin setulae in distal part, ODL with one long setulated setae (Fig. 3f–g).

COMMENTS. *B. sibirica* is wide distributed in North-East Palearctic. Previously this specie regarded as form of *Biapertura affinis* (Leydig, 1860), but a detailed recent revision confirmed its species status [Sinev *et al.*, 2020] within the genus *Biapertura* Smirnov, 1971 [Sinev, 2020].

Coronatella (Coronotella) rectangula (Sars, 1962)
 Fig. 2h–l.

PARTHENOGENETIC FEMALE. Length of examined individual 0.32 mm, height 0.21 mm. Body (Fig. 3h) ovoid, short. Maximum height at the middle. Dorsal and posterior margin of valves convex, ventral margin slightly convex. Posterior margin rounded, anterior margin weakly straight. Head with a short rostrum, without a dorsal keel. Valves with weakly developed longitudinal lines in postero-ventral and postero-dorsal portion (Fig. 3h–i). Postero-ventral angle without denticles (Fig. 3i). Postabdomen (Fig. 3j) short, dorsal margin convex, ventral margin slightly straight. Lateral portion with rows of clustered setae. Postanal margin with well-developed marginal denticles, anal margin weakly convex, preanal margin slightly straight. Postabdominal claw long with long basal spine. Limb I with IDL bearing two setae, armed with long slender spines, ODL with one long seta (Fig. 3k–l).

COMMENTS. Common species in South-East Asia [Sinev, 2016] and Russian Far East. We supposed to found *Coronatella trachystriata* (Chen, Zhang et Liu, 1994) in Chukchagir Lake basin, but it was not found. The Bolon Lake basin seems to be the northeast location for this species.

C. BIODIVERSITY ANALYSIS

Our analysis revealed that the copepods are well-studied taxonomically — both sample-based rarefaction curves and the best species richness estimator reached the same plateau at 14 taxa (Fig. 4b). In contrast, neither the sample-based rarefaction curves nor

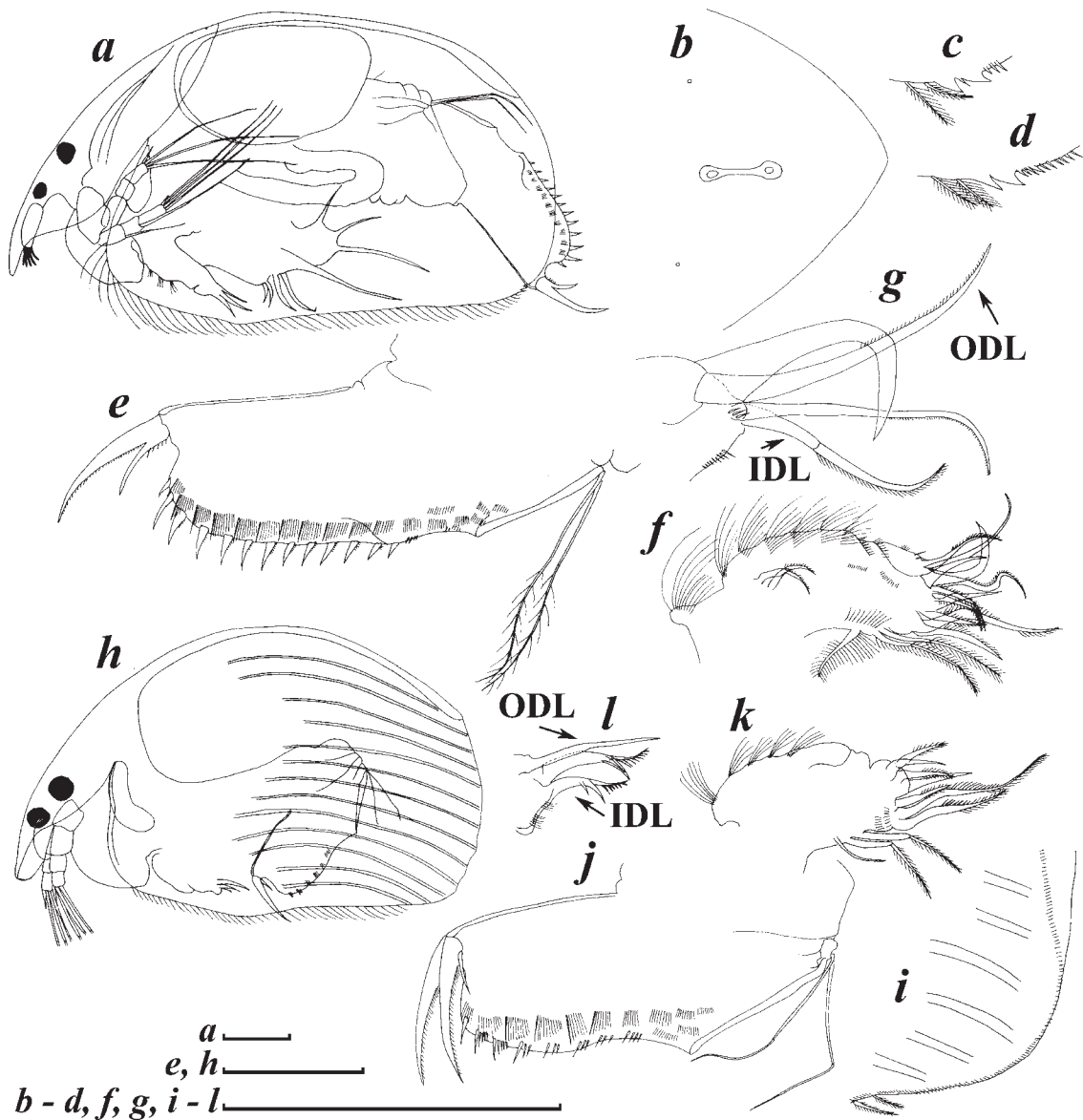


Fig. 3. Parthenogenetic females of *Biapertura sibirica* (a–g) from Chukchagir Lake, 300 m from mouth of the Bikkitkan River: a — lateral view; b — posterior portion of head shield; c–d — postero-ventral margin of valves; e — postabdomen; f–g — limb I and IDL of limb I; *Coronatella rectangula* (h–l) from Chukchagir Lake, 300 m from mouth of the Bikkitkan River: h — lateral view; i — postero-ventral margin of valves; j — postabdomen; k–l — limb I and IDL of limb I. Scale bars: 0.1 mm.

Рис. 3. Партеногенетические самки *Biapertura sibirica* (a–g) из озера Чукчагирское, 300 м от устья реки Биккиткан: a — вид сбоку; b — задняя часть головного щита; c–d — задне-нижний край створки; e — постабдомен; f–g — торакопод I и внешняя дистальная доля торакопода I; *Coronatella rectangula* (h–l) из озера Чукчагирское, 300 м от устья реки Биккиткан: h — вид сбоку; i — задне-нижний край створки; j — постабдомен; k–l — торакопод I и внешняя дистальная доля торакопода I. Масштабная линейка: 0,1 мм.

the best species richness estimator reached a plateau for the Cladocera (Fig. 4a). Therefore, the cladoceran biodiversity is still inadequately studied in this region.

Discussion

Most of the cladoceran taxa from Chukchagir Lake are widespread in Eurasia and the Holarctic (22 species). Three species (*Camptocercus uncinatus* Smirnov,

1971, *Eurycercus macracanthus* Frey, 1973 and *Simocephalus vetuloides* Sars, 1899) are “Beringian” — distributed in eastern portion of Eurasia [Kotov, 2016] — they are distributed predominantly in eastern portion of Eurasia [Ji *et al.*, 2015; Xiang *et al.*, 2015]. Only *D. ikarus* is the endemic of the Far East [Kotov, Sinev, 2011]. Unfortunately, *Ilyocryprus cf. agilis* was represented by a single juvenile specimen, and we are not sure that this population really belongs to *I.*

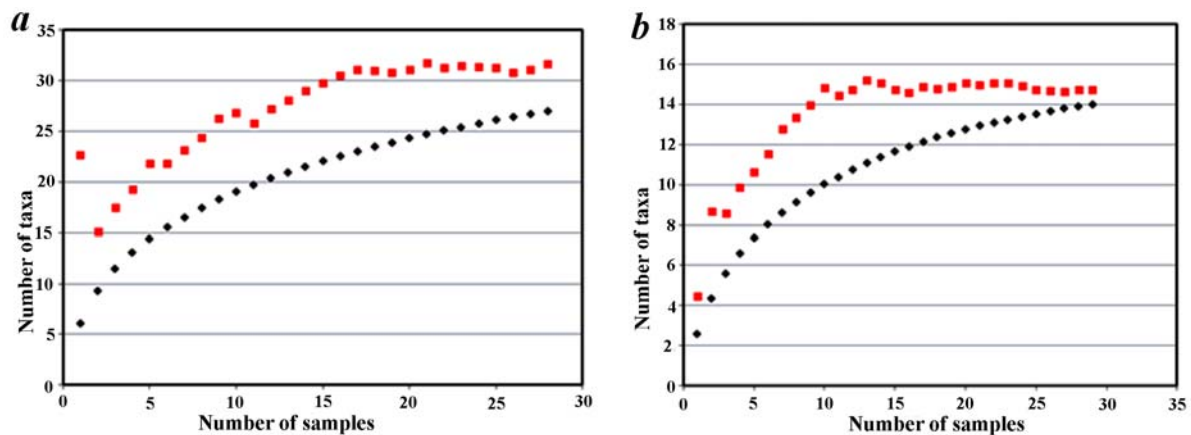


Fig. 4. Empirical and estimated numbers of Cladocera (a), Copepoda (b) taxa. Black rhombus — sample-based rarefaction curve; red quadrates — best species richness estimator (Chao 1).

Рис. 4. Эмпирическое число таксонов Cladocera (a), Соперода (b). Черные ромбы — эмпирическая кривая разрежения; красные квадраты — эмпирическая кривая лучшей модели оценки биоразнообразия (Chao 1).

agilis s.str. instead of *I. yooni* Jeong, Kotov et Lee, 2012 being the endemic of East Asia [Jeong *et al.*, 2012]. *Diaphanosoma dubium* Manujlova, 1964 is a thermophile. Despite the small number of taxa, the fauna of cladocerans from Chukchagir Lake were represented by all of the major faunal complexes of the Far East of Russia [Garibian *et al.*, 2020].

The copepods are less species-rich and heterogeneous in their type ranges as compared to the cladocerans. The fauna of the lake is composed of 14 species with several being cosmopolitan (9) or widely distributed in Eurasia (4). Only one species was endemic to the Far East — *T. asiaticus*, known from the water bodies of the Ussuri Region, the lower reaches of the Amur River, and northeastern China [Barabanshchikov, 2014].

The microcrustacean fauna of Chukchagir Lake is less species rich than the fauna of the nearby Bolon Lake [Garibian *et al.*, 2019]. Only 43 species were found in Chukchagir Lake — approximately 20% less than in Bolon Lake. The anoxic hypolimnion of Chukchagir Lake both in winter and in summer [Shabalin, 1966] may reduce overall diversity. A large number of rotting macrophytes have accumulated at the bottom of the lake, and the bottom layer is rich in hydrogen sulfide. The lowering of zooplanktonic species richness in lakes prone to anoxia has been previously proposed [Rivier, 2016].

Despite the low diversity of the crustaceans of Lake Chukchagir, the cladoceran fauna in it is still understudied (Fig. 4b). This fact indicates the relevance of further investigations of the zooplankton of the Amgun River basin, in general, and Chukchagir Lake in particular. A thorough faunistic study of regional water bodies in the future will form the basis for constructing a sound biogeographic zoning of the Far East of Russia.

Compliance with ethical standards

CONFLICTS OF INTEREST: The authors declare that they have no conflicts of interest.

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