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New for Ukraine Representatives of *Bacillariophyta* from Phytoepiphyton of the Dnieper River Reservoirs (Ukraine)*

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ABSTRACT: Samples of epiphyton collected in 2016–2018 from the Dnieper River reservoirs were studied using scanning electron microscopy and revealed 15 new species for Ukrainian taxa of diatoms. A total of 133 species (138 intraspecific taxa) of *Bacillariophyta* in the phytoepiphyton of Kyiv, Kaniv, Kremenchuk, Kamianske, Zaporizhzhia, Kahovka reservoirs and in the Lower Dnieper were identified. They belong to 43 genera, 22 families, 13 orders, and 3 classes. Among them, 15 taxa are new records for Ukraine: 14 species and one variety from the genera *Achnanthidium* Kützing, *Amphora* Ehrenberg, *Cymbella* Agardh, *Encyonema* Kützing, *Gomphonema* Ehrenberg, *Halamphora* (P.T.Cleve) Levkov, *Navicula* Bory, and *Nitzschia* Hassall. Here we give their brief descriptions illustrated by original microphotographs, synonyms, ecological features, and sampling localities are presented as well. Most of the newly cited Ukraine epiphytic pennate diatoms found on higher aquatic plants are common freshwater taxa. They also include two freshwater-brackish species (*Halamphora thermalis* (Hustedt) Levkov and *Navicula vekhovii* Lange-Bertalot et Genkal). *Navicula* cf. *vaneei* Lange-Bertalot may occur in the moderately to high mineralized water; *Halamphora* cf. *subholsatica* (Krammer) Levkov inhabits mesohaline water bodies. Seven taxa from the genera *Amphora, Aneumastus* D.G.Mann & Stickle, *Cymbella*, *Gomphonema*, *Nitzschia*, and *Ulnaria* Compére were identified to the genus. The largest number of new and interesting records of pennane *Bacillariophyta* were found in Kremenchuk and Kaniv reservoirs, and in the Lower Dnieper. New for Ukraine diatom species belong to the class *Bacillariophyceae*. The algae, identified only to the genus, belong to the classes *Bacillariophyceae* and *Fragilariophyceae*. It has been suggested that the centric small-cell planktonic forms of diatoms respond more quickly to

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increased salinity of the Dnieper water than the pennate forms occurring in epiphyton. This reaction is because the phytoepiphyton is a more inert algocenosis compared to phytoplankton.

KEY WORDS: *Bacillariophyta*, Dnieper reservoirs, phytoepiphyton, new records, pennate diatoms, scanning electron microscopy, Ukraine

INTRODUCTION

In a work that summarizes freshwater and marine diatoms of Ukraine, 1163 taxa of the species and intraspecific rank from 154 genera were cited; representatives of 95 genera were recorded in fresh water bodies and watercourses (Algae…, 2009). Recently, the generic list was replenished with taxa of *Bacillariophyta* from genera *Actinocyclus* Ehrenb., *Achnanthes* Bory, *Amphora* Ehrenb., *Aneumastus* D.G.Mann & Stickle, *Brachysira* Kütz., *Caloneis* P.T.Cleve, *Cymatopleura* W.Sm., *Cymbella* C.Agardh, *Cymbopleura* (Krammer) Krammer, *Encyonema* Kütz., *Eunotia* Ehrenb., *Fragilaria* Lyngb., *Frustulia* Rabenh., *Gomphonema* Ehrenb., *Navicula* Bory, *Opephora* P.Petit, *Placoneis* Mereschk., *Plagiotropsis* Pfitzer, *Planothidium* Round & Bukht., *Psammothidium* Bukht. & Round, *Pseudostaurosira* D.M.Williams & Round, *Puctistriata* D.M.Williams & Round, *Stauroneis* Ehrenb. (Krivenda et al., 2007; Bukhtiyarova, 2009, 2012; Lialiuk and Klimiuk, 2011; Krivenda, 2012; Lilitskaya et al., 2012; Kapustin, 2013; Kryvosheia and Krivenda, 2015; Lilitskaya, 2016a, b; Kryvosheia, 2018; Kryvosheia and Tsarenko, 2018; Beresovskaya, 2019; Tsarenko et al., 2014). A number of diatoms were identified only to the genus: *Cocconeis* Ehrenb., *Fragilaria*, *Navicula*, *Punctastriata*, *Sellaphora* Mereschk., *Stauroneis* (Lilitskaya et al., 2012; Lilitskaya, 2016a, b).

In the spring and autumn, diatoms are known to be diverse and abundant in the algal flora of plankton, benthos, and periphyton of the Dnieper and Dnieper reservoirs (Sirenko et al., 1989).

The use of scanning and transmission electron microscopy has significantly expanded the list of centric planktonic diatoms of the Kiev and Kaniv reservoirs (Genkal and Scherbak, 1987; Scherbak et al., 2006; Maistrova et al., 2007). Small-cell centric brackish-water diatoms from genera *Thalassiosira* P.T.Cleve and *Skeletonema* Greville for the first time were discovered in the plankton of upper cascade reservoirs.

Modern adventitization of the Dnieper algoflora confirms the previously noted tendency to increase the mineralization of the Dnieper water (Romanenko et al., 2000).

A study of the taxonomic diversity of phytoepiphyton of the Dnieper reservoirs showed that pennate diatoms play a significant role in phytofouling of higher aquatic plants of various ecological groups (Aquatic-landscape..., 2014; Zadorozhna et al., 2017). However, the determination of their generic, and especially species affiliation, using light

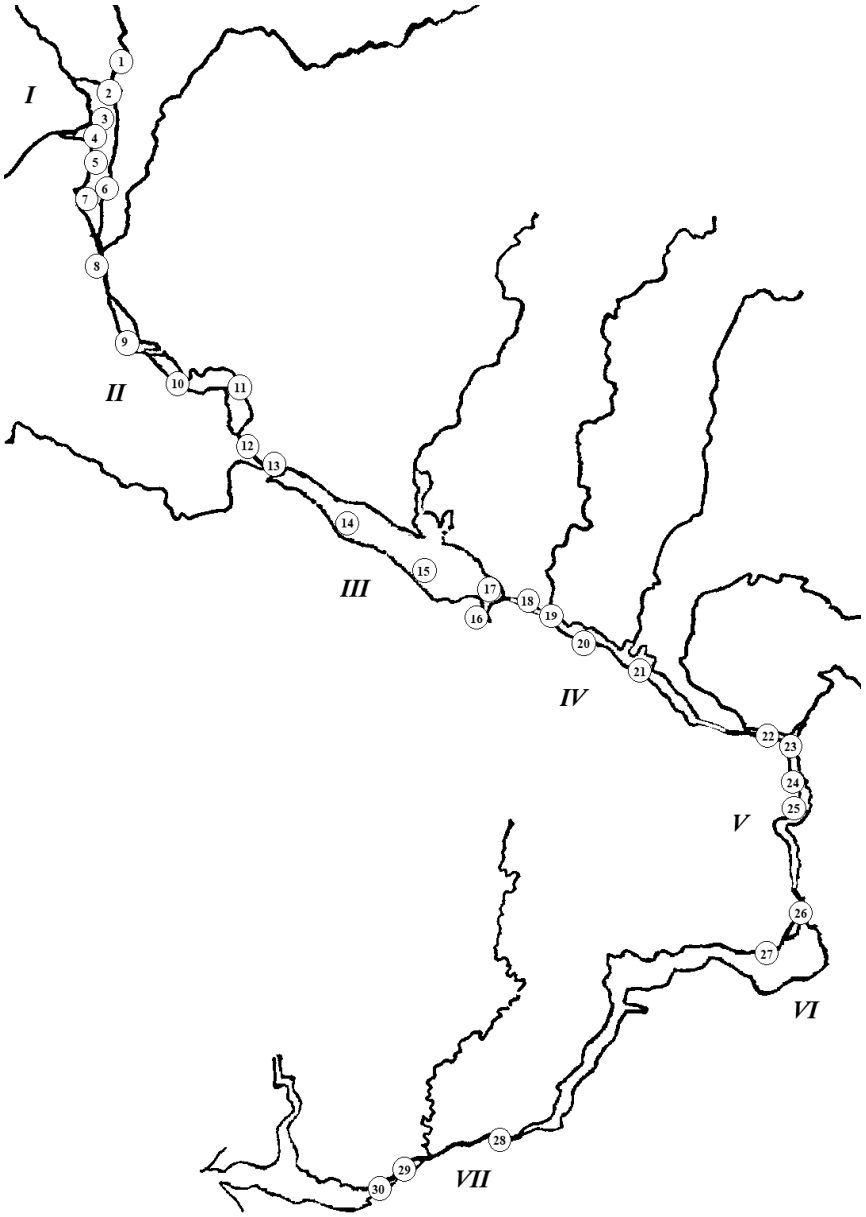
microscopy, even with an immersion lens, is very problematic. Therefore, to more accurately determine the taxonomic diversity of pennate forms of Bacillariophyta in the Dnieper phytoepiphyton, electron microscopy should be used, which, in comparison with light microscopy, allows for a more subtle diagnostic analysis of diatoms, especially small-cell taxa.

Here we present the new records of pennate diatoms from the phytoepiphyton of the cascade of the Dnieper reservoirs and the Lower Dnieper studied using scanning electron microscopy.

MATERIALS AND METHODS

Samples of phytoepiphyton were collected from the Dnieper River cascade of reservoirs during 2016–2018. Sampling stations (S) were located in the Kyiv, Kaniv, Kremenchuk, Kamianske (former Dneprodzerzhynsk), Zaporizzzia (=Dnieper) and Kakhovka reservoirs and in the Lower Dnieper near Kherson (see the map). The Kyiv Reservoir was sampled in 2016 in the upper (Ss 1–2), middle (Ss 3–4), and lower (Ss 5–7) portions: the shallows near the traverse dam of the village of Nizhny Zhary (S 1); village of Teremtsy (S 2); the island of Domontovo (S 3); village of Strakholesye (S 4); village of Tolokun (S 5); village of Rovzhi (S 6); village of Glebovka (S 7). At the Kaniv, Kremenchuk, Kamianske, Dnieper, and Kahovka reservoirs studies were carried out in 2017 as part of a hydro-ecological expedition to the Dnieper cascade, organized by the Ukrainian Hydrometeorological Institute of the State Emergencies Service of Ukraine and the NAS of Ukraine. The location of sampling stations was determined next. Kaniv Reservoir: the upper part within the city of Kiev (S 8), below the town of Ukrainka (S 9), the middle part on the traverse of the city of Rzhyshchev (S 10), the lower part at the entrance to Pereyaslavsky Bay (S 11); Kremenchuk Reservoir: the upper part above the village of Khreschatyk (S 12), on the traverse of the Olshansky shallows (S 13), the lower middle part in the town of Cherkassy (S 14), below village Adamovka (S 15), the lower part at the entrance to the Tsybulnitsky Bay (S 16), on the traverse of the town of Svetlovodsk (S 17); Kamianske Reservoir: the upper part within the town of Kremenchug (S 18), in the area of the confluence of the Psel River (S 19); the middle part on the traverse dam of the village of Derievka (S 20), the lower part on the traverse dam of the village Borodaevka (S 21); Zaporizhzhya (Dnieper) Reservoir: the upper part below the confluence of the Konoplyanka River (S 22), the middle part within the Dnieper city on the traverse of the Samara Bay (S 23) and the village of Alekseyevka (S 24), below the village of Voiskovoe (S 25); Kakhovka Reservoir: the upper part on the traverse of the village of Kushugum (S 26) and the village of Belenkoe (S 27).

In the Lower Dnieper section, samples were taken during the vegetational season of 2018 above (village of Ivanovka, S 28), in (S 29) and below (S 30) the town of Kherson.



A schematic map of the reservoirs of the Dnieper cascade and the Lower Dnieper section with phytoepiphyton sampling stations: I – Kyiv Reservoir, II – Kaniv Reservoir, III – Kremenchuk Reservoir, IV – Kamianske Reservoir, V – Zaporizhzhia Reservoir, VI – Kakhovka Reservoir, VII – Lower Dnieper. The locations of sampling stations are given in *Materials and Methods*

Algae samples were taken from aquatic plants of the dominant complex of the Dnieper higher vegetation (Sirenko et al., 1989): *Phragmites australis* (Cav.) Trin. ex Steud., *Potamogeton pectinatus* L., *Ceratophyllum demersum* L., and *Myriophyllum spicatum* L.

Fragments of plants 5–8 cm long were carefully cut under water, placed in glasses with a volume of 100 cm^3 with distilled water added. In the laboratory, fouling was cleaned with a special brush and fixed by 5 mL of 40% formalin (Methods..., 2006; Semenyuk and Shcherbak, 2016).

Diatom valves were released from organic substances by the method of cold burning (Balonov, 1975). Algae preparations were examined using a JSM-25S scanning electron microscope. Diatoms were identified using modern identification manuals and taxonomic treaties: Krammer and Lange-Bertalot, 1986, 1988, 1991a, b; Lange-Bertalot and Moser, 1994; Krammer, 1997a, b, 2000, 2002, 2003; Lange-Bertalot and Genkal, 1999; Reichardt, 1999; Lange-Bertalot, 2001; Levkov, 2009, 2016; Lange-Bertalot et al., 2011, 2017; Levkov et al., 2013; Genkal et al., 2015; Kulikovskiy et al., 2016; Genkal and Yarushina, 2018). The taxonomic position of revealed diatoms is given according to Kulikovskiy et al. (2016).

RESULTS AND DISCUSSION

We identified a total of 133 species (138 intraspecific taxa) of *Bacillariophyta*∗ in the phytoepiphyton of the Dnieper cascade of reservoirs and the Lower Dnieper section. They belong to 43 genera, 22 families, 13 orders, and 3 classes. Among them, 15 taxa are new records for Ukraine. All of them belong to class *Bacillariophyceae*. The algae, identified only to the genus, belong to the classes *Bacillariophyceae* and *Fragilariophyceae*. No new species of the class *Coscinodiscophyceae* were found. Of the 122 species of pennate diatoms represented by 127 intraspecific taxa, 14 species and 1 species are new to the flora of Ukraine and 7 forms are defined only to the genus.

Below are brief descriptions of new records of diatoms and the taxa identified to the genus supplemented by their synonyms, data on ecology and distribution, and original microphotographs.

Achnanthidium jackii Rabenhorst (Plate I, *1*). (*Achnanthes biasolettiana* var. *jackii* (Rabenhorst) Cleve-Euler, *A. linearis* var. *jackii* (Rabenhorst) Grunow, A. *jackii* (Rabenhorst) Tempere & Peragallo, *A. minutissima* var. *jackii* (Rabenhorst) Lange-Bertalot).

∗ List of *Bacillariophyta* found in the phytoepiphyton of the reservoirs of the Dnieper cascade and in the Lower Dnieper see in electronic supplement: https://algologia.co.ua/archive/29/3.

Valve 19.3 µm long, 4.2 µm broad, striae 22 in 10 µm.

Freshwater, widely distributed species (Krammer and Lange-Bertalot, 1991a, b; Genkal et al., 2015; Genkal and Yarushina, 2018).

Lower Dnieper.

Amphora indistincta Levkov (Plate I, *2*)

Valve 14.3 µm long, 4.3 µm broad, striae 25 in 10 µm.

Freshwater oligotrophic species, in rivers and lakes, often in epipelic and epipsammon communities, widely distributed in Europe (Levkov, 2009).

Kremenchuk Reservoir.

Amphora micra Levkov (Plate I, *3*)

Valves 12.7–15.0 µm long, 3.6–4.0 µm broad, striae 16–18 in 10 µm.

Freshwater oligotrophic species, Europe (Levkov, 2009).

Zaporizhzhia Reservoir and Lower Dnieper.

Amphora sp. (Plate I, *4*)

Valve 45.7 µm long, 10 µm broad, striae 12 in 10 µm.

Kaniv Reservoir.

Aneumastis sp. (Plate I, *5*)

Valve 55.5 µm long, 20 µm broad, striae 9 in 10 µm.

Zaporizhzhia Reservoir.

Cymbella neogena (Grunow) Krammer (Plate I, *6*). (Syn.: *C. gastroides* var. *neogena* Grunow, *C. aspera* var. *neogena* (Grunow) Cleve).

Valve 100 µm long, 31 µm broad, striae 8 in 10 µm.

Freshwater species, prefers water bodies with medium mineralization. Widely distributed in Europe (Krammer, 2002).

Kremenchuk Reservoir.

Cymbella cf. *subhimalaspera* Jütter & Van de Vijver (Plate I, *7*)

Valves 88–109 µm long, 26.0–29.4 µm broad, striae 8 in 10 µm. *Cymbella subhimalaspera* has a smaller valve width: 18–26 µm (Krammer, 2002).

Freshwater species, oligotrophic and mesotrophic lakes; probably, widely distributed in Central Asia (Kulikovskiy et al., 2016).

Kakhovka Reservoir and Lower Dnieper.

Cymbella sp. (Plate I, *8*)

Valves 111–127 µm long, 17–19 µm broad, striae 8–9 in 10 µm.

Kremenchuk Reservoir and Lower Dnieper.

Encyonema caespitosum var. *maxima* Krammer (Plate I, *9*)

Valve 47 µm long, 15.7–17.0 µm broad, striae 7 in 10 µm.

Freshwater species, Europe (Krammer, 1997a).

Kyiv Reservoir and Lower Dnieper.

Encyonema perelginense Krammer (Plate I, *10*)

Valve 55.5 µm long, 17.8 µm broad, striae 5 in 10 µm.

Freshwater species, oligotrophic and slightly acidic water bodies, Holarctic (Kulikovskiy et al., 2016).

Kaniv Reservoir.

Gomphonema pala Reichardt (Plate I, *11*)

Valves 73.5 µm long, 17.6 µm broad, striae 9 in 10 µm.

Freshwater species, oligotrophic alkaline reservoirs, widely distributed (Kulikovskiy et al., 2016).

Kakhovka Reservoir.

Gomphonema sp. 1 (Plate I, *12*)

Valve 53 µm long, 8.9 µm broad, striae 6 in 10 µm.

Kyiv, Kaniv and Kremenchuk reservoirs.

Gomphonema sp. 2 (Plate II, *1*)

Valves 55.5 µm long, 11 µm broad, striae 7 in 10 µm.

Kyiv, Kaniv and Kremenchuk reservoirs.

Gomphonema supertergestinum Reichardt (Plate II, *2*)

Valves 53.3–75.5 µm long, 13.3–16.6 µm broad, striae 6–8 in 10 µm.

Freshwater species, Europe (Hofmann et al., 2017).

Kaniv and Kremenchuk reservoirs.

Halamphora cf. *subholsatica* (Krammer) Levkov (Syn.: *Amphora subholsatica* Krammer) (Plate II, *3*)

Valves 34.4–51.4 µm long, 7.2–7.8 µm broad, striae 16–18 in 10 µm. *Halamphora subholsatica* has a smaller number of striae in 10 µm: 14–15 (Levkov, 2009).

Oligotrophic and mesohaline water bodies, widely distributed species (Kulikovskiy et al., 2016).

Kremenchuk and Zaporizhzhya reservoirs, Lower Dnieper.

Halamphora thermalis (Hustedt) Levkov (Plate II, *4*)

Valves 18.6–20.7 µm long, 5.7–6.0 µm broad, striae 18–20 in 10 µm.

Fresh to slightly brackish water bodies, Europe (Levkov, 2009).

Lower Dnieper.

Navicula catalanogermanica Lange-Bertalot et Hofmann (Plate II, *5*)

Valves 25.7–30 µm long, 7.5–7.8 µm broad, striae 9–10 in 10 µm.

Oligotrophic – mesotrophic water bodies; Europe, West Siberia, probably, widely distributed species (Lange-Bertalot, 2001; Genkal and Yarushina, 2018).

Kremenchuk and Kakhovka reservoirs.

Navicula cf. *vaneei* Lange-Bertalot (Plate II, *6*)

Valve 64.4 µm long, 14.4 broad, striae 8 in 10 µm. *Navicula* v*aneei* has a smaller valve width: 11–13 µm (Lange-Bertalot, 2001).

Water bodies with medium-high salinity, Europe, North-West Siberia, oligotrophic water bodies (Lange-Bertalot, 2001; Genkal et al., 2015; Genkal and Yarushina, 2018).

Kremenchuk Reservoir.

Navicula vekhovii Lange-Bertalot & Genkal (Plate II, *7*)

Valve 51 µm long, 10 µm broad, striae 9 in 10 µm.

Freshwater-brackish species, Europe, Western Siberia (Genkal and Yarushina, 2018).

Kremenchuk Reservoir.

Nitzschia cf. *rectirobusta* Lange-Bertalot (Plate II, *8*) (Syn.: *N. recta* var. *robusta* Hustedt).

Valve 109 µm long, 10 µm broad, fibulae 6 in 10 µm, striae 24 in 10 µm. *Nitzschia rectirobusta* has a smaller valve width (6–7 µm), a larger number of fibulae and striae in 10 µm (7–8 and 28–32 respectively) (Kulikovskiy et al., 2016).

Fresh water bodies of various mineralizations; Holarctic (Kulikovskiy et al., 2016).

Kaniv Reservoir.

Nitzschia sp. (Plate II, *9*)

Valve 37 µm long, 6 µm broad, fibulae 10 in 10 µm, striae 20 in 10 µm.

Kaniv Reservoir.

Ulnaria sp. (Plate II, *10*, *11*)

Valve 255 µm long, 10.7 µm broad, striae 7 in 10 µm.

Kyiv Reservoir.

Most of the pennate *Bacillariophyta* revealed in the epiphyton of higher aquatic plants are common freshwater species. As already noted (Genkal and Scherbak, 1987; Scherbak et al., 2006; Maystrova et al., 2007), in plankton of the upper cascade reservoirs (Kyiv, Kaniv), new species of centric *Bacillariophyta* were found. They include seven typically brackish-water taxa. At the same time, only two new freshwater-brackish species (*Halamphora thermalis* and *Navicula vekhovii*) were found in the phytoepiphyton of the Dnieper cascade reservoirs and the Lower Dnieper, as well as a species that can vegetate in water bodies with medium-high salinity (*Navicula* cf. *vaneei*) and a species that can develop in mesogaline ponds (*Halamphora* cf. *subholsatica*). This suggests that the centric small-cell planktonic forms of diatoms respond more quickly to increased salinity of the Dnieper water than the pennate forms that develop in epiphyton, which are more inert algocenosis compared to plankton. The largest number of new taxa identified to the genus

were found in the Kremenchuk (10) and Kaniv (7) reservoirs, and in the Lower Dnieper (5). Most taxa belong to the genera *Amphora* (3), *Cymbella* (3), *Gomphonema* (4), and *Navicula* (3). In the flora of Ukraine for these genera, 66, 37, 24, and 102 species and varieties were known, respectively (Algae…, 2009). However, many taxa, taking into account the latest systematic studies, have changed their generic affiliation. For example, many representatives of *Amphora* and *Navicula* were transferred to other genera: *Cavinula*, *Chamaepinnularia*, *Eolimna*, *Halamphora*, *Kobayasiella*, *Parlibellus*, *Prestauroneis*, *Pseudofallacia*, and *Sellaphora* (Kulikovskiy et al., 2016; Lange-Bertalot et al., 2017). In the course of this study, we found 7 representatives of the genera *Amphora*, *Aneumastis*, *Cymbella*, *Gomphonema*, *Nitzschia*, and *Ulnaria* identified to the genus only. A number of such forms of *Bacillariophyta* from the genera *Cocconeis*, *Fragilaria*, *Navicula*, *Punctastriata*, *Sellaphora*, and *Stauroneis* have been reported by other researchers (Lilitskaya et al., 2012; Lilitskaya, 2016a, b). This indicates a potentially high taxonomic diversity of diatoms in the water bodies of Ukraine and determines the need for further studies of both pennate and centric Bacillariophyta in plankton, benthos, and periphyton of the Ukrainian water bodies.

CONCLUSIONS

In the phytoepiphyton of the Dnieper reservoirs and the Lower Dnieper, 15 species and varieties of *Bacillariophyta* of the class *Bacillariophyceae*, the genera *Achnanthidium*, *Amphora*, *Cymbella*, *Encyonema*, *Gomphonema*, *Halamphora*, *Navicula*, and *Nitzschia*, which are new to algal flora of Ukraine, were found. Most of them are common freshwater species. Seven forms from the genera *Amphora*, *Aneumastis*, *Cymbella*, *Gomphonema*, *Nitzschia*, and *Ulnaria* are identified as belonging to the genus. The largest number of new and noteworthy records was recorded in the Kremenchuk and Kaniv reservoirs.

Previously, we discovered 7 new brackish water forms of diatoms in plankton of the Kyiv and Kaniv reservoirs. In the present study of phytoepiphyton in reservoirs of Dnieper cascade and the Lower Dnieper, only two new freshwater-brackish species of *Bacillariophyta* were found. This suggests that centric small-cell planktonic forms respond more quickly to increased salinity of the Dnieper water than more inert pennate epiphytic diatoms. The data presented here indicate the need for further studies of pennate and centric *Bacillariophyta*, especially their small-cell forms, in phytoepiphyton, plankton, benthos of water bodies and watercourses of Ukraine using actual methods of microscopy and the literature data. The results of these further studies will significantly increase information on the diversity of diatoms in Ukraine.

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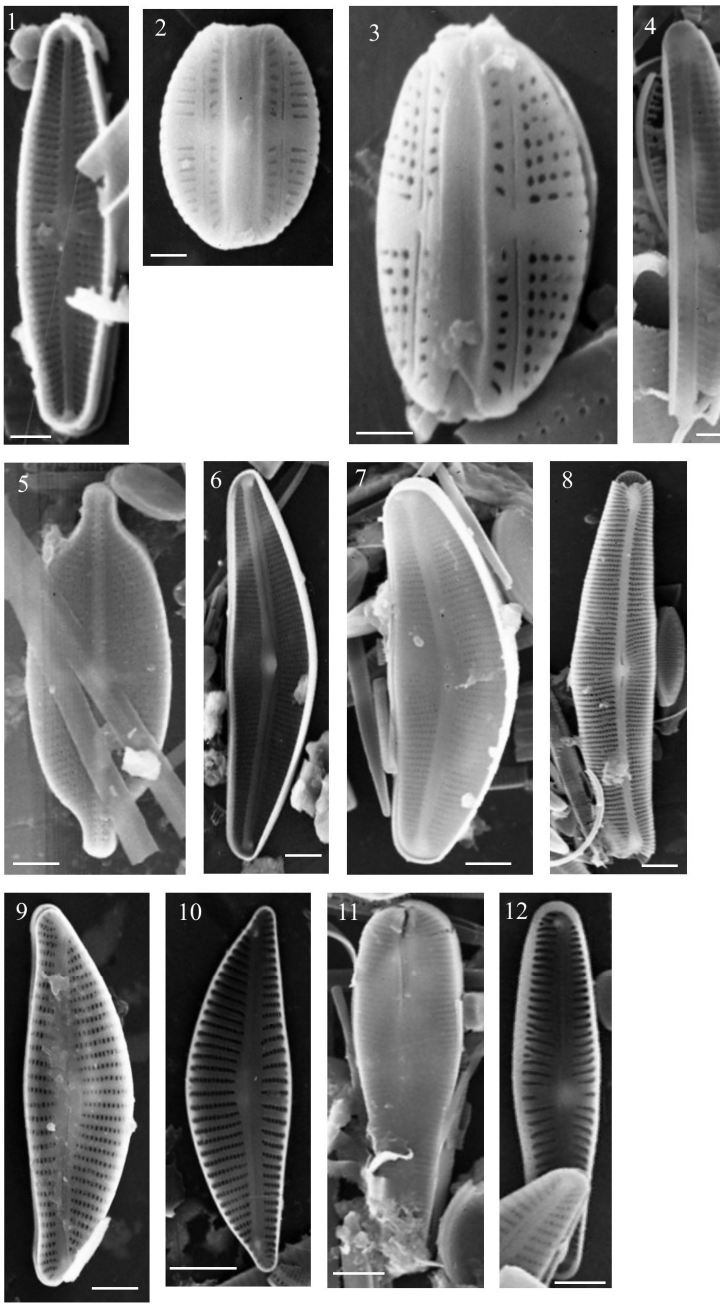

PLATE I: Electron micrographs of *Bacillariophyta* found in the Dnieper reservoirs and the Lower Dnieper (SEM): *1 – Achnanthidium jackii*; *2 – Amphora indistincta*; *3 – A. micra*; *4 – Amphora* sp.; *5 – Aneumastis* sp.; *6 – Cymbella neogena*; *7 – C.* cf. *subhimalaspera*; *8 – Cymbella* sp.; *9 – Encyonema caespitosum* var. *maxima*; *10 – E. perelginense*; *11 – Gomphonema pala*; *12 – Gomphonema* sp. 1. Valves from the outer (*1*, *4*, *6*, *10*) and inner (*2*, *3*, *5*, *7–9*, *11*, *12*) surfaces. Scale: *1–3* – 2 µm; *4*, *5*, *9* – 5 µm; *6–8*, *10–12* – 10 µm

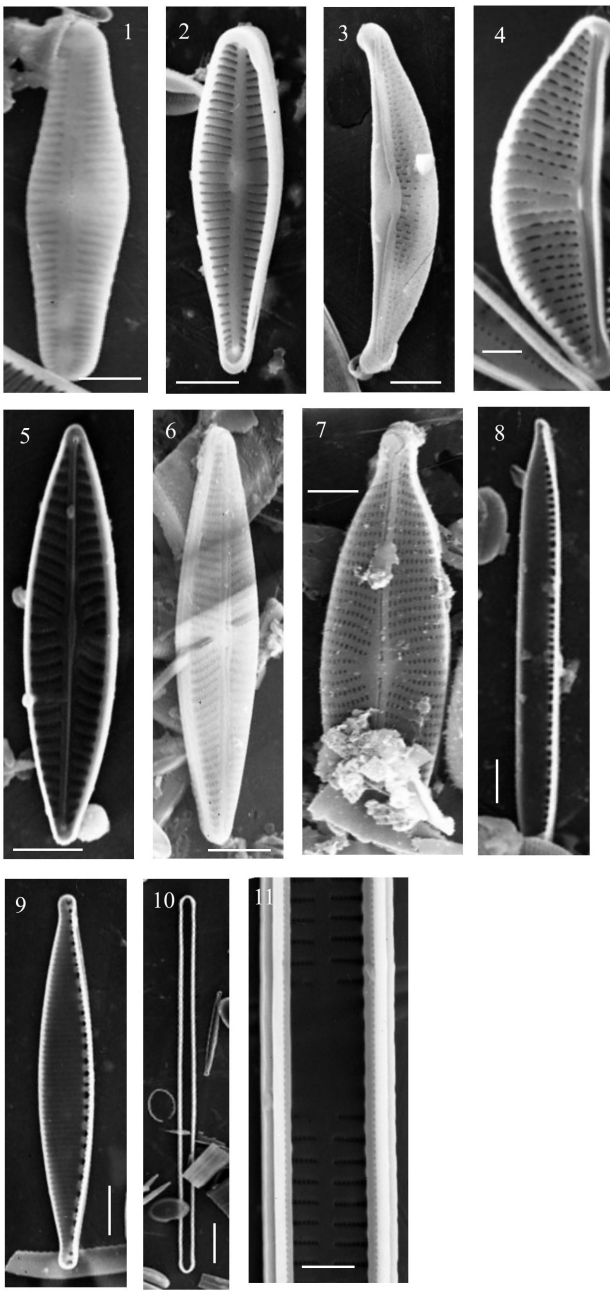

PLATE II: Electron micrographs of *Bacillariophyta* found in the Dnieper reservoirs and the Lower Dnieper (SEM): *1* – *Gomphonema* sp. 2; *2* – *G. supertergestinum*; *3* – *Halamphora* cf. *subholsatica*; *4* – *H. thermalis*; *5* – *Navicula cata-lanogermanica*; *6* – *N.* cf. *vaneei*; *7* – *N. vekhovii*; *8* – *Nitzschia* cf. *rectirobusta*; *9* – *Nitzschia* sp.; *10*, *11* – *Ulnaria* sp. Valves from the outer (*1*, *3*, *6*, *7*) and inner (*2*, *4*, *5*, *8–11*) surfaces. Scale: *1*, *2*, *6*, *8* – 10 μm; *3*, *5*, *7*, *9*, *11* – 5 μm; *10* – 30 μm