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Prestauroneis furatensis sp. nov., a new diatom species from the River Euphrates, Iraq

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Abstract: In a comparative study on epiphytic diatoms in the Rivers Euphrates and Tigris (Iraq), one of the major drainage basins in the Middle East, we report a new species, *Prestauroneis furatensis* sp. nov., It was present in low abundances (up to 5%) solely in the summer samples of the River Euphrates on the macrophytes *Ceratophyllum demersum*, *Typha domingensis, Potamogeton perfoliatus,* and *Najas minor*. Light and scanning electron microscopic observations revealed distinct morphological traits that differentiated *P. furatensis* from other species, leading to its identification as a new species. Detailed physical–chemical parameters were taken and showed its occurrence – among others – under elevated conductivity conditions. The dominant diatoms co–occurring with this new species included *Nitzschia gracilis* and *Mastogloia smithii* on *C. demersum, Gomphonema hebridense* on *T. domingensis, Nitzschia palea* and *Cocconeis placentula on P. perfoliatus. Nitzschia gracilis* and *Nitzschia palea* on *N. minor*. In addition, *Prestauroneis cruciculoides* comb. nov. is validated.

Keywords: Bacillariophyta, epiphytic, freshwater, physical–chemical parameters, *Prestauroneis cruciculoides*

Introduction

The genus *Prestauroneis* was established by Bruder and Medlin (2008). Their description was based on molecular data and morphological characters of *Prestauroneis integra* (W.Smith) Bruder. Morphological features of this genus included pseudosepta at both valve ends, distal raphe endings extending onto the valve mantle, and uniseriate striae that become almost parallel towards the apices (Bruder & Medlin 2008; Rakowska et al. 2017; Glushchenko et al. 2019).

Prestauroneis seems to be a relatively small genus with a limited number of described taxa. To date, 13 taxa have been described or transferred to the genus *Prestauroneis* (Guiry & Guiry 2024): *P. integra* (W.Smith) Bruder, *P. tumida* Levkov (Levkov & Williams 2011), *P. nenwae* Q.Liu, Q.X.Wang et Kociolek*, P. lowei* Q.Liu, Q.X.Wang et Kociolek and *P. protractoides* (Hustedt) Q.Liu et Kociolek (Liu et al. 2015), *P. protracta* (Grunow) Kulikovskiy et Glushchenko (Kulikovskiy et al. 2016), *P. blazenciciae* Metzeltin et Lange–Bertalot (Metzeltin & Lange–Bertalot 2016), *P. bondarenkoae* Vishnyakov (Vishnyakov 2016), *P. crucicula* (W.Smith) Genkal et Yarushina (Genkal & Yarushina 2017), *P. protracta* var. *elliptica* (Gallick) J.Y.Li et Y.Z.Qi (Li & Qi 2018), *P. genkalii* Glushchenko, Kulikovskiy et Kociolek, *P. pseudocrucicula* (Kobayasi) Glushchenko, Kulikovskiy et Kociolek (Glushchenko et al. 2019) and *P. cruciculoides* (C.Brockmann) Al–Handal et Al–Shaheen. Since the transfer of the last name was lacking a full and direct reference to its basionym author and place of valid publication (Al–Handal & Al–Shaheen 2019), in this paper we provide a valid combination that meets all provisions of the Code of Nomenclature (Turland et al. 2018, Art. 41.5).

The ecological breadth of *Prestauroneis* seems notable with most species inhabiting freshwaters except for *P. crucicula* and *P. cruciculoides*, originally described from coastal marine waters (Smith 1853; Brockmann1950) and *P. protracta,* originally described from brackish waters of the Arctic (Cleve & Grunow 1880). Members of this genus have also been reported from different freshwater bodies (Liu et al. 2015) in Europe (Smith 1853; Hustedt 1957; Brockmann 1950; Bruder & Medlin 2008; Levkov & Williams 2011; Metzeltin & Lange–Bertalot 2016; Rakowska et al. 2017), Asia

(Kulikovskiy et al. 2016; Liu et al. 2015; Vishnyakov 2016; Glushchenko et al. 2019), as well as from the Middle East (Al–Handal & Al–Shaheen 2019).

The present study is part of a survey on the composition of epiphytic diatom assemblages in the southern catchment basin of the Rivers Euphrates–Tigris. In this paper, we describe a new freshwater diatom species assigning it to the genus *Prestauroneis* and providing light and scanning electron microscopic observations since the valve ultrastructure of this new species does not match any previously published taxa.

Material and Methods

Study area. Our research focused on the River Euphrates in the northern region of Basra City in Southern Iraq. The River Euphrates enters the city from the West and flows East for more than 30 kilometers before meeting the River Tigris. The River Euphrates is surrounded by agricultural land and a few small villages, and flows between two marshes: the Central Marshes to the North and the Hammar Marsh to the South.

Sampling. Six stations of the Rivers Tigris and Euphrates were sampled but the new species was found only at two stations in the River Euphrates, in Al–Midaina town, in August 2019. The first station (31.09 °N, 47.427778 °E) was located about 39 km west of the confluence of the Rivers Tigris and Euphrates. The second station (30.952°N, 47.14902°E) was located about 5 km east of the first station. At both stations samples were collected from the western banks, which were muddy and supported dense growths of aquatic macrophytes. Both stations were characterized by low water flow and some anthropogenic pollution since palm trees and farmland were distributed on both sides of the river. This part of the river was also exposed to fishing and boats.

Due to the absence of stones as habitats at either of the sampling stations, samples were collected separately from each of the four available macrophyte taxa: *Typha domingensis* Pers., *Ceratophyllum demersum* L., *Potamogeton perfoliatus* L. and *Najas minor* All. At least five stems of each macrophyte were put into a plastic bag, and then shaken vigorously with distilled water to dislodge attached diatoms. The resulting suspension was poured into a plastic container and preserved with 70% alcohol for transport to the laboratory at the BGBM, Freie Universität Berlin.

Water samples from the same sites were taken for physical–chemical parameters analyses. These included air and water temperature (°C), pH, conductivity (µS.cm^{-1}), dissolved oxygen (mg.l^{-1}), water transparency (cm), turbidity (NTU), and total alkalinity (mg.l^{-1}), using different instruments. Nitrate (mg.l^{-1}), phosphate (mg.l^{-1}) and silicate (mg.l^{-1}) were measured according to Strickland & Parson (1972), Lind (1979) and APHA (1999, 2005).

Diatom analysis. The valves for species identification were prepared as follows: the samples were heated to 80 °C on a hotplate adding 35% hydrogen peroxide (H_2O_2) to oxidize the organic material. The suspension was washed 5 times with distilled water and centrifuged between washes as described in Mora et al. (2019). The cleaned valves were air–dried on coverslips and mounted on microscopic slides using the high refractive index medium Naphrax®. Each sample was studied and images of valves were taken with a Zeiss Axioplan Microscope equipped with Differential Interference Contrast (DIC), using a Zeiss 100× Plan Apochromat objective with an AXIOCAM MRc camera. For identification, valves were measured with the AxioVision software. For scanning electron microscopy observations, aliquots of cleaned sample material were mounted on stubs, and observed under a Hitachi FE 8010 scanning electron microscope (SEM) operated at 1.0 kV.

Samples, slides and pictures are deposited in the Diatom Collection of the Botanic Garden and Botanical Museum Berlin, Freie Universität Berlin (B). The nomenclatural novelty is registered in the Registration System for Algae (Phycobank.org).

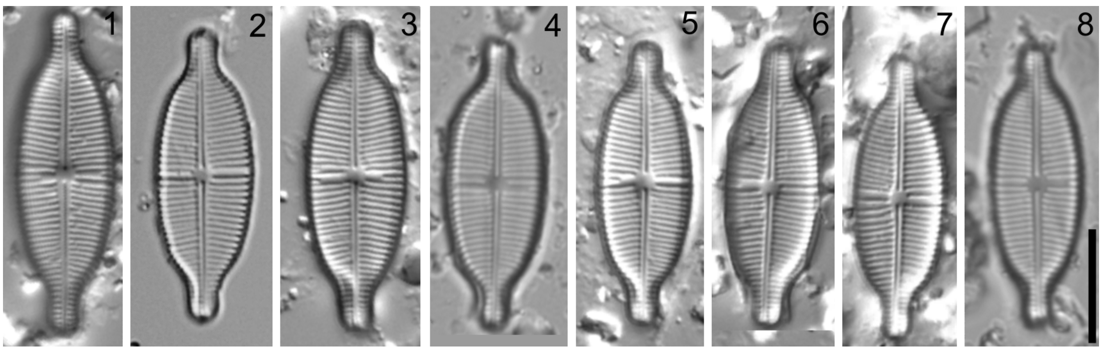
Results and Discussion

The new species belongs to the genus: *Prestauroneis* Bruder et Medlin (Bruder & Medlin, 2008).

Prestauroneis furatensis **H. Mohamad et N. Abarca sp. nov. (Figs 1–14)**

Description:

LM (Figs 1–8): Cells are biraphid. Valves are linear–elliptic to elliptic–lanceolate with distinctly capitate apices. The length of the valves varied between 24.5 and 29.0 µm ($\bar{x}$ = 27.13 ± 1.17); the width between 7.9 and 9.5 µm ($\bar{x}$ = 8.94 ± 0.23 µm) (n=45). Axial area very narrow. The central area is void of any markings, it is small, rounded or dilated on one or both sides due to short and long alternating striae. Striae are radiate, more distant



Figs 1–8. *Prestauroneis furatensis* sp. nov. LM, valve views. Fig. (5) represents the holotype, taken from site 1 on *Najas minor*. Scale bar 10 µm.

at mid–valve, becoming nearly parallel at the apices: at the center: 16–20 in 10 µm ($\bar{x}$ = 18.08 ± 0.94), near the poles: 19–20 in 10 µm ($\bar{x}$ = 19.47 ± 0.50). Raphe straight and filiform. Proximal raphe ends expanded. The distal ends of the raphe extend unto the mantle externally. Areolae invisible in LM.

SEM (Figs 9–15): Externally, the valve face is flat. Striae are uniseriate, reaching the valve mantle. The axial area is very narrow and linear (Fig. 9). The central area is small and round to irregular (Figs 9,10). The proximal raphe endings are small, drop–like and slightly deflected to one side. The distal raphe endings are straight and terminate at the valve mantle (Figs 11,12). Externally, areolae are small, elongated to elliptic with variable sizes, slightly larger around the axial area. Internally, areolae are rounded, almost of same size (Fig. 14). Proximal endings of the raphe are straight, separated by weakly elevated central nodule. Pseudosepta are present on both valve poles (Figs 13,15).

Holotype: Slide B 40 0045797 deposited in Herbarium Berolinense, Botanic Garden and Botanical Museum, Berlin, Germany. Fig. 5 illustrates the holotype specimen (River Euphrates site 1 on *Najas minor)*.
Registration: http://phycobank.org/104497
Type locality: River Euphrates, northern region of Basra Governorate, Iraq (N: 30.946, E: 47.427778). Collected by Maitham Al–Shaheen on 30 August 2019.
Etymology: The species name refers to the River Euphrates; in Arabic its name is Furat.

Comparison with other taxa

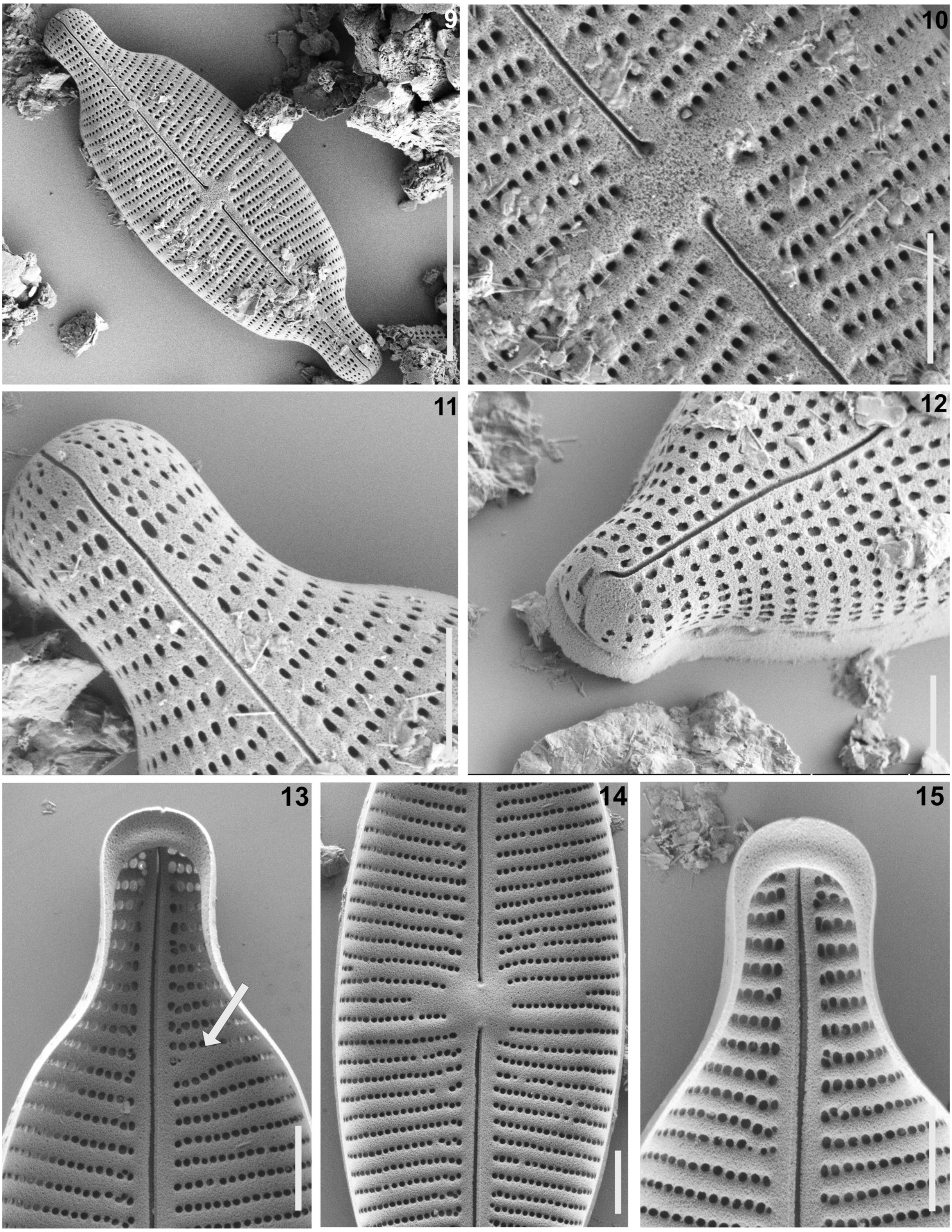
In LM, this species appeared similar in outline to *Dorofeyukea indokotschyi* Kulikovskiy, Maltsev, S.A.Andreeva et Kociolek and *D. kotschyi* (Grunow) Kulikovskiy, Kociolek, Tusset et T.Ludwig (Kulikovskiy et al. 2019). Both have distinct capitate apices and linear–elliptic valves. However, the primary difference lies in the absence of a fascia in our species, whereas *D. indokotschyi* and *D. kotschyi* have a distinct fascia. Additionally, the external areolae are round and clearly visible in *Dorofeyukea*, whereas they are invisible by LM in *Prestauroneis furatensis.*

A genus which had been discussed for a number of taxa now in *Prestauroneis* is *Parlibellus* E.J.Cox (Cox 1988). *Parlibellus* features a raphe terminating noticeably before reaching the valve apex and distal external raphe fissures curving to one side; in addition, pseudosepta at the apices are lacking (Liu et al. 2015; Rakowska et al. 2017). These characters do not align with our taxon.

Prestauroneis furatensis exhibits the distinctive morphological characteristics of the *Prestauroneis* genus as proposed by Bruder & Medlin (2008), including uniseriate striae and pseudosepta at each valve end (SEM Figs 13,15), distal raphe ends that extend onto the valve mantle, and uniseriate striae. Glushchenko et al. (2019) grouped all known species into three groups according to the shape of their apices and their valve outline. The first

Table 1. Comparison of key characters of *Prestauroneis* taxa.

	Outline	Apices	Axial area	Central area	Length (µm)	Width (µm)	Striae in 10 µm	Reference
P. furatensis	linear–elliptic to elliptic–lanceolate	distinctly capitate	narrow	small, rounded or dilated on one or both sides	24.5–29.0	7.9–9.5	radiate central: 16–20 distal: 19–20	This study
P. lowei	lanceolate to lanceolate–elliptical	rostrate to sub–capitate	narrow, linear	small, elliptic–lanceolate	25.9–28.4	7.3–7.8	radiate central: 13–16 distal: 22–24	Liu et al. 2014
P. tumida	linear–lanceolate to elliptic–lanceolate	protracted to subprotracted, broadly rounded	narrow, linear	small lanceolate or elliptic	22–44	9–11	14–17	Levkov & Williams 2011
P. protracta as *Parlibellus protracta*	elliptic–lanceolate to elliptic	not protracted, very slightly sub-capitate, subrostrate, to broadly rostrate, flat, rounded	narrow	small and almost circular	17–60	5–10	14–20	Lange–Bertalot et al. 2017
P. protractoides as *Parlibellus protractoides*	linear	slightly drawn out, broadly rounded or subcapitate	narrow	narrow, elongated	17–19	4–5	central: 20 distal: 28	Lange–Bertalot et al. 2017



Figs 9–15. *Prestauroneis furatensis* sp. nov. SEM: (9) external view of a complete valve; (10) external central area with simple proximal raphe endings which point into the same direction; (11,12) external distal raphe endings; (13) internal view of a valve. The arrow points at Voigt discontinuity; (14) internal central area showing the simple proximal raphe endings. Sternum slightly elevated; (15) internal distal raphe ending and pseudoseptum. Scale bar 10 µm (Fig. 9), Scale bar 2 µm (Fig. 10 – 15).

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Table 2. Comparison of relative abundances (>5%) of *Prestauroneis furatensis* with dominant diatom taxa on the four different macrophytes in the River Euphrates.

	Ceratophyllum demersum		***Typha domingensis***		***Potamogeton perfolitus***		***Najas minor***	
	Site 1	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Prestauroneis furatensis	5.25%	4.5%	1%	4.5%	2%	5%	1.75%	3%
Caloneis australis Zidarova, Kopalová et Van de Vijver					7%	10%		
Cocconeis placentula Ehrenberg complex	6.25%	5.5%	6.25%	7.5%	7.25%	17.5%	7.5%	6.25%
Cyclotella meneghiniana Kützing								5%
Fragilaria koensabbei Al-Handal et Al-Shaheen								6%
Gomphonema auritum A.Braun ex Kützing						5.75%		
Gomphonema graciledictum E.Reichardt				9.5%				
Gomphonema hebridense W.Gregory			7.75%	10%				5%
Gomphonema cf. *hebridense*			10%					
Gomphonema naviculoides W.Smith			5.25%					
Mastogloia belaensis Voigt			5.25%					
Mastogloia smithii Thwaites ex W.Smith		15.75%						
Mastogloia cf. *smithii*			8.75%	6%	6.5%	12.75%	5%	7%
Navicula gregaria Donkin	6 %							
Navicula metareichardtiana Lange-Bertalot et Kusber	9%	7.5%			6.75%			
Nitzschia clausii Hantzsch		7.5%						
Nitzschia elegantula Grunow				5%	6.25%			
Nitzschia gracilis Hantzsch	12.25%	6.25%		6%	8.5%	8%	11.25%	
Nitzschia hantzschiana Rabenhorst	6%							
Nitzschia palea (Kützing) W.Smith					10%		8.75%	7.5%
Seminavis strigosa (Hustedt) Danieledis et Economou-Amilli				5.25%				
Tabularia fasciculata C.Agardh) D.M.Williams et Round				7.5%				

group with small, short–protracted ends and triundulate margins, included *P. integra* and *P. blazenciciae*. The second group with broadly rounded and subcapitate ends with slightly elliptical valves, included *P. protracta, P. protractoides, P. tumida* and *P. lowei.* The third group with rounded and evident ends and lanceolate valve outline, included *P. nenwai, P. crucicula, P. bondarenkoae, P. genkalii* and *P. pseudocrucicula.* This classification was based purely on morphological characteristics, not molecular data. The presence of distinct morphological groups raises the question of whether these groups might be supported by molecular evidence in the future, potentially leading to a revision of the genus and the recognition of additional genera. We used this grouping to differentiate our new species from the most similar species within the genus. *P. furatensis* differs from the first and third groups in terms of valve shape, thus we included it in the second group; for comparison, characters of the second group are given in Table 1. The two species that are most similar in terms of valve shape to *P. furatensis* are *P. lowei* and *P. tumida. P. furatensis* has an outline with distinctly capitate apices, which clearly separates it from *P. lowei and P. tumida.* The central area of *P. furatensis* is characterized by a small, rounded or dilated structure on one or both sides. In contrast, *P. lowei* and *P. tumida* have a small, elliptic–lanceolate central area, each. There are also quantitative differences such as a slightly denser striation in *P. furatensis* than in *P. tumida* and a slightly wider valve in *P. furatensis* than in *P. lowei.*

Habitat and Environmental Data

The new species has been recorded in low numbers in the epiphytic communities of the River Euphrates. It was observed in the summer samples collected at two locations, which were characterized by elevated conductivity as well as high temperatures of both air and water, high silicate concentration, low transparency, low alkalinity, low nitrogen, and low phosphate compared to the winter of the same sites (site1/site2): air temperature: 38.0/41.5 °C, water temperature: 35.5/36.7 °C, pH 7.67/8.21, specific conductivity corrected: 3198/3065 µS.cm^{-1}, dissolved oxygen: 8.3/6.1 mg.l^{-1}, turbidity: 4.96/7.85 NTU, total alkalinity: 58/46 mg.l^{-1}, transparency: 85/76 cm, nitrate nitrogen: 0.8/0.7 mg.l^{-1}, phosphate: 0.195/0.130 mg.l^{-1} and reactive silicate: 16/9 mg.l^{-1}).

This species was living epiphytically on *Ceratophyllum demersum, Potamogeton perfoliatus, Najas minor,* and *Typha domingensis*. The relative abundances on the four macrophytes were as follows (site 1/site 2): *C. demersum:* 5.25–4.5%; *P. perfoliatus:* 2–5%; *N. minor:* 1.75–3%; *T. domingensis*: 1–4.5% (Table 2). The dominant diatoms co–occurring in the samples with this new species included: *Nitzschia gracilis* Hantzsch on *C. demersum* and *N. minor*, *Nitzschia palea* (Kützing) W.Smith on *P. perfoliatus* and *N. minor*, *Gomphonema hebridense* W.Gregory on *T. domingensis*, *Mastogloia smithii* Thwaites ex W.Smith on *C. demersum*, *Cocconeis placentula* Ehrenberg on *P. perfoliatus* (for more taxa see Table 2).

Why this species was found only at the Euphrates summer sites 1 and 2 but not at site 3 where the same four macrophytes grew and the physical–chemical data were almost the same, is not explainable. Nevertheless, differences in the physical–chemical data between summer and winter samples – higher water temperatures (35.5 °C versus 20.5 °C) and silicate (16 mg.l^{-1} versus 9 mg.l^{-1}) – might explain their absence in winter. Concerning the question why this species was not found in the River Tigris which was sampled at the same time might be the somewhat different macrophyte composition (missing *Najas minor* und *Potamogeton perfolitus*), lower turbidity (4.96 NTU versus 55.0 NTU) and higher transparency (85 cm versus 22 cm), lower alkalinity (58 mg.l^{-1} versus 70 mg.l^{-1}) and lower nitrate NO_3 (0.8 mg.l^{-1} versus 1.8 mg.l^{-1}) but more probably the almost three times higher conductivity (3198 µS.cm^{-1} versus 1225 µS.cm^{-1}).

As mentioned in the introduction, the ecological breadth of the current members of the genus *Prestauroneis* seem to be notable with species inhabiting very different water bodies (Liu et al., 2015) such as the brackish waters of the Arctic (Cleve & Grunow 1880), marine coast of Ireland (Smith, 1853), saline spring in Wisselsheim, Germany (Metzeltin & Lange–Bertalot 2016), the ancient Lake Ohrid in Europe (Levkov & Williams 2011) and Lake Hovsgol in Mongolia (Vishnyakov 2016), the Nizhnii saltmarsh in Yamal Peninsula of Russia (Genkal et al. 2017), wetlands in the Sichuan Province of China (Liu et al. 2015), and the Cái River of Vietnam in Southeast Asia (Glushchenko et al. 2019).

Up to now, only the presence of *P. cruciculoides* and *P. crucicula* have been reported for Iraq, specifically in the marshes of the Shatt al–Arab in brackish to marine waters (Al–Handal & Al–Shaheen 2019). This study has added *P. furatensis* to this list, which was found in the River Euphrates in freshwaters with elevated conductivity.

Validation

Prestauroneis cruciculoides (C.Brockmann) Al–Handal et Al–Shaheen, comb. nov.
Basionym: *Navicula cruciculoides* C.Brockmann, Abh. Senckenberg. Naturf. Ges. 478: 15, pl. 4, figs 7–10. 1950.
≡*Parlibelluns cruciculoides* (C.Brockmann) Witkowski, Lange–Bertalot et Metzeltin 2000.
–*Prestauroneis cruciculoides* (Witkowski, Lange–Bertalot et Metzeltin) Al–Handal et Al–Shaheen, 2019, nom. inval. (Turland et al., Art. 41.5)
Registration: http://phycobank.org/104727

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