Botanica Pacifica. A journal of plant science and conservation. 2023. 12(1): 133–139
DOI: 10.17581/bp.2023.12101

Diatoms (Bacillariophyta) of the Tolmachev reservoir (Kamchatka, Russia)

Sergei I. Genkal [1]* & Ekaterina V. Lepskaya [2]

Sergei I. Genkal [1]*
e-mail: genkal47@mail.ru

Ekaterina V. Lepskaya [2]
e-mail: lepskaya.e.v@kamniro.ru

Papanin Institute for Biology of Inland Waters RAS, Borok, Russia

Kamchatka Branch of the Russian Federal Research Institute of Fisheries and Oceanography, Petropavlovsk-Kamchatsky, Russia

* corresponding author

Manuscript received: 22.06.2022
Review completed: 09.11.2022
Accepted for publication: 30.11.2022
Published online: 03.12.2022

ABSTRACT

A study of diatoms from the Tolmachev Reservoir (Kamchatka) was carried out using electron microscopy. As a result, 45 species and varieties of Bacillariophyta from 28 genera were identified, and 4 algae were identified only to the genus level. 12 species from 11 genera, new for the flora of Kamchatka diatoms, were found. Most of the new taxa for Kamchatka flora are rare species, and our study expanded their range.

Keywords: diatoms, electron microscopy, new species, Tolmachev Reservoir, Kamchatka

РЕЗЮМЕ

Генкал С.И., Лепская Е.В. Диатомовые водоросли (Bacillariophyta) Толмачевского водохранилища (Камчатка, Россия). Проведено исследование диатомовых водорослей Толмачевского водохранилища (Камчатка) с помощью электронной микроскопии. В результате выявлено 45 видов и разновидностей Bacillariophyta из 28 родов и 4 водоросли определены только до рода. Обнаружено 12 видов из 11 родов – новых для флоры диатомовых водорослей Камчатки. Большинство обнаруженных новых таксонов для флоры Камчатки относятся к редким видам, и наше исследование расширило их ареал.

Ключевые слова: диатомовые водоросли, электронная микроскопия, новые виды, Толмачевское водохранилище, Камчатка

For more than 100 years of study of Kamchatka diatoms with light microscopy, more than 500 species, varieties and forms were found in water bodies, watercourses and hot springs of the peninsula (Elenkin 1914, Golovenkina 1981, Shkurina et al. 2004, Lepskaya 2007, 2008, 2014, Nikulina et al. 2016, Nikulina & Grishchenko 2017, Nikulina & Sorokin 2021). Further studies of the material mainly from lakes with electron microscopy provided new data on Bacillariophyta in Kamchatka (Genkal & Lupikina 1998, Genkal et al. 2004, 2007, Genkal & Lepskaya 2009, 2013a, b, c, 2014a, b, 2015, Kharitonov & Genkal 2012, Medvedeva & Nikulina 2014).

In 1999, the natural Tolmachev Lake was transformed into the reservoir to support the operation of the Tolmachev cascade of small hydroelectric power plants.

Despite long-term monitoring of the Tolmachev Reservoir ecosystem, which includes, among other things, quantitative assessment of the dominant phytoplankton taxa, there are few published data on its algoflora. Thus, the only publication containing data on the taxonomic composition of phytoplankton in the reservoir (the study was carried out using light microscopy) at the initial stage of its formation shows that the greatest species diversity in plankton was characteristic of the Bacillariophyta division. While 11 species and varieties of diatoms were found in the natural lake in 1999, there were 14 in the reservoir in 2000–2001. (Lepskaya 2003). No special taxonomic studies of the diatom flora using modern microscopic methods have ever been conducted.

This study aims at determining the species composition of diatoms and supplementing the floristic list of Bacillariophyta of Kamchatka based on scanning electron microscopy study of new materials from the Tolmachevo Reservoir and current ideas about the taxonomy of this group.

MATERIAL AND METHODS

Tolmachev Reservoir, a lake-type reservoir (here and after – Tolmachev Lake), is located in the basin of the Bolshaya River (Kamchatka) (Fig. 1, 52°36'32"N 157°38'46"E, altitude 627 m above sea level) (Tepnin et al. 2018). During the period of maximum filling, the length of the reservoir was 14.3 km, average width – 2.9 km, maximum width – 4.1 km, surface area – 30.3 km^2, maximum depth – 38 m, average depth – 9.9 m, shoreline length – 63.2 km, volume – 253.4 million m^3 (Pogodaev et al. 2010). About half of Tolmachev lake is shallow (water depth of 5 m or less). The flow of the lake is regulated, water level fluctuations may reach 2–5 m during a short period of time. The ice-free period is short (July–September) which is characteristic of high-mountainous water bodies. The water body is affected by ash emissions from the Gorely volcano (Lepskaya et al. 2014).

Lake Tolmachev did not have its own ichthyofauna before the introduction of the resident form of Pacific salmon, the sockeye salmon. Access of anadromous fish to the lake was blocked by a 17-meter waterfall located 9 km from the source of the Tolmachev River. At present, the riverbed has been drained and access of anadromous fish to Tolmachev Lake and, accordingly, introduction of marine and estuarine diatom species by fish is impossible.

Phytoplankton samples were collected with a bathometer on October 2, 2019 in the central deep-water part of the

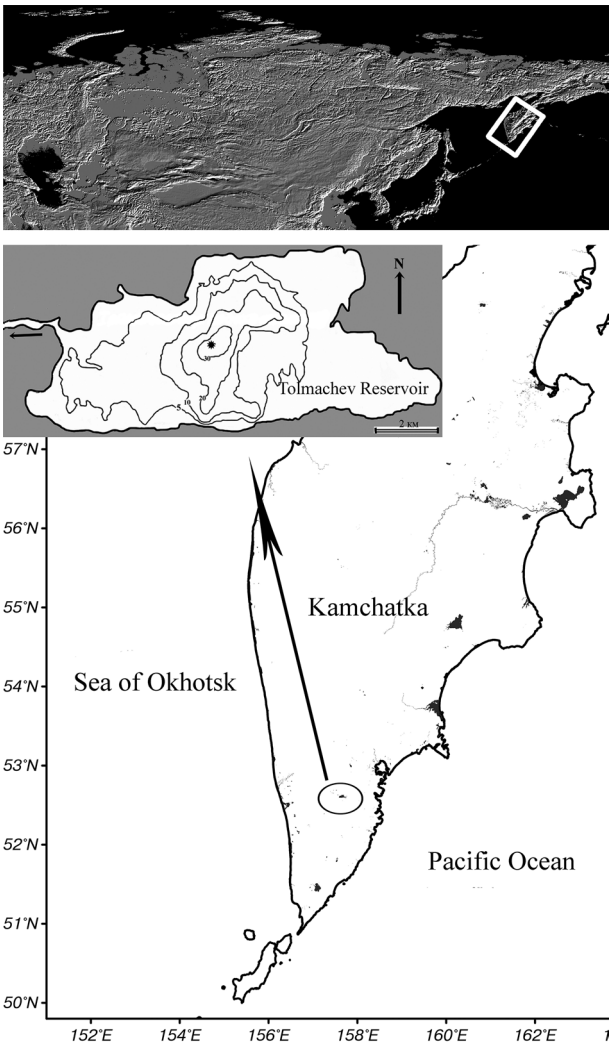

Figure 1 Map-scheme of the sampling site

lake from the horizons 0, 2, 5, 7, 10, 15, 20 and 28 m. The sample from each horizon was concentrated by filtering 50 ml through Vladipor membrane filterswith a pore size of 0.45 μm. To determine the species composition of diatoms, the sediment was washed off the filters, thus preparing a qualitative integral sample. Diatom frustules were freed from organic matter by cold calcination (Balonov 1975). Algae specimens were examined in a JSM-6510 LV scanning electron microscope.

Modern systematic summaries and guides were used to identify the algae (Krammer 2002, 2003, Krammer & Lange-Bertalot, 1986, 1988, 1991a, b, 2001, Lange-Bertalot et al. 1994, 2011, 2017, Lange-Bertalot & Genkal 1999, Genkal & Vekhov 2007, Levkov 2009, 2016, Kharitonov & Genkal 2012, Kulikovskiy et al. 2016, Genkal et al. 2020).

RESULTS

When identifying the material, we found 49 species of diatom algae. Of these, 16 diatom species, including four identified only to the genus, were found in Kamchatka for the first time. Brief diagnoses of 12 species and detailed descriptions of 4 algae in open nomenclature based on original data and their original illustrations are given below.

Achanthidium dolomiticum M. Cantonati et H. Lange-Bertalot (Fig. 2A, B). Valve length 8.4–13.3 μm, width 3.2–4 μm, striae 28–35 in 10 μm. Europe (Lange-Bertalot et al. 2006). In Russia, the only find in the Middle Urals is known (Genkal & Eremkina 2022).

Conticribra weissflogii (Grunow) K. Stachura-Suchoples et D.M. Williams (*Thalassiosira weissflogii* (Grunow) Fryxell et Hasle) (Fig. 2 C). Valve diameter 14 μm, marginal fultoportulae 13 in 10 μm. Europe (Krammer & Lange-Bertalot 1991a). Widely distributed in Russia (Genkal et al. 2020).

Cyclotella distinguenda Hustedt (Fig. 2 D, E, F).Valve diameter 13.5–16 μm, striae 18 in 10 μm. Europe (Krammer & Lange-Bertalot 1991a, Houk et al. 2010). The species was recorded from several locations in the European part of Russia (Kozyrenko et al. 1992, Genkal et al. 2019), the Far East (southern part) (Medvedeva & Nikulina 2014).

Cymbopleura sp. (Fig. 2G). Valve very weakly dorsiventral, linear, subelliptical, dorsal and ventral sides slightly convex, length 30 μm, width 7.5 μm, central area in form of rectangular fascia, striae weakly radial, 11 in 10 μm.

Eunotia subarcuatoides Alles, Norpel et Lange-Bertalot (Fig. 2H). Valve length 10 μm, width 4.2 μm, striae 22 in 10 μm. Europe (Krammer & Lange-Bertalot 1991, Lange-Bertalot et al. 2017). In Russia, it was recorded in water bodies and streams of the European part (Genkal & Trifonova 2009, Genkal et al. 2015), Western Siberia (Genkal et al. 2011, Genkal & Yarushina 2018), the Russian Arctic (Genkal & Vekhov 2007), the Far East (Chukotka, southern part of the Far East) (Kharitonov & Genkal 2012, Medvedeva & Nikulina 2014).

Fallacia pygmaea (Kützing) Stickle et D.G. Mann (*Navicula pygmaea* Kützing) (Fig. 2I). Valve length 20–30 μm, width 10.7 μm, striae 26 in 10 μm. Europe (Krammer & Lange-Bertalot 1986, Lange-Bertalot et al. 2017). In Russia, it occurs in freshwater reservoirs and streams of Western Siberia (Genkal & Yarushina 2018), the Far East (southern part) (Medvedeva & Nikulina 2014).

Gomphosphenia stoermeri Kocioleket Thomas (Fig. 3A). Valve length 13 μm, width 2.6 μm, striae 30 in 10 μm. Several localities of the species are known in Russia: in reservoirs and streams of the European part (Chudaev & Gololobova 2016) and Western Siberia (Genkal & Yarushina 2018).

Halamphora borealis (Kützing) Levkov (*Amphora borealis* Kützing) (Fig. 3B).Valve length 20.5 μm, width 4 μm, striae 40 in 10 μm. Europe (Levkov et al. 2009). In Russia, it has been recorded in water bodies and streams of Western Siberia (Genkal & Yarushina 2018), the Russian Arctic (Lange-Bertalot & Genkal 1999, Genkal & Vekhov 2007).

Halamphora hybrida (Grunow) Levkov (*Amphora angularis* var. *hybrida* Grunow, *A. angularis* var. *lyrata* (Gregory) Van Heurck, *A. coffeaeformis* var. *angularis* (Grunow) Cleve) (Fig. 3 C,D). Valve length 37.5–52.5 μm, width 5–5.7 μm, striae 25 in 10 μm. Europe (Levkov et al. 2009). In Russia, the only record of the species is known from the European part (Genkal & Gorokhova 2021).

Karayevia suchlandtii (Hustedt) Bukhtiyarova (*Achnanthes suchlandtii* Hustedt, *Kolbesia suchlandtii* (Hustedt) J.C. Kingston) (Fig. 3E).Valve length 10.6 μm, width 4.7 μm, striae 18 in 10 μm. Europe (Krammer & Lange-Bertalot 1991b). In Russia, it was recorded in water bodies and streams of the European part (Genkal & Trifonova 2009, Genkal et al. 2015, Chudaev & Gololobova 2016), Eastern and Western Siberia (Genkal et al. 2011, Genkal & Yarushina 2018), the Far East (Yakutia, Chukotka) (Kharitonov & Genkal 2012).

Martyana schulzii (C. Brockmann) Snoeijs (*Fragilaria schulzii* C. Brockmann) (Fig. 3F).Valve length 11 μm, width 3.6 μm, striae 20 in 10 μm. Europe (Krammer & Lange-Bertalot 1991a). In Russia, it occurs in freshwater reservoirs and streams of the European part (Genkal et al. 2015).

Navicula salinarum Grunow (Fig. 3G).Valve length 35.5 μm, width 9.8 μm, striae 14 in 10 μm. Europe (Krammer & Lange-Bertalot 1986, Lange-Bertalot et al. 2017). In Russia, it was found in water bodies and streams of Western Siberia (Genkal & Yarushina 2018), the Russian Arctic (Lange-Bertalot & Genkal 1999, Genkal & Vekhov 2007), and the Far East (southern part) (Medvedeva & Nikulina 2014).

Nitzschia sp. (Fig. 3H).Valve liner-lanceolate, ends slightly capitate, length 14 μm, width 4 μm, fibulae 12 in 10 μm, striae 35 in 10 μm.

Pantocsekiella sp. (Fig. 3I).Valve round, diameter 7 μm, in center 2 fultoportulae with 2 satellite pores, marginal fultoportulae on every 6–7 costa, striae 25 in 10 μm.

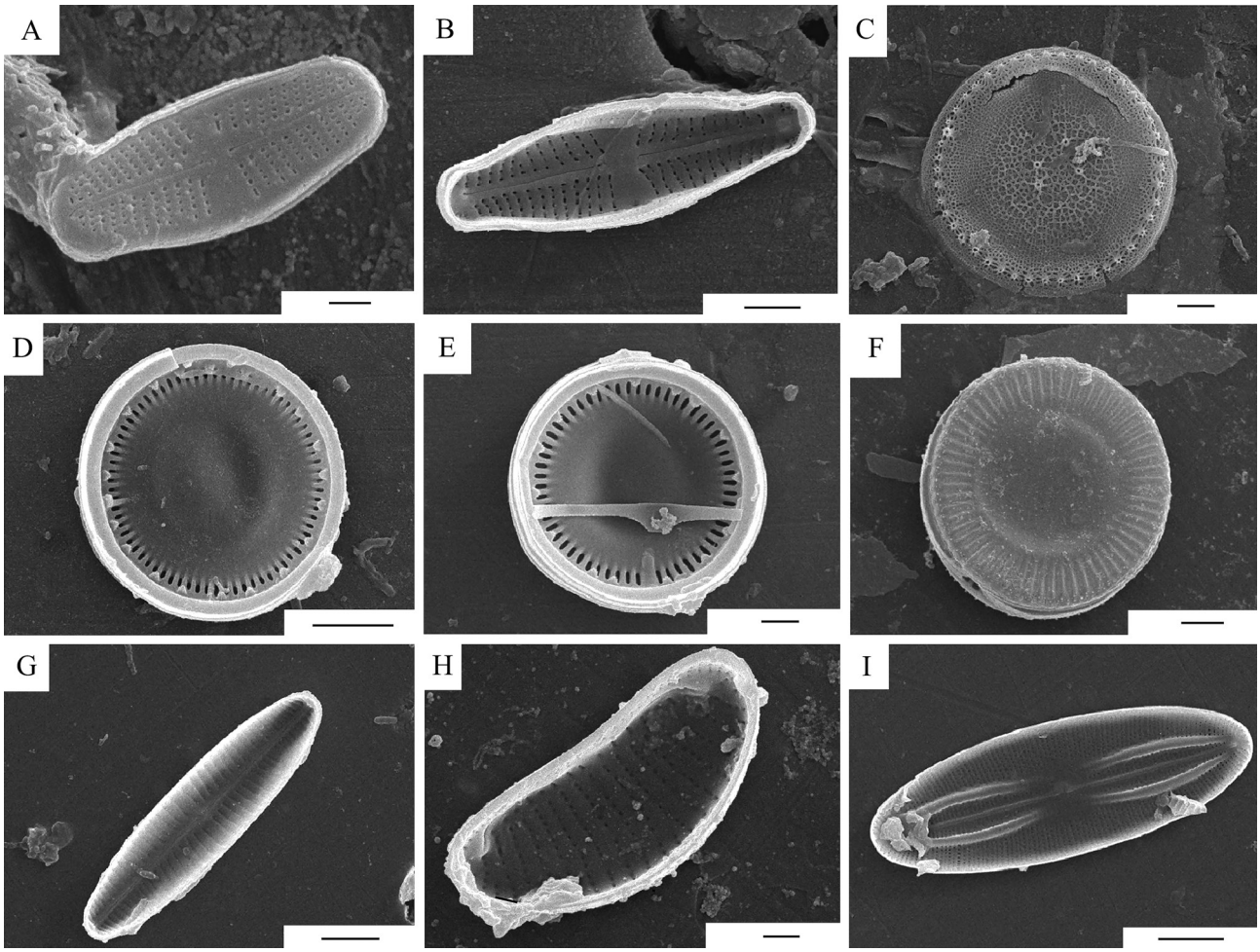

Figure 2 A, B – *Achanthidium dolomiticum* M. Cantonati et H. Lange-Bertalot; C – *Conticribra weissflogii* (Grunow) K. Stachura-Suchoples et D.M. Williams; D, E, F – *Cyclotella distinguenda* Hustedt; G – *Cymbopleura* sp.; H – *Eunotia subarcuatoides* Alles, Norpel et Lange-Bertalot; I – *Fallacia pygmaea* (Kützing) Stickle et D.G. Mann. Scale bars: A – 1 μm; B, E, G – 2 μm; C, D, F, H, I – 5 μm

Placoneis paraelginensis Lange-Bertalot (Fig. 3J).Valve length 21.2 μm, width 7 μm, striae 16 in 10 μm. Europe (Lange-Bertalot et al. 2017). In Russia, several records of the species are known from water bodies and streams of the European part, Eastern and Western Siberia (Chudaev & Gololobova 2016, Genkal & Yarushina 2022).

Planothidium sp. (Fig. 3K). Valve elliptical-lanceolate, ends widely rounded, length 13 μm, width 4.7 μm. Raphe valve with narrow axial area. Central area rectangular-elongated. Raphe straight. Striae radial, three-row, 14 in 10 μm.

DISCUSSION

Of the 49 species of algae we found in the Tolmachev Lake, 37 were previously described from other water bodies of Kamchatka. These are *Achanthidium minutissimum* (Kützing) Czarnecki, *Aulacoseira ambigua* (Grunow) Simonsen, *A. scalaris* (Grunow) Houk, Klee et Passauter, *A. subarctica* (O. Müller) Haworth, *Brachysira brebissonii* Ross, *Chamaepinnularia krookii* (Grunow) Lange-Bertalot et Krammer, *Cocconeis lineata* Ehrenberg, *Cyclotella atomus* Hustedt, *C. meneghiniana* Kützing, *Cymbella cymbiformis* Agardh, *Discostella stelligera* (Cleve et Grunow) Houk et Klee, *Encyonema silesiacum* (Bleish) D.G. Mann, *Epithemia adnata* (Kützing) Brébisson, *Eunotia minor* (Kützing) Grunow, *Fragilaria capucina* Desmazieres, *F. crotonensis* Kitton, *F. gracilis* Oestrup, *Frustulia crassinervia* (Brébisson) Lange-Bertalot et Krammer, *Gomphonema micropus* Kützing, *Karayevia amoena* (Hustedt) Bukhtiyarova, *Meridion circulare* var. *constrictum* (Ralfs) V. Heuick, *Navicula cryptocephala* Kützing, *N. cryptotenella* Lange-Bertalot, *Nitzschia bacilliformis* Hustedt, *N. frustulum* (Kützing) Grunow, *N. perminuta* (Grunow) Peragallo, *Pantocsekiella ocellata* (Pantocsek) K.T. Kiss et Ács, *P. tripartita* (Håkansson) K.T. Kiss et Ács, *Planothidium helveticum* (Hustedt) Bukhtiyarova et Round, *P. lanceolatum* (Brébisson) Lange-Bertalot, *Psammothidium bioretii* (Germain) Bukhtiyarova et Round, *P. subatomoides* (Hustedt) Bukhtiyarova et Round, *Tabellaria flocculosa* (Roth) Kützing (Genkal & Lupikina 1998, Genkal et al. 2004, 2007, Genkal & Lepskaya 2009, 2013а,б,с, 2014а,б, 2015, Kharitonov & Genkal 2012, Medvedeva & Nikulina 2014, Nikulina et al. 2016, Nikulina & Grishchenko 2017, Nikulina & Sorokin 2021, Genkal 2022).

Most of the identified genera (14) were represented by by a single species, and only 7 genera included 3 species each: *Aulacoseira*, *Cyclotella*, *Fragilaria*, *Navicula*, *Nitzschia*, *Pantocsekiella*, *Planothidium*.

Earlier studies of the phytoplankton of the Tolmachev Lake using light microscopy revealed 18 Bacillariophyta species (*Aulacoseira subarctica* (O. Müller) Haworth, *Asterionella formosa* Hassal, *Cyclotella pseudostelligera* Hustedt, *C. tripartita* Håkansson, *Fragilaria crotonensis* Kitton, *Nitzschia*

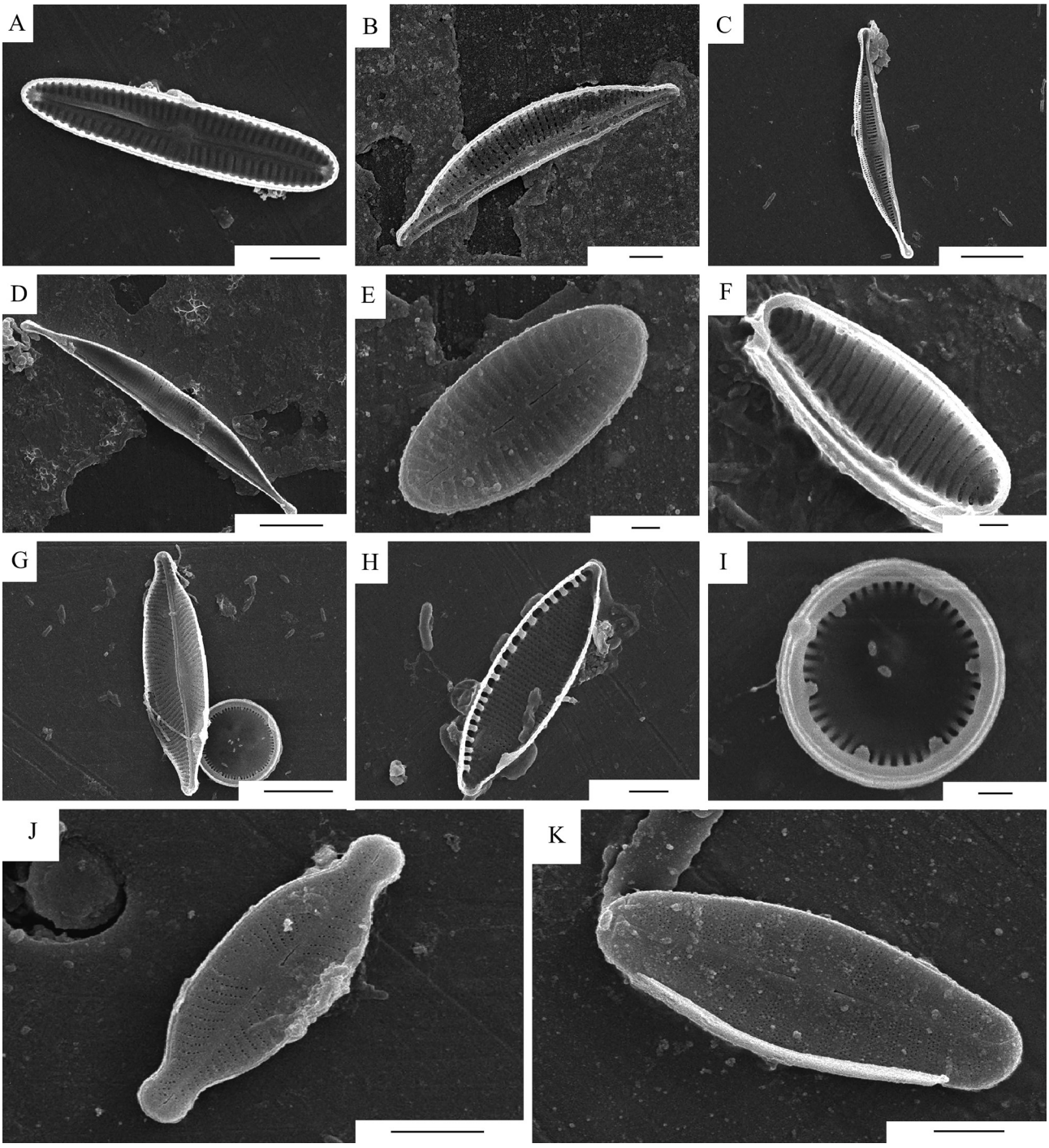

Figure 3 A – *Gomphosphenia stoermeri* Kocioleket Thomas; B – *Halamphora borealis* (Kützing) Levkov, C, D – *Halamphora hybrida* (Grunow) Levkov; E – *Karayevia suchlandtii* (Hustedt) Bukhtiyarova; F – *Martyana schulzii* (C. Brockmann) Snoeijs; G – *Navicula salinarum* Grunow; H – *Nitzschia* sp.; I – *Pantocsekiella* sp.; J – *Placoneis paraelginensis* Lange-Bertalot; K – *Planothidium* sp. Scale bars:A, B, H, K – 2 μm; C, D, G – 10 μm; E, F, I – 1 μm; J – 5 μm

acicularis W. Smith, *N. filiformis* (W.Smith) Hustedt, *Staurosira elliptica* (Shum.) Williams et Round, *Stephanodiscus* sp., *Synedra acus* Kützing, *S.* cf. *actinastroides* Lemm., *S.* cf. *delicatissima* (W. Smith) Lange-Bertalot, *S. ulna* (Nitzsch.) Ehrenberg, *S. ulna* var. *danica* (Kützing) Grunow, *S. vaucheriae* Kützing, *Tabellaria fenestrata* (Lyngb.) Kützing, *T. flocculosa* (Roth.) Kützing, *Urosolenia eriensis* (H.L. Sm.) Round et Crawford) from 10 genera (Lepskaya 2003). At present, some of the listed taxa have changed their systematic position and have been transferred to other genera or have changed their status: *Cyclotella pseudostelligera* Hustedt – *Discostella pseudostelligera* (Hustedt) Houk et Klee, *Cyclotella tripartita* Håkansson – *Pantocsekiella tripartita* (Håkansson) K.T. Kiss et Ács, *Synedra acus* Kützing – *Ulnaria acus* (Kützing) Aboal, *Synedra ulna* var. *danica* (Kützing) Grunow – *Ulnaria danica* (Kützing) Compere et Bukhtiyarova, *Synedra vaucheriae* Kützing – *Fragilaria vaucheriae* (Kützing) Petersen. Of the 18 taxa identified earlier (Lepskaya 2003), we recorded only three (*Aulacoseira subarctica*, *Pantocsekiella tripartita*, *Tabellaria flocculosa*). Most of the discovered new taxa for the flora of Kamchatka are rare species, and our study has expanded their range. Considering the species described in electron

microscopy studies, the taxonomic spectrum of diatoms from the Lake Tolmachev expanded significantly – from 17 species to 58 and from 9 genera to 29.

CONCLUSION

According to the electron microscopy data, 45 species of diatoms from 28 genera were found in the phytoplankton of the Tolmachev Reservoir (Lake Tolmachev) and 4 algae were identified only to the genus. The diatom species we detected include 12 taxa from 11 genera new to the Bacillariophyta flora of Kamchatka which expanded the list of algae in this waterbody at the species and generic levels. The data obtained complement our understanding of the species ranges and are a valuable contribution to the knowledge of Kamchatka biodiversity.

ACKNOWLEDGEMENTS

This study was conducted in the framework of state assignment, projects No. 121051100099-5.

LITERATURE CITED

Balonov, I.M. 1975. Preparation of algae for electron microscopy. In: *Methods of studying biogeocenoses of inland water bodies* (F.D. Mordukhai-Boltovskoi, ed.), pp. 87–89, Nauka, Moscow (in Russian). [Балонов И.М. 1975. Подготовка водорослей к электронной микроскопии // Методика изучения биогеоценозов внутренних водоемов / отв. ред. Ф.Д. Мордухай-Болтовской. М.: Наука. С. 87–89].

Cantonati, M. & H. Lange-Bertalot 2006. *Achnanthidium dolomiticum* sp. nov. (Bacillariophyta) from oligotrophic mountain springsand lakes fed by dolomite aquifers. *Journal of Phycology* 42:1184–1188.

Chudaev, D.A. & M.A. Gololobova 2016. *Diatom algae in Lake Glubokoe (Moscow Region)*. KMK, Moscow, 447 pp. (in Russian). [Чудаев Д.А., Гололобова М.А. 2016. Диатомовые водоросли озера Глубокого (Московская область). М.: Товарищество научных изданий КМК. 447 с.].

Elenkin, A.A. 1914. Fresh water algae of Kamchatka. In: *Kamchatka expedition of F.P. Ryabushinsky. Botanical Department. Issue II: Spore plants: 1) algae, 2) fungi* (A.A. Elenkin, ed.), pp. 3–402, Tip. P.P. Ryabushinskogo, Moscow (in old Russian). [Еленкин А.А. 1914. Пресноводные водоросли Камчатки // Камчатская экспедиція Ѳ.П. Рябушинского. Ботаническій отдѣлъ. Вып. II: Споровыя растенія Камчатки: 1) водоросли, 2) грибы / под ред. А.А. Еленкина. М.: Тип. П.П. Рябушинского. С. 3–402].

Genkal, S.I. & L.G. Lupikina 1998. New and rare species of *Aulacosira* (Bacillariophyta) from Caldera Lakes of Kamchatka. *Botanicheskii Zhurnal* 83(2):104–110, 158–161 (in Russian). [Генкал С.И., Лупикина Л.Г. 1998. Новые и редкие виды *Aulacosira* (Bacillariophyta) кальдерных озер Камчатки // Ботанический журнал. Т. 83, № 2. С. 104–110, 158–161].

Genkal, S.I., E.G. Lupikina & E.V. Lepskaya 2004. *Cyclotella tripartite* Håkansson (Bacillariophyta) from lakes of Kamchatka and Eastern Baikal Region. *Botanicheskii Zhurnal* 89(3):426–435 (in Russian). [Генкал С.И., Лупикина Е.Г., Лепская Е.В. 2004. *Cyclotella tripartita* (Bacillariophyta) из озер Камчатки и Забайкалья // Ботанический журнал. Т. 89, № 3. С. 426–435].

Genkal, S.I., E.V. Lepskaya & E.G. Lupikina 2007. Diatoms of Khangar Lake (Kamchatka). *Botanicheskii zhurnal* 92(10):1500–1507 (in Russian). [Генкал С.И., Лепская Е.В., Лупикина Е.Г. 2007. Диатомовые водоросли озера Хангар (Камчатка) // Ботанический журнал. Т. 92, № 10. С. 1500–1507].

Genkal, S.I. & N.V. Vekhov 2007. *Diatom algae of water bodies in the Russian Arctic: Novaya Zemlya Archipelago and Vaigach island*. Nauka, Moscow, 64 pp. (in Russian). [Генкал С.И., Вехов Н.В. 2007. Диатомовые водоросли водоемов Русской Арктики : архипелаг Новая Земля и остров Вайгач. М.: Наука. 64 с.].

Genkal S. I. & E.V. Lepskaya 2009. Ecology, morphological variability and distribution of *Stephanodiscus niagarae* (Bacillariophyta) in Russia. *Povolzhskii Ekologicheskii Zhurnal* 1:15–25 (in Russian). [Генкал С.И., Лепская Е.В. 2009. Экология, морфологическая изменчивость и распространение *Stephanodiscus niagarae* (Bacillariophyta) в России // Поволжский экологический журнал. № 1. С. 15–25].

Genkal, S.I. & I.S. Trifonova 2009. *Diatom algae of the plankton of Lake Ladoga and water-bodies of its basin*. Rybinskii Dom Pechati, Rybinsk, 72 pp. (in Russian). [Генкал С.И., Трифонова И.С. 2009. Диатомовые водоросли планктона Ладожского озера и водоемов его бассейна. Рыбинск: Рыбинский Дом печати. 72 с.].

Genkal, S.I., N.A. Bondarenko & L.A. Shchur 2011. *Diatom algae of lakes in southern and northern Eastern Siberia*. Rybinskii Dom Pechati, Rybinsk, 72 pp. (in Russian). [Генкал С.И., Бондаренко Н.А., Щур Л.А. 2011. Диатомовые водоросли озер юга и севера Восточной Сибири. Рыбинск: Рыбинский дом печати. 72 с.].

Genkal, S. I. & E.V. Lepskaya 2013a. On morphology, ecology and distribution of *Stephanodiscus alpinus* (Bacillariophyta). *Novosti sistematiki nizshikh rastenii* 47:28–36 (in Russian). [Генкал С.И., Лепская Е.В. 2013a. К морфологии, экологии и распространению *Stephanodiscus alpinus* (Bacillariophyta) // Новости систематики низших растений. Т. 47. С. 28–36].

Genkal, S.I. & E.V. Lepskaya 2013b. *Stephanodiscus popovskayae*, a new species from the volcanic lakes of Kamchatka in East Asia, Russia. *Diatom Research* 28(4):365–372.

Genkal, S.I. & E.V. Lepskaya 2013c. Materials for the flora of centric diatoms of the lake Nerpichye (estuaries of the Kamchatka River). *Issledovaniya vodnykh biologicheskikh resursov Kamchatki i severo-zapadnoi chasti Tikhogo okeana* 31: 62–73 (in Russian). [Генкал С.И., Лепская Е.В. 2013c. Материалы к флоре центрических диатомовых водорослей оз. Нерпичье (эстуарии р. Камчатка) // Исследования водных биологических ресурсов Камчатки и северо-западной части Тихого океана. Вып. 31. С. 62–73].

Genkal, S.I. & E.V. Lepskaya 2014a. Flora of diatoms of salmon lakes of the Koryak highlands of Kamchatka. *Issledovaniya vodnykh biologicheskikh resursov Kamchatki i severo-zapadnoi chasti Tikhogo okeana* 35:31–47 (in Russian). [Генкал С.И., Лепская Е.В. 2014a. Флора диатомовых водорослей лососевых озер Корякского нагорья Камчатки // Исследования водных биологических ресурсов Камчатки и Северо-Западной части Тихого океана. Вып. 35. С. 31–47].

Genkal, S.I. & E.V. Lepskaya 2014b. Centric diatom algae of volcanic Verkhneavachinsk lakes (Kamchatka). *Biology of Inland Waters* 7(1):1–9.

Genkal, S.I., T.A. Chekryzheva & S.F. Komulaynen 2015. *Diatom algae in waterbodies and watercourses of Karelia*. Nauchnyi mir, Moscow, 202 pp. (in Russian). [Генкал С.И., Чекрыжева Т.А., Комулайнен С.Ф. 2015. Диатомовые водоросли водоемов и водотоков Карелии. М.: Научный мир. 202 с.].

Genkal, S.I. & E.V. Lepskaya 2015. Materials to the flora of Bacillariophyta of Lake Kronotskoye (The Kamchatka Peninsula). *International Journal on Algae* 17(1):14–22.

Genkal, S.I., A.G. Okhapkin & E.L. Vodeneeva 2019. On the morphology and taxonomy of *Cyclotella distinguenda* (Bacillariophyta). *Novosti sistematiki nizshikh rastenii* 53(2): 247–253.

Genkal, S.I. & O.G. Gorokhova 2021. Diatoms (Bacillariophyta) of rivers flowing into the Lake Elton. *Botanicheskii Zhurnal* 106(4): 315–323 (in Russian). [Генкал С.И., Горохова О.Г. 2021. Диатомовые водоросли (Bacillariophyta) рек, впадающих в озеро Эльтон // Ботанический журнал. Т. 106, № 4. С. 315–323].

Genkal, S.I. & T.V. Eremkina 2022. Morphological variability of species of the genus *Achnanthidium* (Bacillariophyta) rare for the flora of Russia. *Trudy Instituta biologii vnutrennih vod im. I.D. Papanina RAN* 98(101):55–61 (in Russian). [Генкал С.И., Еремкина Т.В. 2022. Морфологическая изменчивость редких для флоры России видов рода *Achnanthidium* (Bacillariophyta) // Труды Института биологии внутренних вод им. И.Д. Папанина РАН. Вып. 98(101). С. 55–61].

Genkal, S.I., M.S. Kulikovskiy & I.V. Kuznetsova 2020. *Modern freshwater centric diatom algae of Russia*. Filigran', Yaroslavl, 433 pp. (in Russian). [Генкал С.И., Куликовский М.С., Кузнецова И.В. 2020. Современные пресноводные центрические диатомовые водоросли России. Ярославль: Филигрань. 433 с.].

Genkal, S.I. & M.I. Yarushina 2022. Species of the genus *Placoneis* (Bacillariophyta) in Russia: morphology, taxonomy, distribution. *Botanicheskii zhurnal* 107(2):159–172 (in Russian). [Генкал С.И., Ярушина М.И. 2022. Виды рода *Placoneis* (Bacillariophyta) в России: морфология, таксономия, распространение // Ботанический журнал. Т. 107, № 2. С. 159–172].

Golovenkina, N.I. 1981. Diatoms from thermal springs of the Uzon volcano caldera in Kamchatka. *Trudy Biologicheskogo Nauchno-Issledovatel'skogo Instituta* 30:132–148 (in Russian). [Головенкина Н.И. 1981. Диатомовые водоросли из термальных источников кальдеры вулкана Узон на Камчатке // Труды биологического научно-исследовательского института. Вып. 30. С. 132–148].

Houk, V., R. Klee & H. Tanaka 2010. Atlas of freshwater centric diatoms with a brief key and descriptions. Part III. Stephanodiscaceae. A. *Cyclotella*, *Tertiarius*, *Discostella*. *Fottea* 10(Suppl.):1–498.

Houk, V., R. Klee & H. Tanaka 2017. Atlas of freshwater centric diatoms with a brief key and descriptions. Second emended edition of Part I and II. Melosiraceae, Orthoseraceae, Paraliaceae and Aulacoseiraceae. *Fottea* 17 (Suppl.):1–616.

Kharitonov, V.G. & S.I. Genkal 2012. *Diatoms of the Elgygytgyn Lake and its vicinities (Chukotka)*. SVNTs DVO RAN, Magadan, 402 pp. (in Russian). [Харитонов В.Г., Генкал С.И. 2012. Диатомовые водоросли озера Эльгыгытгын и его окрестностей (Чукотка). Магадан: СВНЦ ДВО РАН, 402 с.].

Kozyrenko, T.F., L.P. Loginova, S.I. Genkal, G.K. Khursevich & V.S. Sheshukova-Poretskaya 1992. The genus *Cyclotella* Kütz. In: *Diatoms of the USSR (fossil and modern), vol. II., issue 2* (I.V. Makarova, ed.), pp. 24–46, Nauka, Leningrad (in Russian). [Козыренко Т.Ф., Логинова Л.П., Генкал С.И., Хурсевич Г.К., Шешукова-Порецкая В.С. 1992. Род *Cyclotella* Kütz. // Диатомовые водоросли СССР (ископаемые и современные) / под ред. И.В. Макаровой. Л.: Наука. Т. II. вып. 2. С. 24–46].

Krammer, K. 2002. *Diatoms of Europe, vol. 3. Cymbella*, Koeltz Botanical Books, Oberreifenberg, 584 pp.

Krammer, K. 2003. *Diatoms of Europe, vol. 4. Cymbopleura*, *Delicata*, *Navicymbula*, *Gomphocymbellopsis*, *Afrocymbella*. Koeltz Botanical Books, Oberreifenberg, 530 pp.

Krammer, K. & H. Lange-Bertalot 1986. Bacillariophyceae. Teil 1. Naviculaceae. In: *Sußwassweflora von Mitteleuropa, Bd. 2* (berg. Von A. Pascher), S. 1–876. Gustav Fisher Verlag, Stuttgart.

Krammer, K. & H. Lange-Bertalot 1988. Bacillariophyceae. Teil 2. Epithemiaceae, Bacillariaceae, Surirellaceae. In: *Sußwassweflora von Mitteleuropa, Bd. 2* (berg. H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer), S. 1–437. Gustav Fisher Verlag, Jena.

Krammer, K. & H. Lange-Bertalot 1991. Bacillariophyceae. Teil. 4. Achnanthaceae, Kritische Erganzungen zu *Navicula* (Lineolatae) und *Gomphonema* In: *Sußwassweflora von Mitteleuropa, Bd. 4* (berg. H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer), S. 1–437. Gustav Fisher Verlag, Stuttgart.

Kulikovskiy, M.S., A.M. Glushchenko, S.I. Genkal & I.V. Kuznetsova 2016. *Key to diatoms of Russia*, Filigran', Yaroslavl, 803 pp. (in Russian). [Куликовский М.С., Глущенко А.М., Генкал С.И., Кузнецов И.В. 2016. Определитель диатомовых водорослей России. Ярославль: Филигрань. 803 с.].

Lange-Bertalot, H. 2001. *Navicula* sensu stricto, 10 genera separated from *Navicula* sensu lato, *Frustulia*. In: *Diatoms of Europe, vol. 2* (H. Lange-Bertalot, ed.), pp. 1–526, A.R.G. Gantner Verlag K.G.

Lange-Bertalot, H. & G. Moser 1994. *Brachysira* Monographie der Gattung. Wichtige indicator-species für das gewässer-monitoring und naviculadicta nov. gen. Ein lösungsvorschlag zu dem problem *Navicula* sensu lato onhe *Navicula* sensu stricto. In: *Bibliotheca Diatomologica*, Bd 29, Berlin, Stuttgart, 212 s.

Lange-Bertalot, H. & S.I. Genkal 1999. Diatomeen aus Sibirien, I: Inseln im Arktischen Ozean. In: *Iconographia Diatomologica, volume 6: Phytogeography, Diversity, Taxonomy* (H. Lange-Bertalot & S.I. Genkal, eds), pp. 7–272, A.R.G. Gantner Verlag K.G.

Lange-Bertalot, H., M. Bak & A. Witkowski 2011. *Eunotia* and some related genera. In: *Diatoms of Europe, vol. 6* (H. Lange-Bertalot, ed.), pp. 1–747, A.R.G. Gantner Verlag K.G.

Lange-Bertalot, H., G. Hofmann, M. Werum & M. Cantonati 2017. *Freshwater benthic diatoms of Central Europe*. Schmitten, Oberreifenberg, 942 pp.

Lepskaya, E.V. 2003. Phytoplankton of the Tolmachevo reservoir in the initial stage of its existence. In: *Proceedings of the 3rd scientific conference "Conservation of biodiversity of Kamchatka and adjacent seas" November 27–28, 2002* (A.M. Tokranov, ed.), pp. 80–86, Petropavlovsk-Kamchatskiy (in Russian). [Лепская Е.В. 2003. Фитопланктон Толмачевского водохранилища в начальной стадии его существования // Доклады III научн. конференции "Сохранение биоразнообразия Камчатки и прилегающих морей" 27–28 ноября 2002, г. Петропавловск-Камчатский / отв. ред. А.М. Токранов. Петропавловск-Камчатский. С. 80–86.

Lepskaya, E.V. 2007. Phytoplankton of the Lake Palansky. Taxonomy, ecology, dynamics of quantitative characteristics. *The researches of the aquatic biological resources of Kamchatka and the North-West Part of the Pacific Ocean* 9:10–20.

Lepskaya, E.V. 2008. *Synedra cyclopum* Brutschy in several lakes of Kamchatka. In: *Proceedings of the 19th International Diatom Symposium held at Listvyanka, Irkutsk, Russia, from 28 August to 3 September 2008* (E. Likhoshway, ed.), p. 86, Irkutsk.

Levkov, Z. 2009. *Amphora* sensu lato. In: *Diatoms of Europe, vol. 5* (H. Lange-Bertalot, ed.), pp. 1–916, A.R.G. Gantner Verlag K.G.

Levkov, Z., D. Mitić-Kopanja & E. Reichardt. 2016. The diatom genus *Gomphonema* from the Republik of Macedo-

nia. In: *Diatoms of Europe, vol. 5* (H. Lange-Bertalot, ed.), pp. 1–552, A.R.G. Gantner Verlag K.G.

Medvedeva, L.A. & T.V. Nikulina 2014. *Catalogue of freshwater algae of the Southern part of the Russian Fare East*. Dalnauka, Vladivostok, 271 pp. (in Russian). [Медведева Л.А., Никулина Т.В. 2014. Каталог пресноводных водорослей юга Дальнего Востока России. Владивосток: Дальнаука. 271 с.].

Nikulina, T.V., E.G. Kalitina, E.A. Vakh & N.A. Kharitonova 2016. List of diatoms from three hot springs from Kamchatka – Malkinskiye, Nachikinskiye and Verhne-Paratunskiye (Russia). *Zhizn' presnykh vod* 2:108–115 (in Russian with English abstract). [Никулина Т.В., Калитина Е.Г., Вах Е.А., Харитонова Н.А. 2016. Список диатомовых водорослей трех термальных источников Камчатки – Макинских, Начикинских и Верхне-Паратунских (Россия) // Жизнь пресных вод. Вып. 2. 108–115].

Nikulina, T.V. & O.V. Grishchenko 2017. Diatom flora of Dachnye thermal springs (Kamchatka peninsula, Russia). *Vladimir Ya. Levanidov's Biennial Memorial Meetings* 7:185–193 (in Russian with English abstract). [Никулина Т.В., Грищенко О.В. 2017. Флора диатомовых водорослей Дачных термальных источников (Камчатка, Россия) // Чтения памяти Владимира Яковлевича Леванидова. Вып. 7. С. 185–193.]

Nikulina, T.V. & Yu.V. Sorokin 2021. Diatom flora of the Fal'shivaya river (Kamchatka). *Vladimir Ya. Levanidov's Biennial Memorial Meetings* 9:129–139 (in Russian with English abstract). [Никулина Т.В., Сорокин Ю.В. 2021. Диатомовая флора р. Фальшивая (Камчатка) // Чтения памяти Владимира Яковлевича Леванидова. Вып. 8. С. 129–139].

Pogodaev, E.G., S.I. Kurenkov, L.A. Bazarkina, S.V. Shubkin & N.Yu. Voronin 2010. Population of introduced kokanee in the conditions of transformation of the Tolmachev Lake into water-reservoir. *Voprosy Rybolovstva* 11(1): 65–78 (in Russian). [Погодаев Е.Г, Куренков С.И., Базаркина Л.А., Шубкин С.В., Воронин Н.Ю. 2010. Популяция интродуцированной кокани в условиях преобразования озера Толмачева в водохранилище // Вопросы рыболовства. Т. 11, №1. С. 65–78].

Tepnin, O.B., E.V. Lepskaya, T.V. Bonk & M.A. Pokhodina 2018. The habitat of Kokanee (*Oncorhynchus nerka*, kennerley's salmon) in Tolmachev Reservoir in 2018. *Bulleten Izucheniya Tikhookeanskikh Lososei Na Dal'nem Vostoke* 13:210–221 (in Russian). [Тепнин О.Б., Лепская Е.В., Бонк Т.В., Походина М.А. 2018. Условия среды обитания кокани (*Oncorhynchus nerka*, kennerley's salmon) в Толмачевском водохранилище в 2018 г. // Бюллетень изучения тихоокеанских лососей на Дальнем Востоке. Владивосток: ТИНРО-центр. № 13. С. 210–221.]

Shkurina, N.A, E.V. Lepskaya & G.V. Belyakova 2004. Diatom algae of Dal'nee Lake (Kamchatka). *Issledovaniya vodnykh biologicheskikh resursov Kamchatki i severo-zapadnoi chasti Tikhogo okeana* 7:88–93 (in Russian with English abstract). [Шкурина Н.А., Лепская Е.В., Белякова Г.В. 2004. Диатомовые водоросли озера Дальнее (Камчатка) // Исследования водных биологических ресурсов Камчатки и Северо-Западной части Тихого океана. Вып. 7. С. 88–93].