

## Distribution of *Didymosphenia*, *Gomphonema* and *Gomphosphenia* diatoms (Bacillariophyta) in Turkish inland waters

by

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### Abstract

In this study, a total of 53 taxa were identified from 13 catchments in Turkey. *Gomphonema affine* var. *rhombicum* E.Reichardt, *G. angusticephalum* E.Reichardt & Lange-Bertalot, *G. calcifugum* Lange-Bertalot & E.Reichardt, *G. elegantissimum* E.Reichardt & Lange-Bertalot, *G. exilissimum* (Grunow) Lange-Bertalot & E.Reichardt, *G. graciledictum* E.Reichardt, *G. italicum* var. *densistriatum* Levkov, Mitic-Kopanja & E.Reichardt, *G. linearoides* Levkov, *G. megalobrebissonii* D.A.Chudaev, Kociolek & M.A.Golobova, *G. minusculum* Krasske, *G. minutum* f. *syriacum* Lange-Bertalot & Reichardt, *G. reediae* Levkov, Mitic-Kopanja & E.Reichardt, *G. sarcophagus* W.Gregory, *G. subcapitatum* (Grunow) E.Reichardt & Levkov and *Gomphosphenia holmquistii* (Foged) Lange-Bertalot were recorded for the first time in Turkey. Of the identified taxa, *Didymosphenia geminata* (Lyngbye) M.Schmidt, *Gomphonema acuminatum* Ehrenberg, *G. affine* Kützing, *G. angustatum* (Kützing) Rabenhorst, *G. augur* Ehrenberg, *G. micropus* Kützing, *G. minutum* (C.Agardh) C.Agardh, *G. olivaceum* (Hornemann) Brébisson, *G. parvulum* (Kützing) Kützing and *G. truncatum* Ehrenberg are common in the waters. *G. angustius* E.Reichardt, *G. insignaffine* Reichardt, *G. insigne* W.Gregory, *G. italicum* Kützing, *G. laticollum* E.Reichardt, *G. pumilum* var. *rigidum* E.Reichardt & Lange-Bertalot, *G. stonei* E.Reichardt, *G. supertergestinum* E.Reichardt and *G. vibrio* Ehrenberg have been recently recorded from the Turkish waters. The genus *Gomphosphenia* in Turkey has so far been represented only by *G. grovei* (M.Schmidt) Lange-Bertalot.

**Key words:** diatoms, taxonomy, distribution, freshwater, new records, Turkey

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## 1. Introduction

Many diatom genera belong to the order Cymbellales. These include many widely distributed and common genera, e.g. *Didymosphenia* M.Schmidt, *Gomphoneis* Cleve, *Gomphonema* Ehrenberg, *Gomphopleura* Reichelt ex Tempère, *Gomphosinica* Kociolek, You, X.Wang & Q.Liuand, and *Reimeria* Kociolek & Stoermer. Of these, the following genera were selected for our research: *Didymosphenia*, *Gomphonema*, and *Gomphosphenia*. The genus *Didymosphenia* was described from Streymoy Island (the North Atlantic Faroe archipelago) in 1819 by Lyngbye. The genus is relatively small and currently includes 31 species recognized worldwide (Kociolek et al. 2019). Almost half of these species have been recently described (Metzeltin & Lange-Bertalot 2014). *Gomphonema* Ehrenberg is a large genus (over 500 taxa listed in Kociolek et al. 2019), distributed worldwide, e.g. in South America (Metzeltin & Lange-Bertalot 2007), North America (Kociolek & Kingston 1999), Asia (Lange-Bertalot & Genkal 1999; Karthick et al. 2011), Europe (Reichardt 1999; Levkov 2016), and Africa (Kociolek & Stoermer 1991; Spaulding & Kociolek 1998), and is found in a wide variety of freshwater habitats. This genus is also widespread in Turkish inland waters (Solak et al. 2016). The environmental ranges of some taxa are clearly defined and are therefore used in biomonitoring work (e.g. Lange-Bertalot et al. 2017; Bık et al. 2012). *Gomphosphenia* Lange-Bertalot is represented by a very small group of known diatoms (16 taxa in Kociolek et al. 2019).

The area of Turkey is very heterogenous due to varied geological and climatic conditions. There are seven climate zones in Turkey, namely the Marmara region, the Aegean–Western Mediterranean region, the Black Sea region, Inner Anatolia, the Eastern Anatolian region, the South–Eastern Anatolian region, and the Eastern Mediterranean region. The average annual temperature amplitude ranges from 7.2°C in the Eastern Anatolian region to 18.7°C in the Eastern Mediterranean region. Annual precipitation ranges from 417.5 mm in the Eastern Anatolian region to 1175.8 mm in the Black Sea region. The diversity of climatic conditions is due to the mountain chains in the region of Black and Mediterranean seas and the perpendicular position of the mountain system in the Aegean Sea. *Didymosphenia genimata* was originally known from lakes and streams at northern latitudes, from habitats with low levels of nutrients and low temperature. In recent decades, however, it has spread massively to lowland areas (Spaulding et al. 2005a, b; Ector & Blanco 2009). With regard to

studies on inland waters in Turkey, only *Didymosphenia genimata* was reported from different parts of Anatolia (Solak et al. 2012). This taxon is considered a harmful invasive organism in lotic systems worldwide and can reach the level of nuisance in its native range (Ector & Blanco 2009). The largest genus *Gomphonema* is common in Turkish waters. A total of 75 taxa were recorded in Turkish freshwater diatom flora, with *G. angustum*, *G. constrictum*, *G. olivaceum*, *G. pala* and *G. parvulum* being among the most frequently reported species (Solak et al. 2012; Solak & Wojtal 2012). Until this publication, *Gomphosphenia grovei* was the only *Gomphosphenia* species reported from Turkish waters (Solak et al. 2012; Maraşlıoğlu & Gönülol 2019; Taşkın et al. 2019).

The current study provides an introduction to the variability of selected gomphonemoid genera in the phytobenthos of some springs, small streams, large rivers, shallow and deep lakes in the Meriç-Ergene (1), Marmara (2), Susurluk (3), Kuzey Ege (4), Gediz (5), Antalya (6), Akarçay (7), Sakarya (8), Konya (9), Kızılırmak (10), Yeşilirmak (11), Eastern Black Sea (12), and Euphrates–Tigris (13) catchments of the Anatolian Peninsula.

## 2. Materials and methods

### 2.1. Study area

In geographical terms, Turkey is considered a bridge between Europe and Asia. Central Anatolia is a plateau (ca. 1000–1200 m a.s.l.) surrounded by narrow coastal plains and bordered by the Black Sea Mountains to the north and the Taurus Mountains to the south. The eastern part of the Anatolian Peninsula is a high mountain landscape. The highest peak of Turkey is Mount Ararat (5137 m a.s.l.). The mountains that run parallel to the coasts cause great climatic variability in Turkey. The northern region of the Black Sea is primarily affected by the cold, dry Siberian High Pressure System, while the Mediterranean climate prevails in the southern part (Solak et al. 2012; Kuzucuoğlu et al. 2019). There are two closed catchments in Turkey: Konya and Lake Van. The Konya catchment comprises several brackish lakes, while the largest soda lake is located in the Lake Van catchment. Large cities with high population density are located in Western Anatolia, while Eastern Anatolia has much lower population density. As a result of this and greater industrialization, most polluted rivers are located in Western Anatolia, while Eastern Anatolia has more natural systems (Gaziantep in Southeastern Anatolia is an exception). A total of 125 samples were collected

from 13 different river catchments in Western Anatolia (Gediz, Meriç-Ergene, Kuzey Ege, Marmara, Sakarya and Susurluk), Inner Anatolia (Akarçay, Kızılırmak and Konya), the Mediterranean (Antalya), Eastern Anatolia (Euphrates-Tigris) and the Black Sea (Yeşilirmak and Eastern Black Sea) in Turkey between 2009 and 2019 (Table 1; Fig. 1).

## 2.2. Sample collection

Samples were collected from different substrates in different waterbodies. Epilithic samples were collected by removing submerged stones and brushing them with a toothbrush. Epipelagic samples were collected using a pipette aspirator and epiphytic samples were collected from macrophytes [*Chara vulgaris* L., *Stuckenia pectinalis* (L.) Börner]. Some submerged parts of plants were collected into plastic bags (Taylor et al. 2006).

## 2.3. Sample processing, observations and identification

Samples were boiled in HCl and then in H<sub>2</sub>O<sub>2</sub> to remove organic matter. After rinsing three times with distilled water, the material was air-dried on cover glasses and mounted in Naphrax® (Taylor et al. 2006). Observations of diatoms were performed under an OLYMPUS BX51 light microscope at Dumlupınar University in Turkey, a NIKON Eclipse E600 at the

University of Szczecin and Carl Zeiss Axio Imager A2 at the University of Rzeszow in Poland.

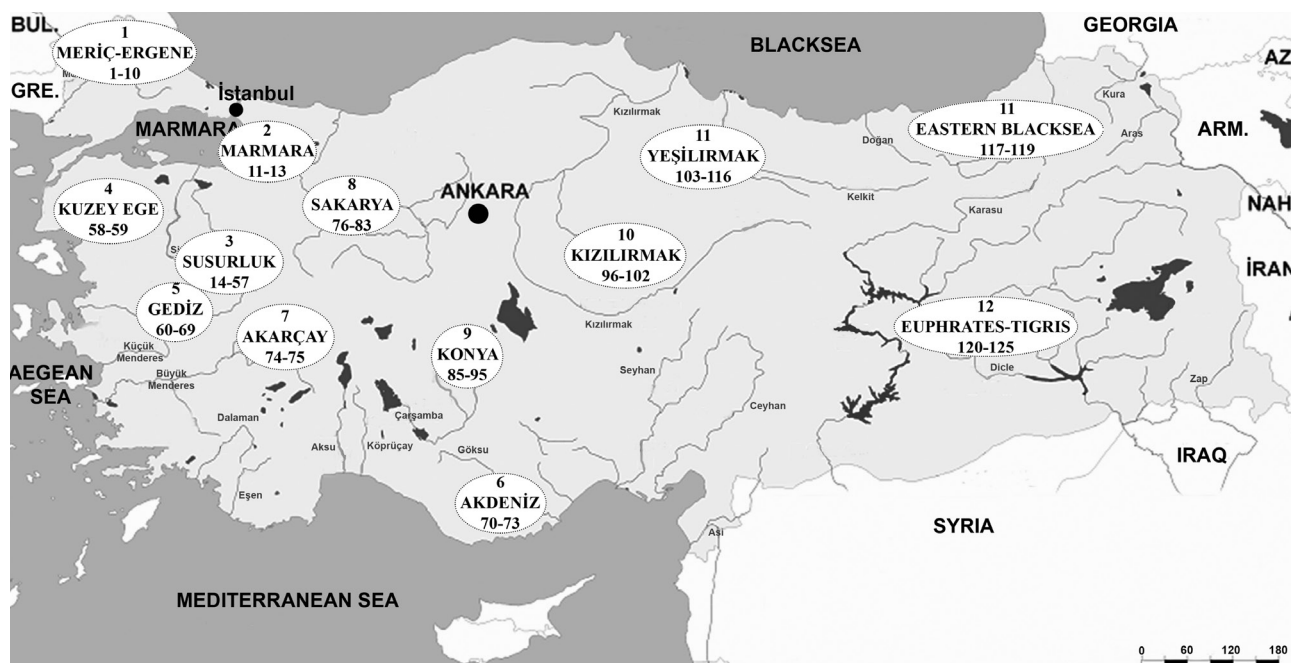
Diatoms were identified according to Krammer & Lange-Bertalot (1986, 1991), Reichardt & Lange-Bertalot (1991), Reichardt (1999, 2009, 2015), Lange-Bertalot et al. (2003), Van de Vijver & McBride (2003), Kulikovskiy et al. (2016), Levkov et al. (2016), and Kociolek et al. 2019. The morphological data provided (length, width, number of striae in 10 µm) for each taxon are based on our own measurements.

## 2.4. Distribution of diatoms

The distribution of each taxon in Turkey is presented according to Maraşlıoğlu & Gönülol (2019) and Taşkın et al. (2019). Taxa reported from Turkey with a value of at least 10% are categorized in the literature as “common” diatoms, those with a range of 2–9% are categorized as “frequent”, and those with a value of less than 2% – as “rare”. Diatoms from our material are also categorized as “common”, “frequent”, and “rare”.

## 3. Results

A total of 52 taxa were identified in our material collected from different catchments in Turkey (Table 1, Figure 1), of which 15 taxa were recorded for the first time in Turkey (\*). The list of identified taxa is shown in Table 2.



**Figure 1**

Map of the study area. Sites codes (T1–T125) for each river basin are listed in Table 1.



Table 1

## Sampling sites with the habitats (EPL: Epilithic, EPP: Epipellic, EPF: Epiphytic)

Site	River Basin	Abbreviation	Water body name – Substrate	Province
T1	1_Meriç-Ergene	MrEr	Süloğlu Reservoir – EPP	Edirne
T2			Meriç River – Edirne Centrum – EPL	
T3			Meriç River – Küplü Köyü District – EPL	
T4			Kuleli Stream – EPL	
T5			Ergene River – Çiftlikköy District – EPL	Kırklareli
T6			Keşiflik Stream – EPL	
T7			Kaynarlı Stream – EPL	
T8			Ergene River – EPL	Tekirdağ
T9			Bent Stream – EPL	
T10			Ergene River – Uzunköprü District – EPL	MR
T11	Ömerli Reservoir – EPP	Yalova		
T12	Ilıca District – EPL			
T13	Gökçedere – EPL	Bursa		
T14	Ulubat Lake – EPP			
T15	Demirtaş Reservoir – EPP			
T16	Nilüfer Reservoir – EPL			
T17	Susurluk River – Karacabey District – EPL			
T18	Gölanyağı Stream – EPL			
T19	Gölbaşı Reservoir – EPL			
T20	Deliçay – Kestel District – EPL			
T21	Kapıkaya Stream – EPL			
T22	Nilüfer Stream – Osmaniye District – EPL		Balıkesir	
T23	Orhaneli Stream – Akçabük District – EPL			
T24	İkizcetepeler Reservoir – EPL			
T25	Manyas Reservoir – EPP			
T26	Manyas Reservoir – EPL			
T27	Susurluk River – Bademli District – EPL			
T28	Susurluk River – Yeniköy District – EPL			
T29	Mürüvetler Stream – EPL			
T30	Simav Stream – Balıklı District – EPL			
T31	Ovaköy District – EPL			
T32	Simav Stream – Susurluk District – EPL	Kütahya		
T33	Kocaçay – Kızılköy District – EPL			
T34	Değirmendere Stream – EPL			
T35	Dursunbey Stream – EPL			
T36	Susurluk River – Sındırgı District – EPL			
T37	Kayaboğazı Reservoir – EPL			
T38	Simav River – Demirci Köyü District – EPL			
T39	Orhaneli Stream – Esatlar Köyü District – EPL			
T40	Orhaneli Stream – Hamitabat Köyü District – EPL			
T41	Aygırlar Stream – Domaniç District – EPL			
T42	Orhaneli Stream – Domaniç District – EPL			
T43	Topuk Stream – Domaniç District – EPL			
T44	Safa Stream – Domaniç District – EPL			
T45	Topuk/Safa junction – Domaniç District – EPL			
T46	Kocasu Str., before Kayaboğazı Reservoir – EPL			
T47	Kocasu Str., after Kayaboğazı Reservoir – EPL			
T48	Ilıcaksu Deresi – Spring – EPL			
T49	Karamanca District – EPL			
T50	Simav River – Spring – EPL			
T51	Mountainous stream – Eğir District – EPL			
T52	Mountainous stream – Yavru District – EPL			
T53	Naşa District – EPL			
T54	Güneyköy District – EPL			
T55	Domaniç District – EPL			
T56	Domaniç entrance – EPL			
T57	Ilıcaksu-branch – EPL			
T58	4_Kuzey Ege	KE	Şahindere – EPL	Balıkesir
T59			Azap Lake – EPF	Aydın
T60	5_Gediz	GDZ	Gediz River – Naşa District – EPL	Kütahya
T61			Gördes Reservoir – EPL	Manisa

Site	River Basin	Abbreviation	Water body name – Substrate	Province			
T62	5_Gediz	GDZ	Marmara Lake – EPF	Manisa			
T63			Demirci Stream – EPL				
T64			Gediz River – EPL				
T65			Derbent Stream – EPL				
T66			Alaşehir Stream – EPL				
T67			Afşar 2 Reservoir – EPL				
T68			Murat Stream – EPL				
T69			Ağıl Stream – EPL				
T70			Aksu Stream – EPL		6-Antalya	ANT	Antalya
T71			Alara Stream – EPL				
T72	Eğirdir Lake – EPF						
T73	Kovada Lake – EPL						
T74	7_Akarçay	AKR	Milyas Stream – EPL	Afyon			
T75			Kayalı Stream – EPL				
T76	8_Sakarya	SKR	Ilıca Stream – EPL	Kütahya			
T77			Porsuk River – before Kütahya – EPL				
T78			Porsuk River – Gelinkaya District – EPL				
T79			Felent Stream – Spring – EPL				
T80			Felent Stream – Köprüören District – EPL				
T81			Kokar Stream – EPL				
T82			Altıntaş District – EPL				
T83			Büyük Akgöl Lake – EPF		Sakarya		
T84			Mamasın Reservoir – EPL		Aksaray		
T85			İbrala Reservoir – EPL		Karaman		
T86	9_Konya	KNY	Meram District – EPL	Konya			
T87			Beyşehir Lake – Chara sample – EPF				
T88			Seydişehir District – EPL				
T89			Kocacay Stream – Spring – EPL				
T90			Derebucak Reservoir – EPP				
T91			Büyükköprü Stream – EPL				
T92			Susuz District – EPL				
T93			Beyşehir Lake – EPL				
T94			İvriz Reservoir – EPP				
T95			Dipsiz Lake – EPP				
T96	10_Kızılırmak	KZL	Kızılırmak River – Şarkışla District – EPL	Sivas			
T97			Fadlım River – EPL				
T98			Kızılırmak River – after Sivas – EPL				
T99			Kesikköprü Reservoir – EPL		Ankara		
T100			Uyuz Lake – EPF				
T101			Kızılırmak River – Bafra District – EPL		Samsun		
T102			Yay Lake – EPF		Kayseri		
T103	11_Yeşilirmak	YŞL	Çakmak Reservoir – EPL	Samsun			
T104			Derinöz Reservoir – EPL				
T105			Mert River – EPL				
T106			Yeşilirmak River-1 – EPL				
T107			Kelkit River – EPL				
T108			Kurtun River – EPL				
T109			Elgazi Stream – EPL				
T110			Karakuş Stream – EPL				
T111			Terme Stream – EPL				
T112			Yeşilirmak River-2 – EPL				
T113	Yeşilirmak River-3 – EPL	Sivas					
T114	Çekerek River – EPL						
T115	Çakraz Stream – EPL						
T116	Gölbek Lake – EPP	Çorum					
T117	12_ Eastern Black Sea	EBL	Moçar Stream – EPL	Artvin			
T118			Tatos Lake – EPL				
T119			Uzungöl Lake – EPL		Trabzon		
T120	13_ Euphrates–Tigris	ET	Gördelli Stream – EPL	Erzurum			
T121			Tuzla Stream – EPL	Erzincan			
T122			Karasu Stream – EPL	Gaziantep			
T123			Altınsu Stream – EPL	Mardin			
T124			Murat River – EPL	Ağrı			
T125			İnekli Lake – EPL	Adıyaman			



Table 2

Distribution of the species in Turkey according to Maraşlıoğlu & Gönüloğlu (2019) and the current study.

Abbreviations: AKR – Akarçay, ANT – Antalya, EBL – Eastern Black Sea, ET – Euphrates–Tigris, GDZ – Gediz, KE – Kuzey Ege, KNY – Konya, KZL – Kızılırmak, MR – Marmara, MrEr – Meriç–Ergene, SKR – Sakarya, SSR – Susurluk, and YŞL – Yeşilirmak river catchments; \* – new record for Turkey, C – common (reported in more than 10% of the literature), F – frequent (between 10% and 2% of the literature), R – rare (less than 2% of the literature)

Species	Turkey (Maraşlıoğlu & Gönüloğlu 2019)	Our results	River basin
<i>Didymosphenia geminata</i>	C	R	EBL (T117, T118)
<i>Gomphonema acuminatum</i>	C	R	KNY (T86); YŞL (T116)
<i>G. cf. aequale</i>		R	KNY (T86); ET (T120)
<i>G. affine</i>	C	R	MrEr (T3, T4); KZL (T101)
<i>G. affine</i> var. <i>rhombicum</i> *		R	SSR (T17)
<i>G. angustatum</i>	C	R	KNY (T86, T87)
<i>G. angusticephalum</i> *		R	SSR (T14); KZL (T99)
<i>G. angustius</i>	R	R	SSR (T50, T56, T60)
<i>G. augur</i>	C	R	MeEr (T7); SSR (T43); SKR (T77); YŞL (T107)
<i>G. brebissonii</i>	R	R	KNY (T86)
<i>G. calcifugum</i> *		C	SSR (T34, T41, T44, T45, T49, T54)
<i>G. capitatum</i>	R	R	KNY (T91)
<i>G. cf. clavatum</i>		R	KZL (T99)
<i>G. elegantissimum</i> *		R	AKR (T73); KNY (T86)
<i>G. exilissimum</i> *		C	MrEr (T6); SSR (T37, T47, T57); SKR (T82); KNY (T94); YŞL (T115); ET (T123)
<i>G. cf. gracile</i>		R	KZL (T99); ET (T118)
<i>G. graciledictum</i> *		R	SSR (T17); GDZ (T62)
<i>G. insignifine</i>	R	R	GDZ (T60)
<i>G. insigne</i>	F	R	SSR (T53); SKR (T81)
<i>G. italicum</i>	R	C	SSR (T14, T24, T30, T40, T38); GDZ (T62, T65); SKR (T77, T80); KNY (T87); KZL (T99); YŞL (T108, T110)
<i>G. italicum</i> var. <i>densistriatum</i> *		R	ET (T125)
<i>G. cf. latelanceolatum</i>		R	MeEr (T8); KE (T59)
<i>G. lateripunctatum</i>	R	R	GDZ (T68); KNY (T85, T93); KZL (T112)
<i>G. laticollum</i>	R	R	GDZ (T61); AKR (T74); SKR (T77)
<i>G. linearoides</i> *		R	YŞL (T106)
<i>G. megalobrebissonii</i> *		R	KNY (T95)
<i>G. micropus</i>	F	C	MrEr (T7); SSR (T34); GDZ (T66); KNY (T92); YŞL (T115)
<i>G. minusculum</i> *		R	SSR (T37, T53); SKR (T79, T80)
<i>G. minutum</i>	F	C	MrEr (T4); SSR (T18, T25, T26, T29, T30, T31, T33, T36, T38, T39, T40); YŞL (T103, T105)
<i>G. minutum</i> f. <i>syriacum</i> *		R	SSR (T19, T22, T23, T42)
<i>G. olivaceoides</i>	F	R	SSR (T21)
<i>G. olivaceum</i>	C	R	MrEr (T9); SSR (T15); GDZ (T69); KNY (T87); ET (T121)
<i>G. parvulum</i>	C	C	MrEr (T6); SKR (T82); KNY (T84); YŞL (T103, T111); ET (124)
<i>G. productum</i>	F	R	SSR (T51)
<i>G. cf. pseudaffine</i>		R	KNY (T87); EBL (T118)
<i>G. pseudoaugur</i>	R	R	SSR (T14)
<i>G. pumilum</i>	F	C	MrEr (T10); MR (T12, T13); SSR (T19, T21, T23, T27, T28, T29, T32, T34, T35, T41, T42, T46, T54, T55, T56); ANT (T70); SKR (T76, T77, T78, T81); KNY (T86, T87, T90); KZL (T99, T101); YŞL (T103, T107); ET (T122, T124)
<i>G. pumilum</i> var. <i>rigidum</i>	R	R	SSR (T54)
<i>G. reediae</i> *		R	GDZ (T61); KNY (T93)
<i>G. sarcophagus</i> *		R	MR (T11); KNY (T86, T91)
<i>G. stonei</i>	R	R	SSR (T48)

Species	Turkey (Maraşlıoğlu & Gönülol 2019)	Our results	River basin
<i>G. cf. subangustatum</i>		R	KNY (T86)
<i>G. subcapitatum</i> *		R	SKR (T83); EBL (T117)
<i>G. subclavatum</i>	F	R	EBL (T118, T119)
<i>G. supertergestinum</i>	R	R	MeEr (T6); SSR (T28, T46, T54); SKR (T77); YŞL (T114)
<i>G. tergestinum</i>	F	C	SSR (T52); KZL (T96, T97, T98); YŞL (T103, T108, T114, T115); ET (T121)
<i>G. vibrio</i>	F	R	SSR (T51)
<i>Gomphonema</i> sp. 1		R	KZL (T99)
<i>Gomphonema</i> sp. 2		R	KZL (101)
<i>Gomphonema</i> sp. 3		R	YŞL (T113)
<i>Gomphonema</i> sp. 4		R	SSR (T17, T33, T54); SKR (T77)
<i>Gomphosphenia holmquistii</i> *		R	SSR (T54); KZL (T102)

### *Didymosphenia geminata* (Lyngbye) M.Schmidt

Plate 1: 2, 3

Basionym. *Echinella geminata* Lyngbye

Ref. Kulikovskiy et al. 2016 (p. 200; pl. 134: 1–4), Metzeltin & Lange-Bertalot 2014 (p. 16; pl. 4: 1–4, 9: 1–7).

Dimensions: 65.5–110.9 µm long, 28.9–34.4 µm wide, 10–12 striae in 10 µm.

Distribution in our study: common in high-mountain lakes in the Black Sea region.

Distribution in Turkey: common.

### *Gomphonema acuminatum* Ehrenberg

Plate 2: 4

Ref. Kulikovskiy et al. 2016 (p. 207; pl. 125: 1–7), Reichardt 1999 (p. 45; pl. 52: 1–14, 53: 1–17).

Dimensions: 46.3–60.7 µm long, 12.7–13.8 µm wide, from 10–12 (middle valve portion) to 13–16 (near apices) striae in 10 µm.

Distribution in our study: rare in Inner Anatolia.

Distribution in Turkey: common.

### *Gomphonema cf. aequale* W.Gregory

Plate 2: 5, 6

Ref. Levkov et al. 2016 (p. 23; pl. 91: 1–42).

Dimensions: 19.8–24.0 µm long, 6.0–6.9 µm wide, 7–8

striae in 10 µm.

Distribution in our study: rare in Inner and Eastern Anatolia.

Distribution in Turkey: *Gomphonema aequale* is so far unknown from Turkey. However, the observed specimens differ from this species.

Remarks: Our specimens are more elliptical (not linear to linear-lanceolate) and have fewer striae than reported by Levkov et al. (2016). The occurrence was recorded only in Konya (T86) and Euphrates–Tigris river basins (T120).

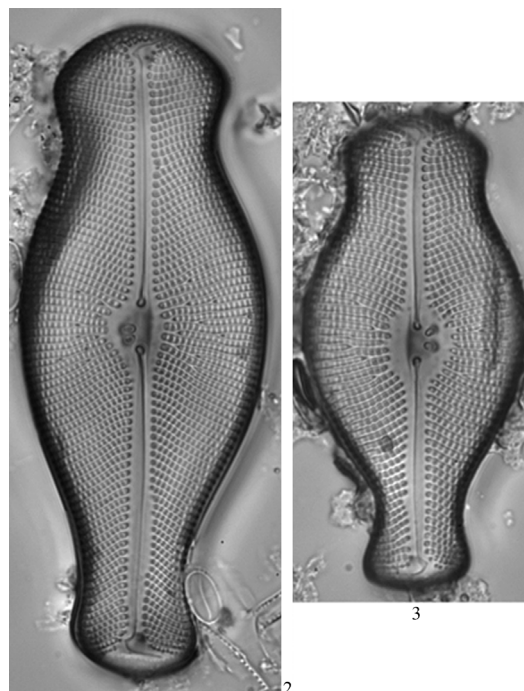
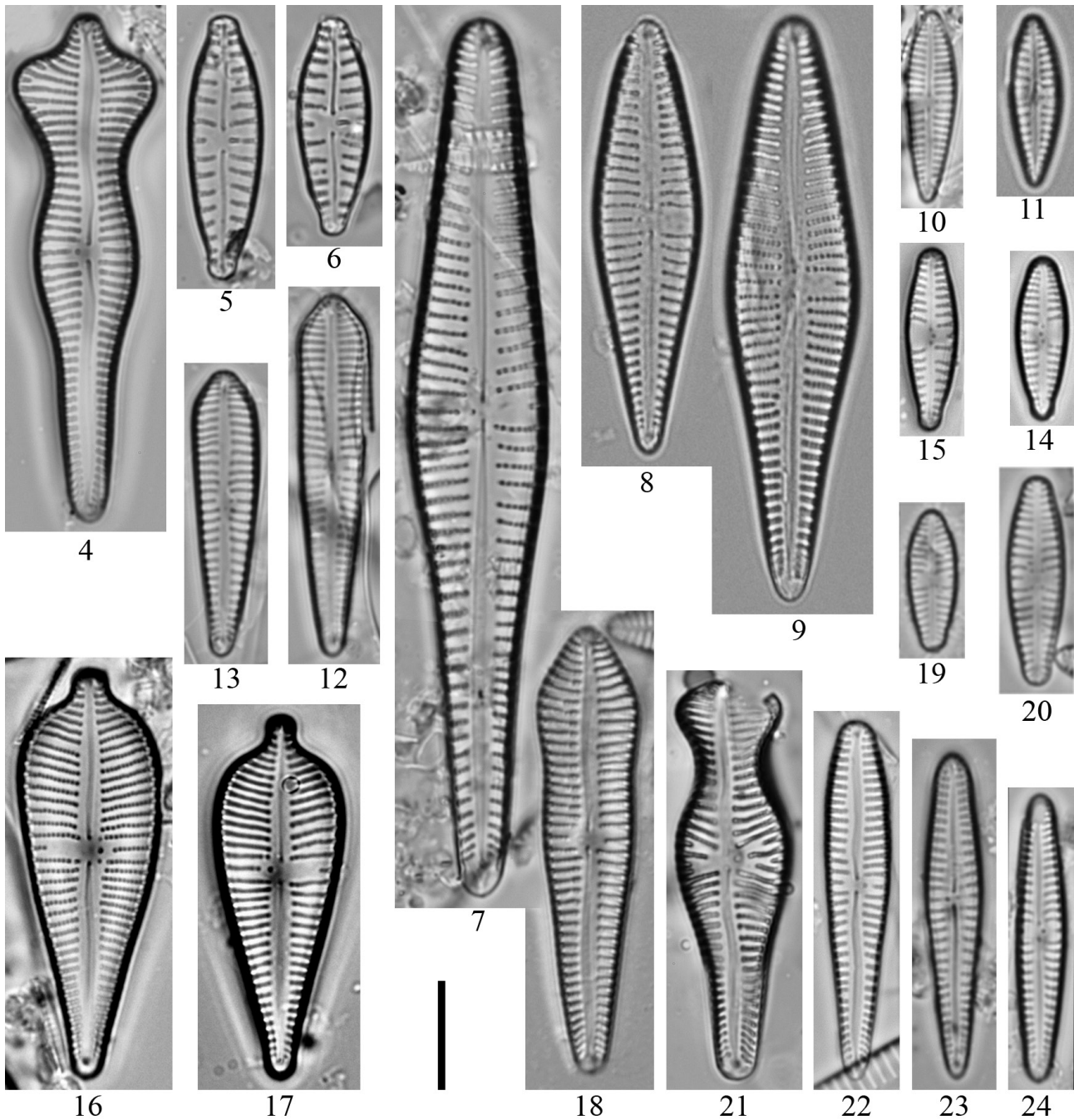


Plate 1

2, 3 – *Didymosphenia geminata* (Lyngbye) M.Schmidt.

Scale bar: 10 µm





## Plate 2

4 – *Gomphonema acuminatum* Ehrenberg; 5, 6 – *G. cf. aequale* W. Gregory; 7 – *G. affine* Kützing; 8, 9 – *G. affine* var. *rhombicum* E. Reichardt; 10, 11 – *G. angustatum* (Kützing) Rabenhorst; 12, 13 – *G. angusticephalum* E. Reichardt & Lange-Bertalot; 14, 15 – *G. angustus* E. Reichardt; 16, 17 – *G. augur* Ehrenberg; 18 – *G. brebissonii* Kützing; 19, 20 – *G. calcifugum* Lange-Bertalot & E. Reichardt; 21 – *G. capitatum* Ehrenberg; 22 – *Gomphonema cf. clavatum* E. Reichardt; 23, 24 – *G. elegantissimum* E. Reichardt & Lange-Bertalot. Scale bar: 10 µm



***Gomphonema affine*** Kützing

Plate 2: 7

Ref. Reichardt 1999 (p. 13; pl. 7: 1–9, 8: 1–14, 9: 1–14),  
Levkov et al. 2016 (p. 24; pl. 41: 1–12).

Dimensions: 43.9–53.5 µm long, 10.4–11.3 µm wide,  
7–11 striae in 10 µm.

Distribution in our study: rare in Inner and Thrace  
regions.

Distribution in Turkey: common.

Remarks: Some of the observed valves are similar to  
the *Gomphonema* species – *G. insignifine* (Levkov  
2016).

\****Gomphonema affine* var. *rhombicum*** E.Reichardt

Plate 2: 8, 9

Ref. Reichardt 1999 (p. 15; pl. 10: 1–15).

Dimensions: 39.8–80.2 µm long, 9.6–12.9 µm wide,  
9–11 striae in 10 µm.

Distribution in our study: rare in the Susurluk River in  
Western Anatolia.

***Gomphonema angustatum*** (Kützing) Rabenhorst

Plate 2: 10, 11

Basionym. *Sphenella angustata* Kützing

Ref. Reichardt 1999 (p. 23; pl. 24: 1–37), Levkov et al.  
2016 (p. 26; pl. 51: 19–23).

Dimensions: 17.3–24.3 µm long, 4.4–5.8 µm wide, 12–15  
striae in 10 µm.

Distribution in our study: rare in Altıntaş and Meram  
districts in Inner Anatolia.

Distribution in Turkey: common.

Remarks: Some specimens of *G. angustatum* were  
smaller than those described in papers by Reichardt  
(1999) and Levkov et al. (2016).

\****Gomphonema angusticephalum*** E.Reichardt &  
Lange-Bertalot

Plate 2: 12, 13

Ref. Kulikovskiy et al. 2016 (p. 208; pl. 125: 1–14),  
Reichardt 1999 (p. 49; pl. 60: 1–26).

Dimensions: 25.9–38.5 µm long, 4.9–6.5 µm wide, from  
11–13 (middle valve portion) to 14–16 (near apices)  
striae in 10 µm.

Distribution in our study: found in Lake Uluabat in  
Western Anatolia (rare) and the Kesikköprü Reservoir in  
Inner Anatolia (common in *Chara vulgaris*).

***Gomphonema angustius*** E.Reichardt

Plate 2: 14, 15

Ref. Reichardt 2009 (p. 163; Figs 9–30), Levkov et al.  
2016 (p. 29; pl. 163: 32–51, 165: 1–32).

Dimensions: 14.0–16.9 µm long, 4.8–5.4 µm wide, 11–14  
striae in 10 µm.

Distribution in our study: rare in the Simav and Gediz  
rivers and in the Domaniç district in Western Anatolia.

Distribution in Turkey: rare, observed only in the  
Aegean region – Kütahya flowing waters (Solak et al.  
2016).

***Gomphonema augur*** Ehrenberg

Plate 2: 16, 17

Ref. Levkov et al. 2016 (p. 32; pl. 35: 1–23).

Dimensions: 29.1–51.8 µm long, 11.4–12.9 µm wide,  
10–13 striae in 10 µm.

Distribution in our study: rare in the Kaynarlı stream in  
the Thrace region, the Topuk stream in the Domaniç  
district and the Kelkit River in the Black Sea region,  
but common in the Porsuk River in Western Anatolia  
(Conductivity COND: 515 µS cm<sup>-2</sup>, pH: 8.37 and  
dissolved oxygen DO: 10.2 mg l<sup>-1</sup>).

Distribution in Turkey: common.

***Gomphonema brebissonii*** Kützing

Plate 2: 18

Ref. Kulikovskiy et al. 2016 (p. 208; pl. 125: 18–20),  
Reichardt 1999 (p.46; pl. 56: 1–14, 57: 1–10), Levkov et al.



2016 (p. 37; pl. 5: 1–16).

Dimensions: 33.2 µm long, 7.1 µm wide, 13 striae in 10 µm.

Distribution in our study: rare, found only in the Meram district in Inner Anatolia.

Distribution in Turkey: rare in Lake Uluabat (Dalkiran et al. 2016) in Inner Anatolia.

\**Gomphonema calcifugum* Lange-Bertalot & E.Reichardt

Plate 2: 19, 20

Ref. Levkov et al. 2016 (p. 39; pl. 199: 29–53).

Dimensions: 12.3–19.9 µm long, 3.7–4.8 µm wide, 13–17 striae in 10 µm.

Distribution in our study: rare in the Değirmendere, Aygırlar, Safa, Topuk streams in Western Anatolia, also sparse in Lake Azap in North-Western Anatolia and common in some mountain streams in the Domaniç Kütahya (altitude: 1118–1204 m a.s.l., COND: 102–130 µS cm<sup>-2</sup>, pH: 7.89–8.03 and DO: 10.8–11.1 mg l<sup>-1</sup>).

*Gomphonema capitatum* Ehrenberg

Plate 2: 21

Ref. Kulikovskiy et al. 2016 (p. 208; pl. 126: 25–28), Levkov et al. 2016 (p. 40; pl. 32: 1–17).

Dimensions: 36.1–36.3 µm long, 10.4–11.7 µm wide, from 12 (middle valve portion) to 14 (near apices) striae in 10 µm.

Distribution in our study: rare in the Büyükköprü stream in Inner Anatolia.

Distribution in Turkey: rare in Lake Uluabat (Dalkiran et al. 2016) in Inner Anatolia, the Özlüce Reservoir (Şen et al. 2005) and the Kalecik Reservoir (Sönmez 2011) in Eastern Anatolia.

*Gomphonema cf. clavatum* E.Reichardt

Plate 2: 22

Ref. Reichardt 1999 (p. 25; pl. 25: 1–23, 27–28).

Dimensions: 28.6–39.4 µm long, 5.7–7.1 µm wide, from

11 (middle valve portion) to 13 (near apices) striae in 10 µm.

Distribution in our study: rare, found only in the Kesikköprü Reservoir in Inner Anatolia.

Remarks: Our specimens of *Gomphonema cf. clavatum* have more subrostrate apices than the type specimens (Reichardt 1999). The occurrence was noted only in the Kızılırmak river basins (T99). The exact identity of this taxon will be verified using scanning electron microscopy (SEM).

\**Gomphonema elegantissimum* E.Reichardt & Lange-Bertalot

Plate 2: 23, 24

Ref. Levkov et al. 2016 (p. 48; pl. 153: 28–55).

Dimensions: 22.2–29.6 µm long, 4.2–5.0 µm wide, from 11–12 (middle valve portion) to 13–15 (near apices) striae in 10 µm.

Distribution in our study: rare in Lake Kovada in the Mediterranean region and in the Meram district in Inner Anatolia.

Remarks: the observed specimens probably belong to a group similar to *G. elegantissimum*. They have a different, more lanceolate outline, such as Fig. 23, which was identified as a *Gomphonema* species.

\**Gomphonema exilissimum* (Grunow) Lange-Bertalot & E.Reichardt

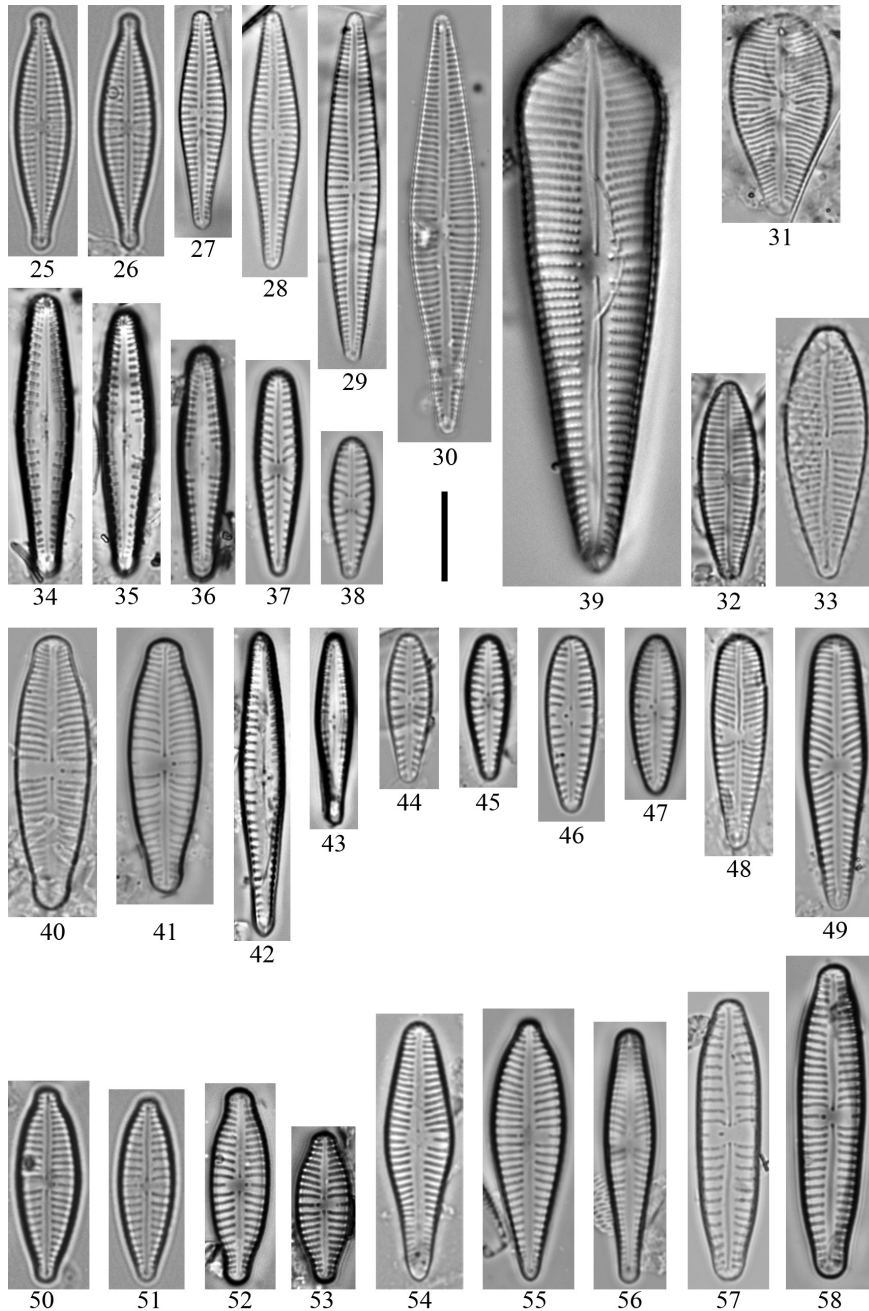
Plate 3: 25, 26

Basionym. *Gomphonema parvulum* var. *exilissimum* Grunow

Ref. Levkov et al. 2016 (p. 49; pl. 127: 1–33).

Dimensions: 15.0–26.3 µm long, 4.8–6.4 µm wide, from 13–14 (middle valve portion) to 15–16 (near apices) striae in 10 µm.

Distribution in our study: common, in the Keşiflik stream in the Thrace region, in the Kayaboğazi reservoir, the Kocasu and Ilıcaksu streams in Western Anatolia, the İvriz reservoir in Inner Anatolia, the Çakraz stream in Eastern Anatolia and the Altınsu stream in South–Eastern Anatolia. The species most likely occurs in other parts of the country.



### Plate 3

25, 26 – *Gomphonema exilissimum* (Grunow) Lange-Bertalot & E.Reichardt; 27–29 – *Gomphonema* cf. *gracile* Ehrenberg; 30 – *G. graciledictum* E.Reichardt; 31 – *G. italicum* var. *densistriatum* Levkov, Mitic-Kopanja & E. Reichardt; 32, 33 – *G.* cf. *latelanceolatum* Levkov, Mitic-Kopanja & E. Reichardt; 34–36 – *G. lateripunctatum* E. Reichardt & Lange-Bertalot; 37, 38 – *G. linearoides* Levkov; 39 – *G. megalobreissonii* D.A.Chudaev, Kociolek & M.A.Golobova; 40, 41 – *G. micropus* Kützing; 42, 43 – *G. minusculum* Cleve-Euler; 44, 45 – *G. minutum* (C.Agardh) C.Agardh; 46, 47 – *G. minutum* f. *syriacum* Lange-Bertalot & E. Reichardt; 48 – *G. olivaceoides* Hustedt; 49 – *G. olivaceum* (Hornemann) Brébisson; 50, 51 – *G. parvulum* (Kützing) Kützing; 52, 53 – *G. productum* (Grunow) Lange-Bertalot & E. Reichardt; 54 – *G.* cf. *pseudaffine* Levkov, Mitic-Kopanja & E. Reichardt; 55 – *G. pseudoaugur* Lange-Bertalot; 56 – *G. reediae* Levkov, Mitic-Kopanja & E. Reichardt; 57, 58 – *G. sarcophagus* W. Gregory. Scale bar: 10 µm



**Gomphonema cf. gracile** Ehrenberg auct. Nonnull.

Plate 3: 27–29

Ref. Kulikovskiy et al. 2016 (p. 209; pl. 128: 1–3), Reichardt 2015 (p. 369; Figs 1–6).

Dimensions: 23.8–42.3 µm long, 4.9–6.9 µm wide, from 13–15 (middle valve portion) to 16–17 (near apices) striae in 10 µm.

Distribution in our study: rare in the Kesikköprü Reservoir in Inner Anatolia and Lake Tatos in the eastern Black Sea region.

Remarks: according to Reichardt (2015), the type specimens of *G. gracile* differ from those found in our sample. The most similar is *G. graciledictum* E. Reichardt, however, our specimens are smaller and more slender (less than 6.0 µm wide). They are also morphologically similar to *G. hebridense* (Fig. 29). They were found only in the Kızılırmak (T99) and Euphrates-Tigris river basins (T118). The exact identity of this taxon will be verified using scanning electron microscopy (SEM).**\*Gomphonema graciledictum** E.Reichardt

Plate 3: 30

Ref. Levkov et al. 2016 (p. 53; pl. 44: 1–25), Reichardt 2015 (p. 373; Figs 36–61).

Dimensions: 32.0–46.5 µm long, 6.7–7.5 µm wide, from 13 (middle valve portion) to 17 (near apices) striae in 10 µm.

Distribution in our study: rare in the Susurluk River and Lake Marmara in Western Anatolia.

**Gomphonema insignifine** Reichardt

Ref. Reichardt 2009 (p. 164; Figs 31–42).

Dimensions: 41.1 µm long, 9.9 µm wide, 7 striae in 10 µm.

Distribution in our study: rare, noted only in the Gediz River in Western Anatolia.

Distribution in Turkey: rare in the Aegean region (Kütahya flowing waters – Solak et al. 2016, p. 574; Fig. 3: 52).

**Gomphonema insigne** W.Gregory

Ref. Levkov et al. 2016 (p. 60; pl. 50: 1–17).

Dimensions: 54.7–68.0 µm long, 11.1–12.7 µm wide, 7–8 striae in 10 µm.

Distribution in our study: rare in the Naşa and the Kokar stream in Western Anatolia.

Distribution in Turkey: frequent in Kütahya flowing waters (Solak et al. 2016, p. 574; Fig. 3: 50–51), Lake Uluabat (Dalkiran et al. 2016) in Western Anatolia, in the Darıören and Isparta streams (Çiçek et al. 2010) in the Mediterranean, in Karagöl (Açıkgöz &amp; Baykal 2005), in Inner Anatolia and the Keban Reservoir (Pala 2007) in Eastern Anatolia.

**Gomphonema italicum** Kützing

Ref. Kulikovskiy et al. 2016 (p. 211; pl. 127: 9–14), Levkov et al. 2016 (p. 63; pl. 15: 1–16).

Dimensions: 20.0–57.7 µm long, 7.5–12.0 µm wide, 10–13 striae in 10 µm.

Distribution in our study: rare in Lake Uluabat, Lake Marmara, the İközetepe reservoir, the Simav, Orhaneli, Derbent, Porsuk and Felent streams in Western Anatolia, Lake Beyşehir in Inner Anatolia, the Kurtun River and abundant in the Karakuş stream in the Black Sea region.

Distribution in Turkey: common in Kütahya flowing waters (Solak et al. 2016, p. 574; Fig. 4: 58, 59) in Western Anatolia.

**\*Gomphonema italicum var. densistriatum** Levkov, Mitic-Kopanja & E.Reichardt

Plate 3: 31

Ref. Levkov et al. 2016 (p. 64; pl. 16: 1–18).

Dimensions: 22.5 µm long, 11.2 µm wide, 18 striae in 10 µm.

Distribution in our study: rare, found in Lake İnekli in South Eastern Anatolia.

**Gomphonema cf. latelanceolatum** Levkov, Mitic-Kopanja & E.Reichardt

Plate 3: 32, 33

Ref. Levkov et al. 2016 (p. 71; pl. 73: 1–22).

Dimensions: 18.6–27.7  $\mu\text{m}$  long, 5.9–9.0  $\mu\text{m}$  wide, 13–15 striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Meriç River in the Thrace region and Lake Azap in Western Anatolia.

Remarks: our specimens differ in size (generally less than 25  $\mu\text{m}$  long, more slender, less than 9.0  $\mu\text{m}$  wide) with high density of striae (11–14 striae in 10  $\mu\text{m}$ ). They were found only in the Meriç-Ergene (T8) and Kuzey Ege river basins (T59). This taxon will be verified by SEM.

***Gomphonema lateripunctatum*** E.Reichardt & Lange-Bertalot

Plate 3: 34–36

Ref. Levkov et al. 2016 (p. 73; pl. 143: 1–31).

Dimensions: 21.5–41.5  $\mu\text{m}$  long, 3.6–6.6  $\mu\text{m}$  wide, from 8–9 (middle valve portion) to 13–14 (near apices) striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Mutlu stream in Western Anatolia, Lake Beyşehir and the İbrala Reservoir in Inner Anatolia and the Elgazi stream in Black Sea region.

Distribution in Turkey: rare in Sakarya flowing waters (Morkoyunlu et al. 2017) in Western Anatolia and Lake Ladik (Maraşlıoğlu et al. 2007) in the Black Sea.

***Gomphonema laticollum*** E.Reichardt

Ref. Kulikovskiy et al. 2016 (p. 212; pl. 126: 1–7), Levkov et al. 2016 (p. 74; pl. 22: 1–15, 23: 1–5, 24: 1–25, 25: 1–8, 26: 13–19).

Dimensions: 21.1–32.2  $\mu\text{m}$  long, 8.7–9.5  $\mu\text{m}$  wide, 11–13 striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Gördes Reservoir, the Milyas stream and the Porsuk River in Western Anatolia.

Distribution in Turkey: rare in Western Anatolia (Kütahya flowing waters – Solak et al. 2016, p. 574; Fig. 4: 60, 61).

***Gomphonema linearoides*** Levkov

Plate 3: 37, 38

Ref. Levkov et al. 2016 (p. 75; pl. 195: 25–35).

Dimensions: 22.9  $\mu\text{m}$  long, 4.7  $\mu\text{m}$  wide, from 10 (middle valve portion) to 12 (near apices) striae in 10  $\mu\text{m}$ .

Distribution in our study: rare, found only in the Yeşilirmak River in the Black Sea region.

**\**Gomphonema megalobreissonii*** D.A.Chudaev, Kociolek & M.A.Golobova

Plate 3: 39

Ref. Van de Vijver & McBride 2003 (p. 443; Figs 1–14).

Dimensions: 49.4–70.0  $\mu\text{m}$  long, 12.7–14.6  $\mu\text{m}$  wide, 7–10 striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in Lake Dipsiz in Inner Anatolia.

***Gomphonema micropus*** Kützing

Plate 3: 40, 41

Ref. Levkov et al. 2016 (p. 83; pl. 96: 21–40, 97: 1–37), Reichardt 1999 (p. 34; pl. 36: 1–14, 37: 1–29, 38: 1–15).

Dimensions: 17.3–29.9  $\mu\text{m}$  long, 6.4–7.4  $\mu\text{m}$  wide, from 11–12 (middle valve portion) to 13–15 (near apices) striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Kaynarlı stream in the Thrace region, the Değirmendere and Alaşehir streams in Western Anatolia, the Susuz and the Çakraz stream in Inner Anatolia.

Distribution in Turkey: Common.

**\**Gomphonema minusculum*** Cleve-Euler

Plate 3: 42, 43

Ref. Levkov et al. 2016 (p. 5; pl. 161: 1–25).

Dimensions: 21.0–40.0  $\mu\text{m}$  long, 4.0–5.2  $\mu\text{m}$  wide, from 10–12 (middle valve portion) to 13–14 (near apices) striae in 10  $\mu\text{m}$ .



Distribution in our study: rare in the Kayaboğazi Reservoir, the Naşa District, the Felent stream in Western Anatolia.

***Gomphonema minutum*** (C.Agardh) C.Agardh

Plate 3: 44, 45

Basionym. *Licmophora minuta* C.Agardh

Ref. Krammer & Lange-Bertalot 1986 (p. 370; pl. 81: 1–5), Levkov et al. 2016 (p.87: pl.171: 1–22, 172: 1–8).

Dimensions: 10.9–33.5 µm long, 4.0–6.1 µm wide, 10–15 striae in 10 µm.

Distribution in our study: rare in the Kuleli stream in the Thrace region, the Gölayağı stream, the Manyas Reservoir, the Mürüvetler, Simav, Kocaçay, Susurluk and Orhaneli streams, the Ovaköy district in Western Anatolia and the Çakmak Reservoir and the Mert River in the Black Sea region.

Distribution in Turkey: common.

\****Gomphonema minutum* f. *syriacum*** Lange-Bertalot & E.Reichardt

Plate 3: 46, 47

Ref. Krammer & Lange-Bertalot 1986 (pl. 81; Figs 9–14)

Dimensions: 17.7–23.0 µm long, 5.1–6.2 µm wide, 11–12 striae in 10 µm.

Distribution in our study: Rare in the Gölbaşı Reservoir, the Nilüfer and Orhaneli streams in Western Anatolia.

***Gomphonema olivaceoides*** Hustedt

Plate 3: 48

Ref. Reichardt 2009 (p. 168; Figs 60–65)

Dimensions: 23.5 µm long, 5.9 µm wide, 15 striae in 10 µm.

Distribution in our study: rare, found only in the Deliçay stream in Western Anatolia.

Distribution in Turkey: frequent in the Black Sea and Eastern Anatolia.

***Gomphonema olivaceum*** (Hornemann) Brébisson

Plate 3: 49

Basionym. *Ulva olivacea* Hornemann

Ref. Levkov et al. 2016 (p. 91; pl. 184: 1–47).

Dimensions: 15.7–38.7 µm long, 4.6–7.1 µm wide, 10–15 striae in 10 µm.

Distribution in our study: rare in the Bent stream in the Thrace region, the Demirtaş Reservoir, the Ağıl stream in Western Anatolia, Lake Beyşehir in Inner Anatolia, the Tuzla stream in South Eastern Anatolia.

Distribution in Turkey: commonly reported from lentic and lotic waters in the country (Solak & Wojtal 2012, Solak et al. 2012).

***Gomphonema parvulum*** (Kützing) Kützing

Plate 3: 50, 51

Basionym. *Sphenella parvula* Kützing

Ref. Kulikovskiy et al. 2016 (p. 213; pl. 128: 12–17), Levkov et al. 2016 (p. 98; pl. 102: 1–38, 103: 1–14).

Dimensions: 15.9–26.2 µm long, 4.5–7.1 µm wide, from 11–13 (middle valve portion) to 13–15 (near apices) striae in 10 µm.

Distribution in our study: rare in the Keşiflik stream in the Thrace region, the Altıntaş District in Western Anatolia, the Mamasın Reservoir in Inner Anatolia, the Çakmak Reservoir and the Terme stream in the Black Sea region and the Murat River in Eastern Anatolia.

Distribution in Turkey: common.

***Gomphonema productum*** (Grunow) Lange-Bertalot & E.Reichardt

Plate 3: 52, 53

Basionym. *Gomphonema angustatum* var. *productum* Grunow

Ref. Reichardt 1999 (p. 31; pl. 32: 1–18), Levkov et al. 2016 (p. 106; pl. 96: 1–20).

Dimensions: 16.9–26.9 µm long, 6.1–6.9 µm wide, 11–13 striae in 10 µm.

Distribution in our study: rare, found in large numbers in the Eğir in Western Anatolia.

Distribution in Turkey: frequent in the Tersakan stream (Maraşlıoğlu et al. 2016) and some lakes (Soylu et al. 2005) in the Black Sea, in the Darıören and Isparta streams (Çiçek et al. 2010) in the Mediterranean and in Lake Hazar (Yıldırım et al. 2003), the Topçu pond (Akköz et al. 2004), the Özlüce Reservoir (Şen et al. 2005), the Keban Reservoir (Pala 2007), the Kalecik Reservoir (Sönmez 2011) in Eastern Anatolia.

***Gomphonema cf. pseudaffine*** Levkov, Mitic-Kopanja & E.Reichardt

Plate 3: 54

Ref. Levkov et al. 2016 (p. 107; pl. 71: 1–25).

Dimensions: 40.0–73.9 µm long, 8.8–10.7 µm wide, from 9–11 (middle valve portion) to 13–17 (near apices) striae in 10 µm.

Distribution in our study: rare in Lake Beyşehir in Inner Anatolia and Lake Tatos in Black Sea region.

Remarks: our specimens have an outline that corresponds to *G. pseudaffine*, however, the striae are clearly more radiate in our valves. The occurrence was recorded only in Konya (T87) and the eastern Black Sea river basins (T118).

***Gomphonema pseudoaugur*** Lange-Bertalot

Plate 3: 55

Ref. Krammer & Lange-Bertalot 1986 (p. 364; pl. 159: 1–4).

Dimensions: 28.7 µm long, 8.1 µm wide, from 11 (middle valve portion) and 14 (near apices) striae in 10 µm.

Distribution in our study: rare in Lake Uluabat in Western Anatolia.

Distribution in Turkey: rare in Lake Salt (Akbulut 2013) in Inner Anatolia and in Acarlar floodplain forest (Tunca et al. 2014) in Western Anatolia.

***Gomphonema pumilum*** (Grunow) E.Reichardt & Lange-Bertalot

Basionym. *Gomphonema intricatum* var. *pumilum*

Grunow

Ref. Kulikovskiy et al. 2016 (p. 214; pl. 125: 15–17), Levkov et al. 2016 (p. 110; pl. 151: 26–52).

Dimensions: 15.4–36.4 µm long, 3.1–6.5 µm wide, 10–14 striae in 10 µm.

Distribution in our study: frequent in the Ergene River in the Thrace region, the Ilıca District and the Gökçedere stream in the Marmarean region, the Gölbaşı Reservoir, the Kapıkaya, Orhaneli, Susurluk, Mürüvet, Simav, Değirmendere, Dursunbey, Aygırlar, Kocasu, Ilıca, Porsuk, Kokar streams, the Güneyköy and Domaniç districts in Western Anatolia, the Aksu stream in the Mediterranean region, the Kızılırmak River, Lake Beyşehir, the Meram District, Derebucak and Kesikköprü reservoirs in Inner Anatolia, the Çakmak Reservoir in the Black Sea region, the Yeşilirmak, Karasu and Murat rivers in Eastern Anatolia.

Distribution in Turkey: common in Akçay (Solak et al. 2005), Kütahya flowing waters (Solak et al. 2016, p. 575; Fig. 4: 62–64), the Küçük Menderes river basin (Solak et al. 2018a) in Western Anatolia, in the Çubuk River (Yıldız & Özkıran 1994) in Inner Anatolia and in the Black Sea (Taş & Yılmaz 2015).

Remarks: until now, this taxon has only been found in a few locations in Turkey. However, our results showed that *G. pumilum* occurs in many parts of the country.

***Gomphonema pumilum* var. *rigidum*** E.Reichardt & Lange-Bertalot

Ref. Lange-Bertalot et al. 2017 (p. 319; pl. 99: 15–20).

Dimensions: 15.4–36.4 µm long, 3.1–6.5 µm wide, 10–14 striae in 10 µm.

Distribution in our study: rare, noted only in the Güneyköy District in Western Anatolia.

Distribution in Turkey: rare in Kütahya flowing waters (Solak et al. 2016, p. 575; Fig. 4: 65–67) in the Aegean region.

**\**Gomphonema reediae*** Levkov, Mitic-Kopanja & E.Reichardt

Plate 3: 56

Ref. Levkov et al. 2016 (p. 112; pl. 187: 1–31).



Dimensions: 28.3–29.2  $\mu\text{m}$  long, 5.6–5.8  $\mu\text{m}$  wide, from 13–14 (middle valve portion) to 15–16 (near apices) striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Gördes Reservoir in Western Anatolia and Lake Beyşehir in Inner Anatolia.

\**Gomphonema sarcophagus* W.Gregory

Plate 3: 57, 58

Ref. Reichardt 1999 (p. 30; pl. 30: 1–30, 31: 1–6), Levkov et al. 2016 (p. 116; pl. 94: 1–27).

Dimensions: 25.9–34.9  $\mu\text{m}$  long, 6.7–7.8  $\mu\text{m}$  wide, from 9–10 (middle valve portion) to 10–13 (near apices) striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Ömerli Reservoir in the Marmara region, the Büyükköprü stream and the Meram District in Inner Anatolia.

Remarks: The observed specimens have varying numbers of striae in 10  $\mu\text{m}$  (see Figs 57 and 58).

*Gomphonema stonei* E.Reichardt

Ref. Reichardt 1999 (p. 16; pl. 13: 1–17).

Dimensions: 33.5–41.9  $\mu\text{m}$  long, 8.7–9.6  $\mu\text{m}$  wide, with 10–13 striae in 10  $\mu\text{m}$ .

Distribution in our study: rare, found in the İlicaksu creek in Western Anatolia.

Distribution in Turkey: rare in the Aegean region (Kütahya flowing waters – Solak et al. 2016, p. 575; Fig. 4: 68, 69).

*Gomphonema cf. subangustatum* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito

Plate 4: 59, 60

Ref. Lange-Bertalot et al. 2003 (p. 47; pl. 91: 1–15).

Dimensions: 15.8–23.3  $\mu\text{m}$  long, 3.6–4.3  $\mu\text{m}$  wide, from 14–16 (middle valve portion) to 14–18 (near apices) striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the Meram District in Inner Anatolia.

Remarks: in our material, the specimens are very narrow, resulting in uncertainty in precise identification of individuals as *G. subangustatum*. The occurrence was recorded only in the Konya river basin (T86).

\**Gomphonema subcapitatum* (Grunow) E.Reichardt & Levkov

Plate 4: 61

Basionym. *Gomphonema constrictum* var. *subcapitatum* Grunow

Ref. Levkov et al. 2016 (p. 122; pl. 34: 1–29).

Dimensions: 29.3–31.9  $\mu\text{m}$  long, 8.0–9.2  $\mu\text{m}$  wide, 11–12 striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in Lake Büyük Akgöl in Western Anatolia, the Moçar stream in the Black Sea region.

*Gomphonema subclavatum* (Grunow) Grunow

Plate 4: 62, 63

Basionym. *Gomphonema montanum* var. *subclavatum* Grunow

Ref. Levkov et al. 2016 (p. 123; pl. 64: 1–19).

Dimensions: 32.5–52.9  $\mu\text{m}$  long, 6.4–9.6  $\mu\text{m}$  wide, 9–12 striae in 10  $\mu\text{m}$ .

Distribution in our study: rare in the İlicaksu creek in Western Anatolia, the Meram District in Inner Anatolia, the Kızılırmak River in the Black Sea region, Lake Tatos and Lake Uzungöl in the Black Sea region.

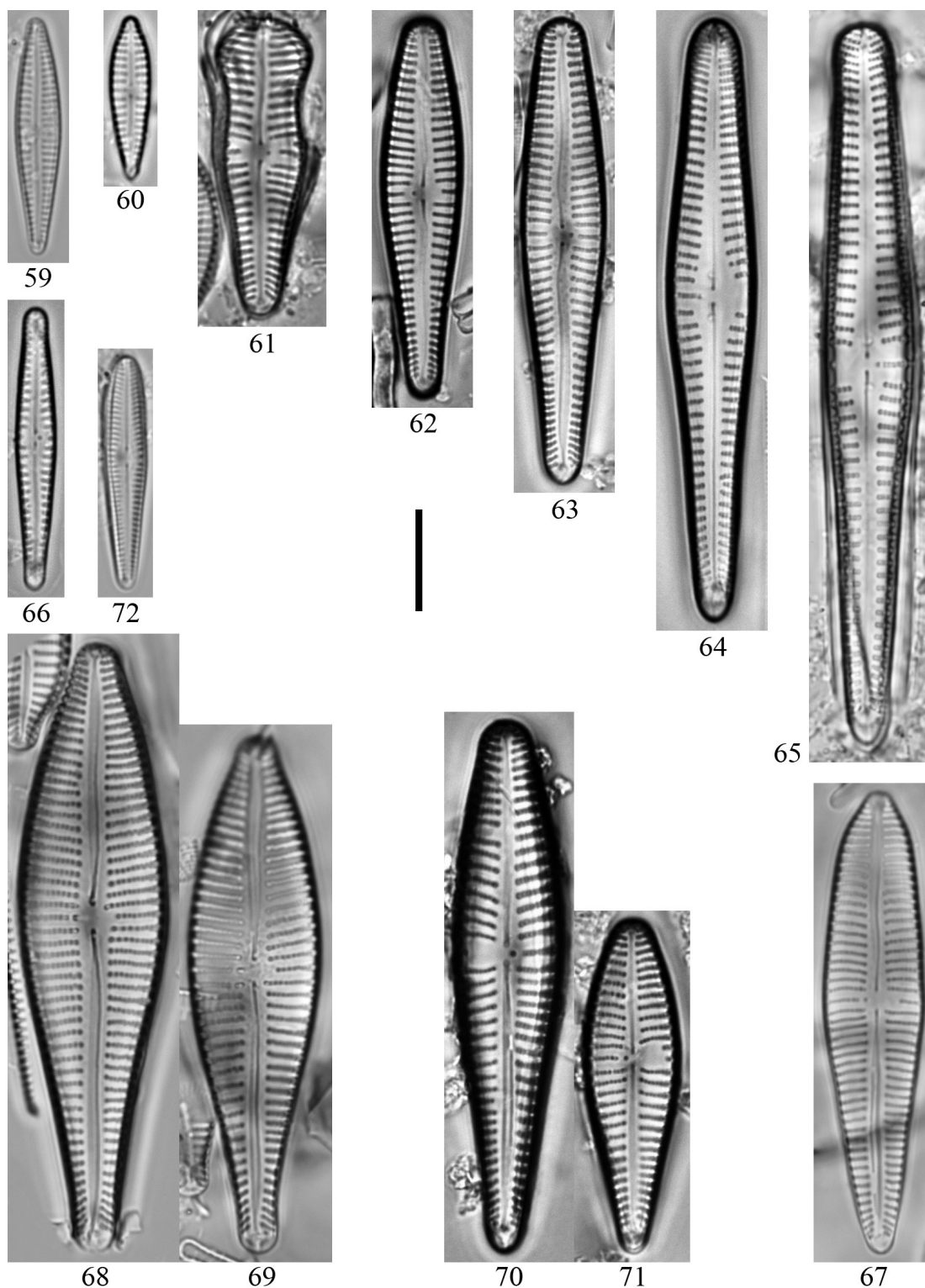
Distribution in Turkey: frequent in the Seyhan River (Kandemir-Çevik et al. 1994) in the Mediterranean, in Kazangöl (Aysel et al. 1998), Lake Stream (Aysel et al. 2001) in Western Anatolia, in the Keban Reservoir (Pala 2007) in Eastern Anatolia and in Lake Uzungöl (Şahin 1998) in the Black Sea.

*Gomphonema supertergestinum* E.Reichardt

Ref. Levkov et al. 2016 (p.127; pl. 165: 33–42).

Dimensions: 16.5–34.9  $\mu\text{m}$  long, 6.1–8.6  $\mu\text{m}$  wide, 11–12 striae in 10  $\mu\text{m}$ .



**Plate 4**

59, 60 – *G. cf. subangustatum* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito; 61 – *G. subcapitatum* (Grunow) E. Reichardt & Levkov; 62, 63 – *G. subclavatum* (Grunow) Grunow; 64, 65 – *G. vibrio* Ehrenberg; 66 – *Gomphonema* sp. 1; 67 – *Gomphonema* sp. 2; 68, 69 – *Gomphonema* sp. 3; 70, 71 – *Gomphonema* sp. 4; 72 – *Gomphosphenia holmquistii* (Foged) Lange-Bertalot. Scale bar: 10  $\mu$ m



Distribution in our study: rare in the Keşiflik stream in the Thrace region, the Susurluk and Porsuk rivers, the Kocasu stream and the Güneyköy District in Western Anatolia, the Çekerek River in the Black Sea region.

Distribution in Turkey: rare in Kütahya flowing waters (Solak et al. 2016, p. 575; Fig. 4: 70, 71) in the Aegean region.

***Gomphonema tergestinum*** (Grunow) Fricke

Basionym. *Gomphonema semiapertum* var. *tergestinum* Grunow

Ref. Levkov et al. 2016 (p. 128; pl. 163: 1–31).

Dimensions: 10.3–26.6 µm long, 4.1–6.5 µm wide, 10–15 striae in 10 µm.

Distribution in our study: common in the Yavru District in Western Anatolia, the Kızılırmak and Fadlım rivers in Inner Anatolia, the Çakmak Reservoir, the Yeşilirmak and Çekerek rivers, the Çakrak and Tuzla streams in Eastern Anatolia.

Distribution in Turkey: frequent in Kütahya flowing waters (Solak et al. 2016, p. 575; Fig. 4: 72–74) in Aegean regions, in Uzungöl (Şahin 1998), the Cimil stream (Taş & Yılmaz 2015) in the Black Sea, in Hotamış (Yıldız et al. 1998), the Hirfanlı Reservoir (Baykal & Açıkgöz 2004), the Çamlıdere Reservoir (Baykal 2006) in Inner Anatolia.

***Gomphonema vibrio*** Ehrenberg

Plate 4: 64, 65

Ref. Reichardt & Lange-Bertalot 1991 (p.522; pl. 2: 1–9).

Dimensions: 59.2–69.6 µm long, 8.9–10.1 µm wide, from 7–9 (middle valve portion) to 12–14 (near apices) striae in 10 µm.

Distribution in our study: rare in the Eğir District in Western Anatolia.

Distribution in Turkey: frequent in Akçay (Solak et al. 2005), Kütahya flowing waters (Solak et al. 2016) in Aegean and in Uzungöl (Şahin 1998) in the Black Sea regions.

Remarks: *G. vibrio* shows morphological variability, for example, the outline and the density of striae in the head pole (Figs 64 and 65), however, all specimens found were identified as belonging to this species and

not to any variety as shown by Kowalska-Eliasz (2017).

***Gomphonema* sp. 1**

Plate 4: 66

Dimensions: 26.8–34.1 µm long, 3.9–4.5 µm wide, from 10–12 (middle valve portion) to 12–14 (near apices) striae in 10 µm.

Distribution in our study: rare, found only in the Kesikköprü Reservoir in Inner Anatolia.

Remarks: the studied valves have a different central area compared to *G. bavaricum* (Reichardt & Lange-Bertalot 1991, p. 534, pl. 7, Figs 2–7), and striae are much denser near the apices. The central area of *G. bavaricum* sensu Reichardt and Lange-Bertalot is cross-rectangular to square, while the central area in our material is smaller and there are two striae there (as in *G. dichotomum*). In our specimens, the apical striae are much denser, as in *G. pumilum*. The difference between our specimens and *G. pumilum* are clear – in the axial area, *G. pumilum* has a much wider, lanceolate area.

***Gomphonema* sp. 2**

Plate 4: 67

Dimensions: 45.1 µm long, 9.6 µm wide, 11 striae in the middle and 13 striae near apices in 10 µm.

Distribution in our study: rare, found only in Lake Uyuz in Inner Anatolia.

Remarks: the valves are similar to *G. longiceps* Ehrenberg (Reichardt 2015, p. 142, Figs 10–18), but they differ in the head pole outline and the width of striae. Another, more similar species is *G. bukycanyonum* Bukhtiyarova (Levkov et al. 2016, p. 38; pl. 80: 23–26).

***Gomphonema* sp. 3**

Plate 4: 68, 69

Dimensions: 47.9–64.9 µm long, 12.1–14.2 µm wide, from 9–10 (middle valve portion) to 12–13 (near apices) striae in 10 µm.

Distribution in our study: rare, found only in the Karakuş stream in the Black Sea region.

Remarks: the most similar taxon is *G. mexicanum*

Grunow (Reichardt 1999, p. 20; pl. 18: 1–15, 19: 1–13). This species was reported from Turkey as *G. subclavatum* var. *mexicanum* (Grunow) R.M. Patrick in Uzungöl (Şahin 1998) in the Black Sea and in the Tatar Reservoir (Varol et al. 2018) in Eastern Anatolia. The exact identity of this taxon will be verified using scanning electron microscopy (SEM).

#### *Gomphonema* sp. 4

Plate 4: 70, 71

Dimensions: 29.7–59.2 µm long, 9.4–11.3 µm wide, 8–11 striae in 10 µm.

Distribution in our study: rare in the Nilüfer Reservoir, the Kocaçay stream, the Porsuk River, the Güneyköy District in Western Anatolia.

Remarks: the most similar taxon is *G. zellense* E.Reichardt (1999, p. 11; pl. 5: 1–11). This species is known from Macedonia (Levkov et al. 2016). The observed morphological variability, including the size of valves and an outline, results in uncertainty in the precise identification of individuals.

\**Gomphosphenia holmquistii* (Foged) Lange-Bertalot

Plate 4: 72

Basionym. *Gomphonema holmquistii* Foged

Ref. Kulikovskiy et al. 2016 (p. 217; pl. 124: 59–61).

Dimensions: 17.9–22.8 µm long, 3.5–3.8 µm wide, 18–19 striae in 10 µm.

Distribution in our study: rare in the Güneyköy District in Western Anatolia and Lake Yay in Inner Anatolia.

## 4. Discussion

In this study, a total of 52 taxa were found in the material collected from different basins in Turkey. Of the identified taxa, *Gomphonema affine* var. *rhombicum*, *G. angusticephalum*, *G. angustivalva*, *G. calcifugum*, *G. elegantissimum*, *G. exillissimum*, *G. graciledictum*, *G. italicum* var. *densistriatum*, *G. linearoides*, *G. megalobrebissonii*, *G. minusculum*, *G. minutum* f. *syriacum*, *G. reediae*, *G. sarcophagus*, *G. subcapitatum*, and *Gomphosphenia holmquistii* are the first records for the Turkish freshwater diatom flora. Several taxa were found in only one or a few

basins. *G. exillissimum*, *G. italicum*, *G. micropus*, *G. minutum*, *G. parvulum*, *G. pumilum* and *G. tergestinum* were abundant in several different basins (Table 2). At individual sites, they occurred in populations of greatly varying size. *Gomphonema augur* occurred abundantly in the Porsuk River (T77: DO – 10.1 mg l<sup>-1</sup>, pH – 8.4 and conductivity – 515.2 µS cm<sup>-2</sup>). This species is mainly found in alkaline, nutrient-rich lakes and other large water bodies (Lange-Bertalot et al. 2017). According to Lange-Bertalot et al. (2017), more data are needed to understand its autoecology. *Gomphonema italicum* was found in large numbers in the Karakuş Stream (T113: DO – 9.4 mg l<sup>-1</sup>, pH – 7.8 and conductivity – 213.1 µS cm<sup>-2</sup>). The distribution of the species is not well established due to the fact that the species was previously identified as *G. truncatum* (Lange-Bertalot et al. 2017). *Gomphonema productum* was found abundant in a mountain stream in the Eğir District (T51: DO – 9.8 mg l<sup>-1</sup>, pH – 7.6 and conductivity – 599.2 µS cm<sup>-2</sup>). This diatom is an indicator of good ecological quality and occurs in upland streams (Lange-Bertalot et al. 2017). *Gomphosphenia holmquistii* is poorly studied. The species prefers water with low temperatures, low conductivity and alkaline or near neutral pH (Noga et al. 2016).

Some identified taxa had different morphological dimensions compared to the type material. For example, *Gomphonema angustatum* was smaller than the type material in Reichardt (1999): 17.3–24.3 µm length and 4.4–5.8 µm width vs. 15.0–48.0 µm length and 5.2–6.6 µm width, respectively. *G. capitatum* was also smaller than specimens in Levkov et al. (2016): 36.1–36.3 µm vs. 44.0–52.0 µm length.

The recorded diversity of diatoms in Turkey is relatively low compared to other parts of the world, such as England (Hartley et al. 1996), the Netherlands (Cremer & Koolmees 2010) and Poland (Bağ et al. 2012), but the list continues to grow each year with new studies (e.g. centric diatoms – Solak et al. 2018b; nitzschoid diatoms – Solak et al. 2019). In many cases, rare taxa are not reported in the results of publications on diatoms in Turkish inland waters (Solak et al. 2012). However, records of these taxa are important for the assessment of biodiversity (Gillett et al. 2011).

Since 2013, the Turkish Government has been implementing the WFD program for freshwater biomonitoring in Turkey and has been trying to improve specific diatom indices for Turkish waters. However, a reliable index is based on correct taxonomic identification. Studies such as this will facilitate the identification of the most common, and perhaps even some rare, species found in Turkish waters.



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