On the morphology and taxonomy of *Cyclotella distinguenda* (Bacillariophyta)

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Abstract. The study of morphology of *Cyclotella distinguenda* from the karst Lake Klyuchik (Nizhny Novgorod Region) revealed that several quantitative characters (such as valve diameter and the number of marginal fultoportulae) demonstrated more variability in that species as compared to published data. Among the investigated characteristics, valve diameter (variation coefficient CV = 34.5%) and number of marginal fultoportulae (CV = 31.5%) were the most variable. The number of striae in 10 μm (CV = 10.0%) was the least variable character. For the first time, during the investigated period of massive growth of that species in the lake, the presence of initial valves was revealed. *C. distinguenda* can be characterized as cryophilic halophilous taxon which prefers sulphate-hydrocarbonate and neutral to light alkaline waters.

Keywords: Bacillariophyta, *Cyclotella distinguenda*, morphology, scanning electron microscopy, Klyuchik Lake, Nizhny Novgorod Region, Russia.

К морфологии и таксономии *Cyclotella distinguenda* (Bacillariophyta)

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Резюме. Изучение морфологии *Cyclotella distinguenda* в популяции из карстового озера Ключик (Нижегородская область) показало, что отдельные количественные признаки (диаметр створки и частота расположения краевых выростов) проявляют бóльшую изменчивость по сравнению с литературными данными. Среди исследованных количественных признаков в наибольшей степени варьировали диаметр створки (коэффициент вариации CV = 34.5%) и число краевых выростов (CV = 31.5%), в наименьшей – число штрихов в 10 мкм (CV = 10%). Массовое развитие этого вида в озере впервые позволило зафиксировать инициальные створки и характеризует его как криофильный галофил, предпочитающий сульфатно-гидрокарбонатные и нейтрально слабощелочные воды.

Ключевые слова: Bacillariophyta, *Cyclotella distinguenda*, морфология, сканирующая электронная микроскопия, Нижегородская область, озеро Ключик, Россия.

The species *Cyclotella distinguenda* Hust. was described from the Lower Lunz Lake (Lunzer Untersee, Austria) (Hustedt, 1927). This species belongs to large-sized diatoms

(valve diameter 10–35 μm) and is characterized by the tangentially undulate central area and the absence of central fultoportulae (Hustedt, 1927). Krammer and Lange-Bertalot (1991) give a similar range of valve diameter (6–35 μm). Similar descriptions of *C. distinguenda* with numerous light and electron microscopy micrographs are presented in the number of works (Kiss *et al.*, 2007; Houk *et al.*, 2010). Other characteristics, both quantitative (frequency of marginal fultoportulae and number of satellite pores, number of central fultoportulae and rimoportulae, striae structure) and qualitative (structure of alveoli and intercalary bands, arrangement and structure of marginal fultoportulae and rimoportulae), were added to the diagnosis (Kozyrenko *et al.*, 1992; Håkansson, 2002; Kiss *et al.*, 2007, 2012; Houk *et al.*, 2010). According to other sources, this species is found in the littoral and sometimes pelagic zones of alkaline oligo- to mesotrophic lakes or ponds (Houk *et al.*, 2010). Kiss *et al.* (2012) report findings of *C. distinguenda* from mesotrophic lakes and rivers with connection to lakes.

During the study of the unique azonal lakes in the Nizhny Novgorod Region, mass development of *C. distinguenda* (up to several tens of millions cell/l) was recorded in one of them — Lake Klyuchik (Donskinskoe Svayatoe). It was the reason for conducting this study of morphological variability in this species.

Material and Methods

Phytoplankton samples for this study, 0.5 l in volume, were collected in June, July and August of 2017 from Lake Klyuchik (Donskinskoe Svayatoe). Samples were taken with a Ruttner sampler at five stations selected according to their hydrochemistry (stations 1 and 2 — in sulfate zone, station 3 — in ecotone zone, stations 4 and 5 — in hydrocarbonate zone of the lake). Integral samples were collected at all the stations. At stations 1, 3 and 5, we also took horizontal phytoplankton samples from every meter starting from the surface to the bottom (76 samples total). This paper presents only integral sampling data.

The samples were fixed in an iodine-formalin fixative, settled for two weeks and concentrated to 5 ml using a combination of sedimentation and filtration methods (Okhapkin *et al.*, 2014). Qualitative and quantitative analysis of the phytoplankton samples was made using generally accepted methods (Methods..., 1975; Okhapkin, 1994), light microscopy and oil immersion (MEIJI Techno, magnification ×1000). Diatom frustules were released from the organic matter by cold burning (Balonov, 1975) with sulphuric acid and potassium dichromate. Cleaned specimens were dried onto stubs, coated with gold using EIKO-IB-3 sputter coater and examined using JSM-25S scanning electron microscope operating at 15 kV.

During the algological sampling, we measured water transparency with a Secchi disk, as well as water pH and temperature using a Testo 206-pH1 pH meter.

Lake Klyuchik is situated in the Pavlov District of the Nizhny Novgorod Region and is a unique natural object of the Volga Basin (Bakka, Kiseleva, 2009). The waterbody belongs to brackish water (mineralization up to 2 g/dm^3) karst lakes — quite rare and azonal type of lakes not only for the Volga Basin but for the whole Russia (Dedkov,

2001). The lake's surface area is 11 hectares and its maximum depth is 12 meters. The Surin, a subterranean river and the right-bank tributary of the Kishma River, contributes water to the lake. The Surin River enters the lake from the southwest as a small stream and flows out from the northeast as a mature one-meter-deep watercourse. There is an underwater cave (voklina) at the bottom of the lake. Lake Klyuchik is characterized by a distinct ecotone with hydrochemical gradient: the west part of the lake is sulfate (the water is bluish) and the east one is hydrocarbonate (the water is greenish). In the summertime, the water temperature in the west part of the lake is about 8–10 °C, transparency measured with a Secchi disk reaches 9.5 m and the pH level ranges from 7.4 to 7.5. In the central part of the lake, the water clarity decreases to 4.5 m, in the east part — to 3.6 m; here the water warms up to 22–25 °C, and its pH increases to 8.1–8.2. The most distinct changes in the main hydrological and hydrochemical parameters are recorded in the transition zone between the west and the central parts of the lake.

Results and Discussion

Only single cells occur in the population under study. Their valve diameters range from 11.4 to 40 μm, number of striae in 10 μm — from 11 to 16. Marginal fultoportulae with three satellite pores are located on each–sixth interstria. Only one rimoportula is observed (Plate I). Our data on the maximum size of cells (40 μm) exceeds the corresponding data from literature sources (Table) but the number of striae in 10 μm and the number of rimoportulae on the valve face correspond to the published data.

Table

Published data on morphological characters of the *Cyclotella distinguenda*

Valve diameter, μm	Number of striae in 10 μm	Marginal fultoportulae arrangement	Number of rimoportulae	References
10–35	12–14			Hustedt, 1927
6–35	12–14			Krammer, Lange-Bertalot, 1991
10–35	12–16	On every 2–4 costa	1–2	Kozyrenko et *al*., 1992
(8)10–32	12–14	-	1	Håkansson, 2002
9.1–23.8	10–14	On every 2–4(5) costa	1	Kiss *et al*., 2007
6–35	12–15	On every 2–4(5) costa	1	Houk *et al*., 2010
9–24	10–14	On every 2–4 costa	1	Kiss *et al*., 2012

In the population from Lake Klyuchik, marginal fultoportulae are more widely spaced as compared to the literature data (Table). Of the quantitative characteristics the most variable are the valve diameter (coefficient of variation CV = 34.5%) and the number of marginal fultoportulae (CV = 31.5%), the least variable is the number of striae in 10 μm (CV = 10%). The same is known for other representatives of this genus (Genkal, Kharitonov, 1996; Genkal, Popovskaya, 2004; Genkal, Yarushina, 2004). There are no published data on the presence of auxospores in *C. distinguenda* except

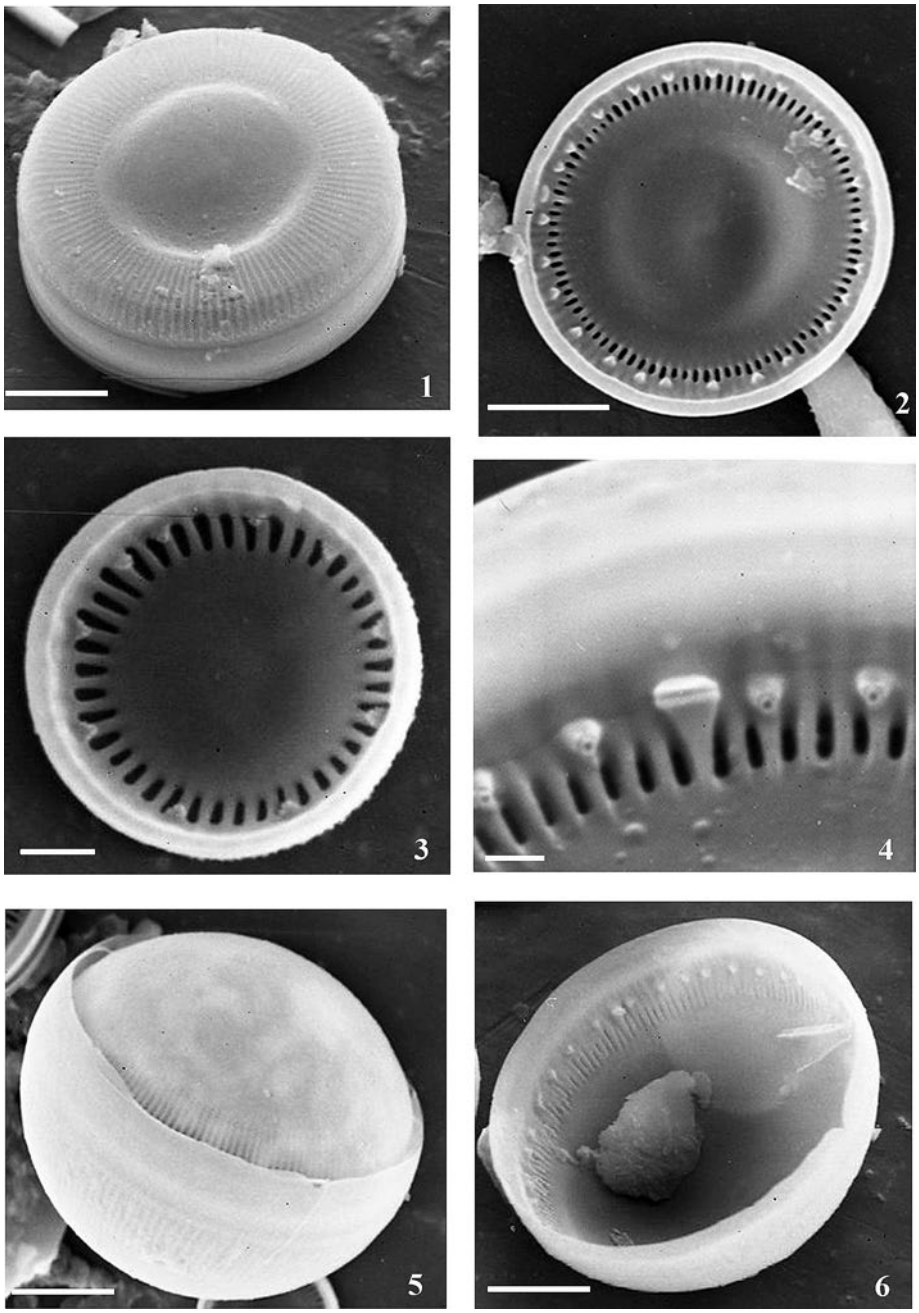

Plate I. SEM micrographs of *Cyclotella distinguenda*.
1 — external valve view; *2, 3* — internal valve view; *4* — internal valve view, marginal fultoportulae and rimoportula; *5, 6* — external and internal view of initial valves.
Scale bars: *1, 2, 5, 6* — 10 μm; *3* — 2 μm; *4* — 1 μm.

for the only one illustration of an initial valve, 27 μm in diam., presented by Houk *et al.* (2010, Tab. 166, Fig. 6). Valves of larger diameters (34–40 μm) are found in our material (Plate I, *5, 6*).

The emended diagnosis of the species, based on our data, is presented below.

Cyclotella distinguenda Hust. 1927, Internationale Revue der gesamten Hydrobiologie 18: 320 (Plate I, *1–6*).

Cells cylindrical, 6.0–40 μm in diam., mainly solitary. Striae of equal lengths 10–16 in 10 μm. Marginal fultoportulae on every 6 costa, externally with a simple opening, internally with a short central tube surrounded by three satellite pores. Single rimoportula (sometimes two) situated in the marginal area, external with a small opening on a shortened costa, internally with a short-stalked labium, the relatively wide slit oblique or oriented circumferentially. The valve central area strongly transversally undulate, externally smooth or finely punctuated, sometimes with one to several coarser punctae. There are no central fultoportulae. The girdle band is smooth, composed of several copulae. Auxospores are present.

The study of *C. distinguenda* from the small karst lake with unique limnological characteristics (thermal stability, high mineralization and clarity of water under low temperature conditions and the predominance of groundwater over surface runoff in to the lake feeding) has shown a higher variability in the valve morphological parameters than in European aquatic ecosystems studied by other researchers. The presence of initial valves in appreciable quantities and mass development of the population indicate optimal growth conditions for the species and characterizes it as a cryophile halophile preferring sulfate-hydrocarbonate and neutral-alkalescent waters.

Conclusions

Investigations of growth and development of *C. distinguenda* in small karst lake with unique limnological characteristics revealed a higher variability in the valve morphological parameters of that species than in European aquatic ecosystems studied by other researchers. The presence of initial valves of the population indicates optimal growth conditions for the species and characterize it as a cryophilic halophile taxon which prefers sulphate-hydrocarbonate and neutral to light alkaline water.

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