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Epiphytic diatoms as bioindicators of trophic status of Lake Modrac (Bosnia and Herzegovina)

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Abstract: Biodiversity of diatoms and applicability of diatom indices in biomonitoring based on littoral epiphytic samples of Lake Modrac were investigated. Diatoms were taken mostly from *Phragmites australis* stems in 2017, during which physical and chemical parameters of the water were measured. A total of 85 diatom taxa were identified. *Gomphonema* (13 spp.), *Navicula* (11 spp.), and *Nitzschia* (8 spp.) were the most abundant genera. Obtained values of trophic indices (TID, TvD, and TDIL) pointed to meso- to eutrophic status for most localities, while values of the IBD, EPI, –D, and IPS indices indicated good ecological status, except for localities at the mouth of 2 main tributaries which had moderate or poor ecological status. Based on the hierarchical group average clustering and nonmetric multidimensional scaling, 4 groups were identified, mainly related to the sampling period, with higher spatial variation in species composition during summer. Since environmental legislation in Bosnia and Herzegovina still does not provide detailed instructions on using diatoms in biological assessment, results of this study can be useful for the development of biomonitoring tools for lakes in Bosnia and Herzegovina.

Key words: Epiphyton, diatoms, biodiversity, biomonitoring, Lake Modrac, diatom indices, trophic status

1. Introduction

Lake Modrac is an artificial lake located in northeastern Bosnia and Herzegovina. It originated in 1964 after dam construction on the Spreča River in order to provide a water supply for industries in the Tuzla region. It covers 16.75 km^2, with a maximal length of 10.4 km, maximal width of 1.78 km, and maximal depth of 18 m (average depth of 5.2 m). Water retention time is 5–6 per year (Mihaljević et al., 2000). The lake is fed by 2 rivers, Spreča and Turija, and several small streams. Nowadays, Lake Modrac is used for drinking water supply after treatment. Most of the previous studies of Lake Modrac are oriented toward ichthyological research (Adrović et al., 2009) and ectoparasites of fishes (Skenderović et al., 2011). The previous hydrobiological research on the phytoplankton community of Lake Modrac which was conducted by Mihaljević et al. (2000) proved the mesoeutrophic state of the reservoir. Research on epipelon diatom communities was done at the Šerićka bara marsh located in the vicinity of Lake Modrac (Kamberović et al., 2017).

Phytoplankton is the most commonly used community in assessing the water quality of lakes. Macrophytes and phytobenthos are particularly sensitive to nutrients and acidification, and together form one "biological element" that needs to be assessed in freshwater bodies, as has been stated in the Water Framework Directive (WFD, European Union, 2000).

Phytobenthos have been used considerably less often in monitoring lakes than in the monitoring of rivers. However, several recently published studies showed good potential for using epiphytic diatoms in water quality assessment. Stenger-Kovács et al. (2007) developed the Trophic Diatom Index for Lakes (TDI); Hofmann (1994) delineated principles for the use of periphytic algae in lakes as trophic and saprobic indicators; Kitner and Poulíčková (2003) examined the indicator role of diatoms in the littoral regions of eutrophic shallow lakes in the Czech Republic; Poulíčková et al. (2004) compared littoral diatom assemblages from natural substrates for estimating trophic status in 7 perialpine lakes in Austria; Ács et al. (2005) conducted water quality analysis for Lake Velence using epiphytic diatoms. Bearing in mind different approaches in European countries for the use of littoral diatoms in biomonitoring purposes, intercalibration of ecological

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status concepts across European lakes was performed by Kelly et al. (2014). Lake Modrac has enormous importance for its surrounding area, but data on its algae as water bioindicators are scarce. This paper gives detailed insight into the species diversity of epiphytic diatoms from the reed stalks in Lake Modrac. Considering that algae-based monitoring has not yet been established in Bosnia and Herzegovina, this is a pioneering study on the possibility of using epiphytic diatoms in water quality assessment. The main objectives of this study were: (i) to explore epiphytic diatom diversity in littoral habitats of Lake Modrac; (ii) to describe physical and chemical characteristics of water quality; and (iii) to estimate the ecological quality using diatom indices.

2. Materials and methods

Diatom samples were collected at 5 sampling points (L1 to L5) of Lake Modrac over 3 months in 2017 (Figure 1). Samples were taken in the littoral region of the lakes from *Phragmites australis* stems, or if it was above the water level (in July), from other available macrophytes (*Trapa natans*, *Nymphoides peltata*).

List of localities on Lake Modrac including the sampled periods May (a), June (b), July (c):

L1 - Prokusovići (a, b, c);
L2 - the mouth of the river Turija (a, b, c);
L3 - the mouth of the river Spreča (a, b, c);
L4 - Kiseljak (b, c);
L5 - Babice (b, c).

Water samples were collected in 1000-mL glass bottles, 10 cm beneath the lake surface. Temperature, pH, dissolved oxygen, and conductivity were measured in situ using a Multi 3410 mobile instrument (WTW Company, Weilheim, Germany). Total nitrogen (TN), total phosphorus (TP), and total alkalinity were determined in the laboratory. Total nitrogen was determined as the sum

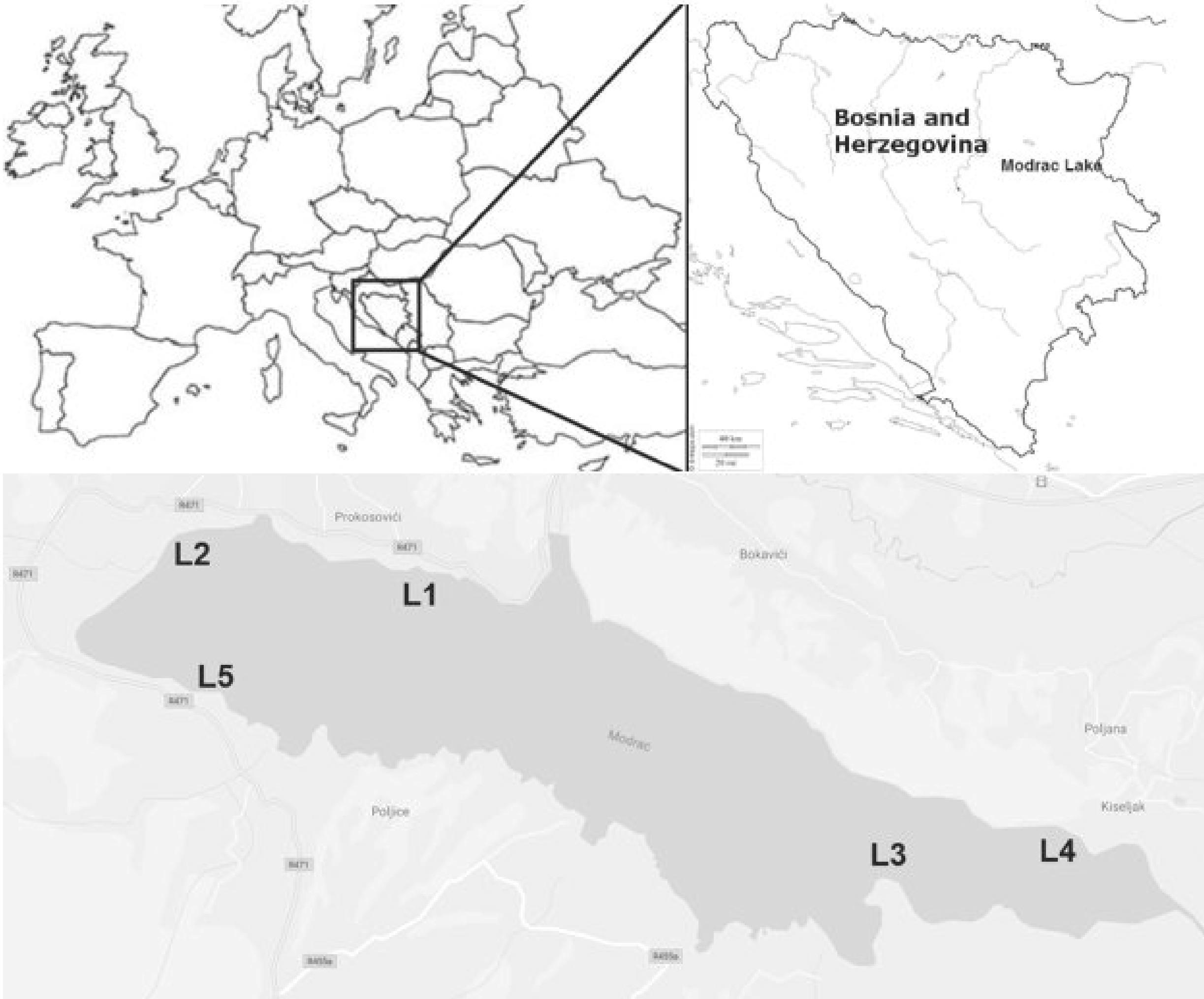

Figure 1. Study area.

of total Kjeldahl nitrogen (ammonia and organic nitrogen) and inorganic nitrogen (nitrite nitrogen and nitrate nitrogen). The method consists of 3 stages: digestion at a temperature of 340 °C (boiling point of H_2SO_4) in the presence of concentrated sulfuric acid and selenium Kjeldahl catalyst; distillation in the presence of NaOH captured in the solution of boric acid, and titration with 0.1 M HCl in the presence of indicator bromocresol green. Determination has been made on a Kjeldahl apparatus (Gerhardt, Bonn, Germany) (Institute for Standardization of Bosnia and Herzegovina, BAS EN 25663:2000, 2000). Nitrate nitrogen was determined spectrophotometrically with sulfosalicylic acid (Institute for Standardization of Bosnia and Herzegovina, BAS ISO 7890-3:2002, 2002). Nitrite nitrogen was determined spectrophotometrically with sulfanilic acid and alpha-naphthylamine (Čoha, 1990).

Phosphorus is the substrate of the organic orthophosphate or polyphosphate forms; therefore, the method is based on the translation of the entire content of phosphorus in the orthophosphates prior to the determination (Institute for Standardization of Bosnia and Herzegovina, BAS EN ISO 6878:2006, 2006). Alkalinity was determined via volumetric analysis with 0.1 M HCl (APHA, AWWA, and WEF, 1999).

Diatoms were acid-cleaned (Hustedt, 1930) and mounted in Naphrax (Brunel Microscopes Ltd., Chippenham, UK) for the preparation of permanent slides. At least 400 diatom valves were counted on each slide using random transects under a BA310 Motic optical microscope (Speed Fair Co. Ltd., Hong Kong, China). Diatoms were identified using the following literature: Krammer and Lange-Bertalot (1986, 1988, 2000, 2004a, 2004b), Krammer (2000, 2002), Hofmann et al. (2011), and Lange-Bertalot et al. (2017). Nomenclature was checked following the Algaebase webpage (Guiry and Guiry, 2018). Microphotographs were taken with Optika Pro 3LT camera processed with Optika Vision Pro Software (Optika Microscopes, Ponteranica, Italy).

Biodiversity was estimated for each sample using the Shannon–Wiener index of species diversity: *H*'(ln) (Shannon and Weaver, 1949). In the absence of national procedures, 6 diatom-based indices were used and compared for estimation of the trophic state: Trophic Diatom Index for Lakes (TDIL; Stenger-Kovács et al., 2007); Eutrophication Pollution Index Diatoms (EPI-D; Dell Uomo, 1996); Biological Diatom Index (IBD; Lenoir et Coste, 1996); Pollution Sensitivity Index (IPS; Cemagref, 1982); Trophic Index (TID; Rott et al., 1999); and Trophic Index by van Dam et al. (1994) (TvD; modified trough weighting by the relative abundance of diatom taxa). Diatom indices were calculated using OMNIDIA software, version 5.3 (Lecointe et al., 1993), except for TDIL and van Dam Trophic indices, which were calculated in Microsoft Excel. Nonmetric multidimensional scaling (nMDS), hierarchical group average clustering, and the SIMPROF test based on mean values of the relative diatom abundance for each sample were used for locality ordering. Species contribution to the groups was described by the SIMPER analysis. The correlation between quality classes based on diatom indices was estimated with the Pearson correlation coefficient. Statistical analyses were performed in IBM SPSS Statistics for Windows v. 22.0 (IBM Corp., Armonk, NY, USA) and Primer 6.0 (Clarke and Warwick, 2001).

3. Results

3.1 Physicochemical analysis

Physicochemical analysis has shown that the water of the littoral zone of the lake is slightly alkaline. Dissolved oxygen decreased seasonally from May to July, from a maximum of 9.39 to 6.32 mg L^{-1}. The concentration of total phosphorus remaining uniform during the investigated months and following boundaries by Besse-Lototskaya et al. (2011) indicates the mesoeutrophic and eutrophic status of the lake. Total nitrogen and water level were much lower in July than in May. The transparency of the water in the littoral zone was low, and decreased to 73 cm. The values of the physical and chemical parameters of Lake Modrac are represented in Table 1.

3.2 Diatom diversity

A total of 85 taxa were determined in epiphytic samples of Lake Modrac. Genera with the highest number of species were *Gomphonema*, *Navicula*, and *Nitzschia* with 13, 11, and 8 species, respectively. The most abundant and most frequent species were *Achnanthidium minutissimum* (Kützing) Czarnecki, *Pantocsekiella ocellata* (Pantocsek) K.T.Kiss & E.Ács, *Encyonema ventricosum* (C.Agardh) Grunow, *Navicula cryptotenella* Lange-Bertalot, *Navicula capitatoradiata* H.Germain, *Nitzschia palea* (Kützing) W.Smith, and *Cymbella cymbiformis* C.Agardh. The total number of recorded taxa per site location ranged between 19 and 43. Diatom taxa identified per location studied are listed in Table 2, and microphotographs of selected epiphytic diatoms in Lake Modrac are presented in Figure 2. Average value of Shannon–Wiener Diversity Index (*H*`) was 2.1 (ranging between 1.27 and 2.86), indicating high species diversity. Species diversity was the highest in May, with a declining trend in June and a slight increase in July.

Results of nMDS analysis and hierarchical group average clustering are shown in Figure 3. Hierarchical group average clustering and the SIMPROF test followed by SIMPER analysis identified 4 groups mainly related to the sampling period. The first group included all samples from June and 2 samples from July (L3c and L5c); it was characterized by species *Achnanthidium minutissimum*, *Pantocsekiella ocellata*, and *Navicula cryptotenella*.

Table 1. The maximum and minimum values of physical and chemical parameters per location in the study period.

Parameters	L1	L2	L3	L4	L5
Temperature [°C]	17.6–26.4	18.1–26.4	16.9–27.8	26.8–33.6	24.5–26.1
pH	8.35–8.60	8.19–8.11	8.26–8.50	8.66–8.72	8.61–8.06
Conductivity [µS cm^{-1}]	331–393	371–443	355–409	367–362	367–424
Dissolved oxygen [mg L^{-1}]	9.39–7.90	9.21–7.91	8.63–7.68	7.73–6.32	7.91–7.87
Alkalinity [mg L^{-1} $CaCO_3$]	165–165	170–145	170–125	130–110	140–140
Total P [µg L^{-1}]	38–38	49–47	85–83	88–55	41–49
Total N [µg L^{-1}]	107–4.3	111–4.2	86–5.4	31–3.9	120–3.7
Water depth in littoral zone [cm]	169–55	117–165	165–17	30–10	51–183
Secchi depth [cm]	66–to bottom	75–55	57–bottom	to bottom	51–73

Samples from May formed group 2 and were characterized by *Encyonema ventricosum*, *Navicula cryptotenella*, and *Cymbella cymbiformis*. The third group consisted of samples from the mouths of the rivers Turija and Kiseljak (L2c and L4c), with the lowest water quality and dominance of *Nitzschia palea*. The fourth group included only 1 spring (L1c), characterized by *Fragilaria vaucheriae*, *Nitzschia dissipata* var. *media*, and *Cocconeis placentula* var. *lineata*. Similar to the methods of clustering, nMDS analysis summarizes the distribution of the diatom community mainly through seasonal aspect. Diatom assemblages in samples from May from the left side of the ordination diagram have a tendency toward total nitrogen, while samples from June are positioned centrally. Samples from July show higher spatial variation. The dynamics of epiphytic communities were changing in the direction of the domination of *E. ventricosum*, *C. cymbiformis* in May, species *A. minutissimum* and *P. ocellata* in June, and *P. ocellata* and *Nitzschia palea* in July. Species *Navicula cryptotenella* was consistently present in samples in all 3 months.

3.3 Diatom indices and water quality

The average of the taxa used for the index calculation was the highest for IPS (96%), IBD (86.67%), and EPI-D (83%), whilst trophic indices had a lower percentage of indicator taxa: TID (78.42%), TvD (74%), and TDIL (50%). Based on the values of the IBD, EPI-D, and IPS, the water of Lake Modrac belongs to water class II, which corresponds with good ecological status, except for localities L2c and L4c, with moderate and poor ecological status, respectively. The values of TDIL indicated mostly moderate to good status. The values of the trophic index by Rott et al. (TID) indicated meso- to eutrophic and eutrophic status for most localities, and eu- to polytrophic status for localities L2c and L4c. Similar to the TID, the trophic index by van Dam et al. (TvD) pointed to mesoeutraphenic and eutraphenic status for most localities (Figure 4). The concentration of total phosphorus following the boundaries by Besse-Lototskaya et al. (2011) indicates the mesoeutrophic and eutrophic status of the lake, which mostly coincides with the assessment of water quality using diatom indices. However, the contents of total phosphorus and nitrogen in water were statistically insignificant and low correlated with the values of the used indices. In contrast, the values of all indices are significantly correlated with each other ($P < 0.01$), and the highest statistically significant correlation was achieved with the IPS and IBD indices ($r = 0.964$, $P < 0.01$). The values of IBD, IPS, and H' indices were highly correlated with dissolved oxygen ($r = 0.7$, 0.63, and 0.58, $P < 0.05$). Correlating ecological status using diatom indices and concentration of total phosphorus in water, the highest and most statistically insignificant values of the Pearson correlation coefficient were obtained for the classes obtained by IPS index and TID index in relation with ecological status given by concentration of total phosphorus in water ($r = 0.265$, $P = 0.48$; $r = 0.212$, $P = 0.48$, respectively).

4. Discussion

Previous research on primary production in lakes has focused much more on planktonic than on benthic algae (Cantonati and Lowe, 2014). However, epiphytic diatoms living in association with macroalgae and aquatic macrophytes have been proposed as an important community for the assessment of lake trophic status (Poulíčková et al., 2004; Stenger-Kovács et al., 2007). Diatoms are recognized as good indicator organisms in aquatic ecosystems which can be used as proxies for phytobenthos when the ecological status of lakes is being assessed (Kelly et al., 2008). Diatoms occur in a wide variety of environments, showing a broad range of tolerance along several gradients of abiotic factors, while individual species are sensitive to changes in nutrient concentrations and ratios (Round, 1991). The most abundant and frequent

Table 2. Diatom taxa identified per location studied.

Taxa	Locations
Achnanthidium minutissimum (Kützing) Czarnecki	1, 2, 3, 4, 5
Amphipleura pellucida (Kützing) Kützing	5
Amphora copulata (Kützing) Schoeman et R.E.M.Archibald	1, 3, 4, 5
Amphora inariensis Krammer	2
Amphora ovalis (Kützing) Kützing	1, 2, 3, 4, 5
Amphora pediculus (Kützing) Grunow ex A.Schmidt	1, 2, 3, 4, 5
Anomoeoneis sphaerophora Pfitzer	2
Aulacoseria sp.	2
Brebissonia lanceolata (C. Agardh) R.K.Mahoney et Reimer	1, 2, 3, 4, 5
Caloneis aerophila W. Bock	2
Cocconeis placentula var. lineata (Ehrenberg) Van Heurck	1, 2, 3
Cocconeis placentula Ehrenberg	1, 2, 5
Cocconeis placentula var. euglypta (Ehrenberg) Grunow	2, 3, 4, 5
Craticula cuspidata (Kutzing) D.G.Mann	3, 4
Cymatopleura elliptica (Brébisson) W.Smith	1, 2, 3, 4
Cymatopleura solea (Brébisson) W.Smith	1, 2, 4
Cymbella cymbiformis C.Agardh	1, 2, 3, 4, 5
Cymbella excisa Kützing	2, 5
Cymbella neocistula Krammer var. *neocistula*	1
Cymbella tumida (Brébisson) Van Heurck	1, 2, 3, 4
Diatoma vulgaris Bory	1, 2
Diploneis oculata (Brébisson) Cleve	2
Discostella stelligera (Cleve & Grunow) Houk et Klee	2, 3, 4, 5
Encyonema auerswaldii Rabenhorst	1, 2, 3, 4, 5
Encyonema ventricosum (C.Agardh) Grunow	1, 2, 3, 4, 5
Encyonopsis microcephala (Grunow) Krammer	1, 2, 3, 5
Fallacia pygmaea (Kützing) Stickle et D.G.Mann in Round, R.M.Crawford et D.G.Mann	1, 2, 4
Fragilaria acus (Kützing) Lange-Bertalot	1, 2, 3, 5
Fragilaria gracilis Østrup	1
Fragilaria radians (Kützing) D.M.Williams et Round	1, 2, 3, 4
Fragilaria vaucheriae (Kützing) J.B.Petersen	1, 2, 3, 5
Gomphonema acuminatum Ehrenberg	1, 2, 3
Gomphonema augur Ehrenberg	5
Gomphonema auritum A.Braun ex Kützing	2, 3, 4, 5
Gomphonema clavatum Ehrenberg	1
Gomphonema extentum E.Reichardt et Lange-Bertalot	1
Gomphonema innocens E.Reichardt	1
Gomphonema italicum Kützing	1
Gomphonema micropus Kützing	1, 2, 3
Gomphonema olivaceum (Hornemann) Brébisson	1, 2, 3, 4, 5
Gomphonema parvulum (Kützing) Kützing	1, 2, 3, 4, 5
Gomphonema rhombicum Fricke	1, 2

Table 2. (Continued).

Gomphonema subclavatum (Grunow) Grunow	4
Gomphonema truncatum var. *turgidum* (Ehrenberg) R.M. Patrick in Patrick et Reimer	1, 2, 3, 4, 5
Grunowia solgensis (A.Cleve) Aboal	1
Grunowia tabellaria (Grunow) Rabenhorst	1, 5
Gyrosigma acuminatum (Kützing) Rabenhorst	1, 2, 3, 4, 5
Gyrosigma kuetzingii (Grunow) Cleve	2
Lindavia comta (Kützing) Nakov, Gullory, Julius, Theriot et Alverson	1, 2, 3, 5
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	2
Melosira varians C.Agardh	1, 2, 3
Meridion circulare (Greville) C.Agardh	2
Navicula antonii Lange-Bertalot	3,4
Navicula capitatoradiata H.Germain	1, 2, 3, 4, 5
Navicula cryptotenella Lange-Bertalot	1, 2, 3, 4, 5
Navicula germainii J.H.Wallace	5
Navicula lanceolata Ehrenberg	1, 2, 5
Navicula oblonga (Kützing) Kützing	5
Navicula radiosa Kützing	1, 2,5
Navicula tripunctata (O.F.Müller) Bory	1, 3, 4
Navicula trivialis Lange-Bertalot	1, 2, 3, 4
Navicula veneta Kützing	2
Navicula wildii Lange-Bertalot	3
Neidium affine (Ehrenberg) Pfitzer	1
Nitzschia acicularis (Kützing) W.Smith	3
Nitzschia dissipata var. *media* (Hantzsch) Grunow	1, 2, 3
Nitzschia gracilis Hantzsch	4
Nitzschia inconspicua Grunow	1, 2, 3, 4, 5
Nitzschia intermedia Hantzsch	1, 2, 3
Nitzschia littoralis var. *slesvicensis* Grunow	3
Nitzschia palea (Kützing) W.Smith	1, 2, 3, 4, 5
Nitzschia vermicularis (Kützing) Hantzsch in Rabenhorst	1, 2
Pantocsekiella ocellata (Pantocsek) K.T.Kiss et E.Ács	1, 2, 3, 4, 5
Placoneis sp.	1, 2
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	1, 3
Pinnularia subcommutata var. *nonfasciata* Krammer	5
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot	1
Rhopalodia gibba (Ehrenberg) Otto Müller	3
Sellaphora pupula (Kützing) Mereschkovsky	2, 4
Surirella angusta Kützing	1, 2, 3, 4
Tryblionella angustata W.Smith	3, 4, 5
Tryblionella apiculata W.Gregory	2
Tryblionella hungarica (Grunow) Frenguelli	1, 2
Tryblionella littoralis (Grunow) D.G.Mann	1, 2, 3, 5
Ulnaria ulna (Nitzsch) Compère in Jahn et al.	1, 2, 3, 4, 5

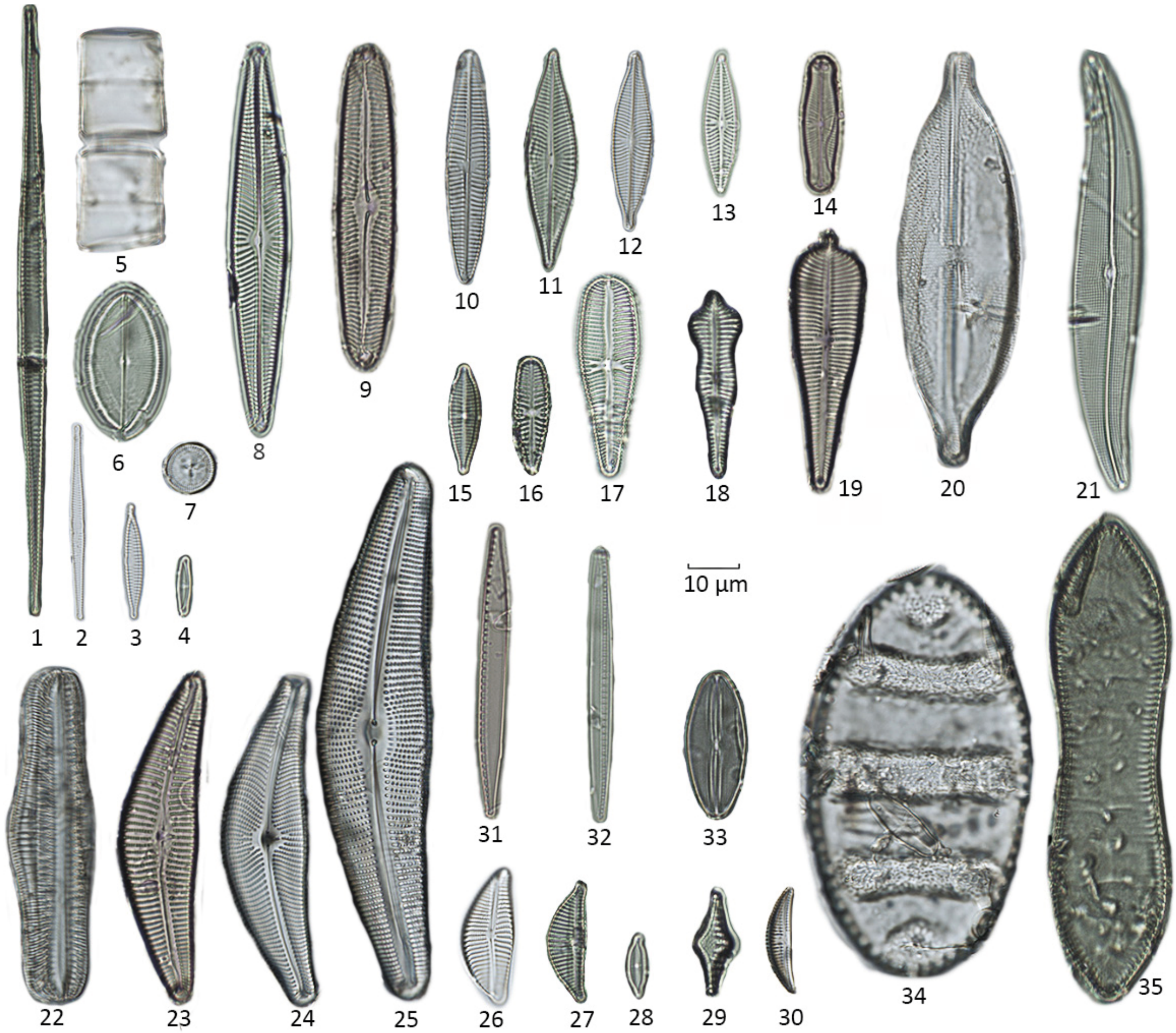

Figure 2. Microphotographs of selected epiphytic diatoms in Lake Modrac: 1 - *Fragilaria acus*, 2 - *F. gracilis*, 3 - *F. vaucheriae*, 4 - *Achnanthidium minutissimum*, 5 - *Melosira varians*, 6 - *C. placentula* var. *lineata*,7 - *Pantocsekiella ocellata*, 8 - *Navicula radiosa*, 9 - *Pinnularia subcommutata* var. *nonfasciata*, *10 - N. tripunctata*, *11 - N. trivialis*, *12 - N. capitatoradiata*, *13 - N. cryptotenella*, *14 - Sellaphora pupula sensu lato*, *15 - Gomphonema parvulum*, *16 - G. olivaceum*, *17 - G. truncatum var. turgidum*, *18 - G. acuminatum*, *19 - G. augur*, *20 - Anomoeoneis sphaerophora*, *21 - Gyrosigma acuminatum*, *22 - Rhopalodia gibba*, *23 - Cymbella cymbiformis*, *24 - C. tumida*, *25 - Brebissonia lanceolata*, *26 - Encyonema auerswaldii*, *27 - E. ventricosum*, 28 - *Encyonopsis microcephala*, *29 - Grunowia tabellaria*, *30 - Amphora copulata*, *31 - Nitzschia palea*, *32 - Nitzschia dissipata* var. *media (Hantzsch) Grunow*, *33 - Fallacia pygmaea*, *34 - Cymatopleura elliptica*, 35 - *Cymatopleura solea*.

species in our study was *Achnanthidium minutissimum*, a typical cosmopolitan species with a wide ecological spectrum (Krammer and Lange-Bertalot, 2004b); it has been observed as the most abundant in spring ecosystems in a previous study in northeastern Bosnia and Herzegovina (Kamberović et al., 2019). According to Kelly et al. (2014), this species is an indicator of good water status. However, most of the other taxa identified in this study such as *Amphora pediculus*, *Cocconeis placentula*, *Cymatopleura solea*, *Diatoma vulgaris*, *Fragilaria vaucheriae*, *Gomphonema parvulum*, *Hippodonta capitata*, *Navicula capitatoradiata*, *N. tripunctata*, *N. veneta*, and *Nitzschia palea* belong to the group of indicators of moderate status for high alkalinity lakes listed in Kelly et al. (2014). Some typical planktonic taxa were abundant in epiphytic samples such as *Pantocsekiella ocellata*, which is a mesoeutraphentic taxon with high oxygen demands (van Dam et al., 1994).

Since that species composition differs greatly among the substrate, results of the study by Poulíčková et al. (2004)

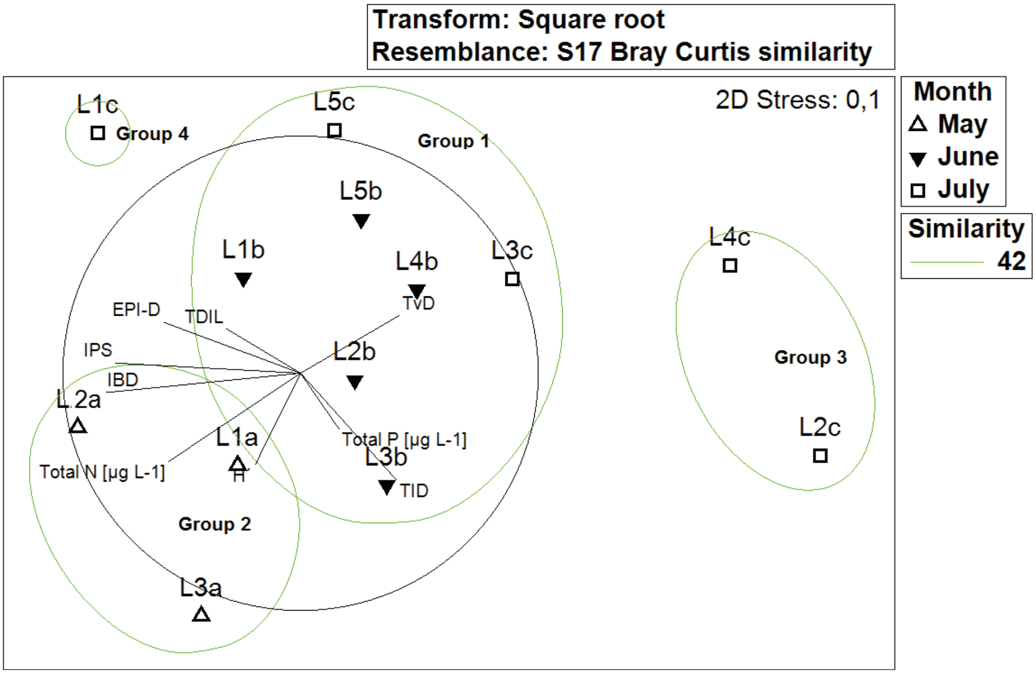

Figure 3. Nonmetric multi dimensional scaling (nMDS) of sites (presented by site codes) based on a Bray–Curtis matrix of similarities of algal assemblages, overlapped with clusters and Pearson correlation vectors for diatom indices and nutrients.

pointed out advantages of using samples from reed stalks in comparison with epilithic and epipelic assemblages. Diversity of diatom taxa estimated for epiphytic samples from reed stalks in our study was moderately high, and the total number of taxa was higher in comparison with epipelic samples from Šerićka bara marsh, which is near Lake Modrac (Kamberović et al., 2017). However, the use of reed as substrate may present difficulty in a lake with a large variation in water levels, when underwater reed stalks are not always available. A large decline in water levels was recorded in July when several samples were taken from other macrophytes, which could have caused variability in the species composition in samples from July observed on the nDMS diagram.

Blanco et al. (2014) demonstrated significant effects of TP, conductivity, and pelagic chlorophyll *a* in the configuration of epiphytic diatom assemblages in western European shallow lakes, concluding that epiphytic diatom assemblages are useful bioindicators of shallow-lake trophic status. Testing the applicability of some diatom indices for water quality assessment based on littoral diatoms resulted in various recommendations. The Rott Trophic Index was found to be most applicable to perialpine lakes in Austria (Poulíčková et al., 2004); the index given by van Dam et al. (1994) was the best for water assessment in shallow fishponds in the Czech Republic (Kitner and Poulíčková, 2003). Ács et al. (2005) explored the application of diatom indices in water quality monitoring of Lake Velence in Hungary and concluded that samples of reed periphyton can successfully be used for the estimation of water quality, giving a recommendation for the use of the IBD index due to it having the best correlation with the total phosphorus in water and the highest percentage of indicator species. Having in consideration the highest percentage of indicator taxa, the most applicable in our study was the IPS index. Jakovljević et al. (2016) also gave the recommendation for use of the IPS index in the research of benthic diatoms in water quality assessment of the Mlava River in Serbia. The index developed for littoral diatoms, TDIL, had the lowest percentage of indicator taxa. Both TID and TvD indices indicated the mesoeutrophic status of Lake Modrac. Bearing in mind that results of the intercalibration process of ecological status concepts across European lakes for littoral diatoms which were based on the Rott Trophic Index (Kelly et al., 2014), TID are the most suitable for further application on littoral diatoms for estimation of trophic state. Given that the environmental legislation in Bosnia and Herzegovina does not provide detailed instructions on using diatoms in biological assessment, expressed in the form of Ecological Quality Ratios (EQRs), a monitoring system based on biological quality elements and reference water bodies should be developed as soon as possible. The results of this study can be useful for the development of biomonitoring tools for lakes in Bosnia and Herzegovina.

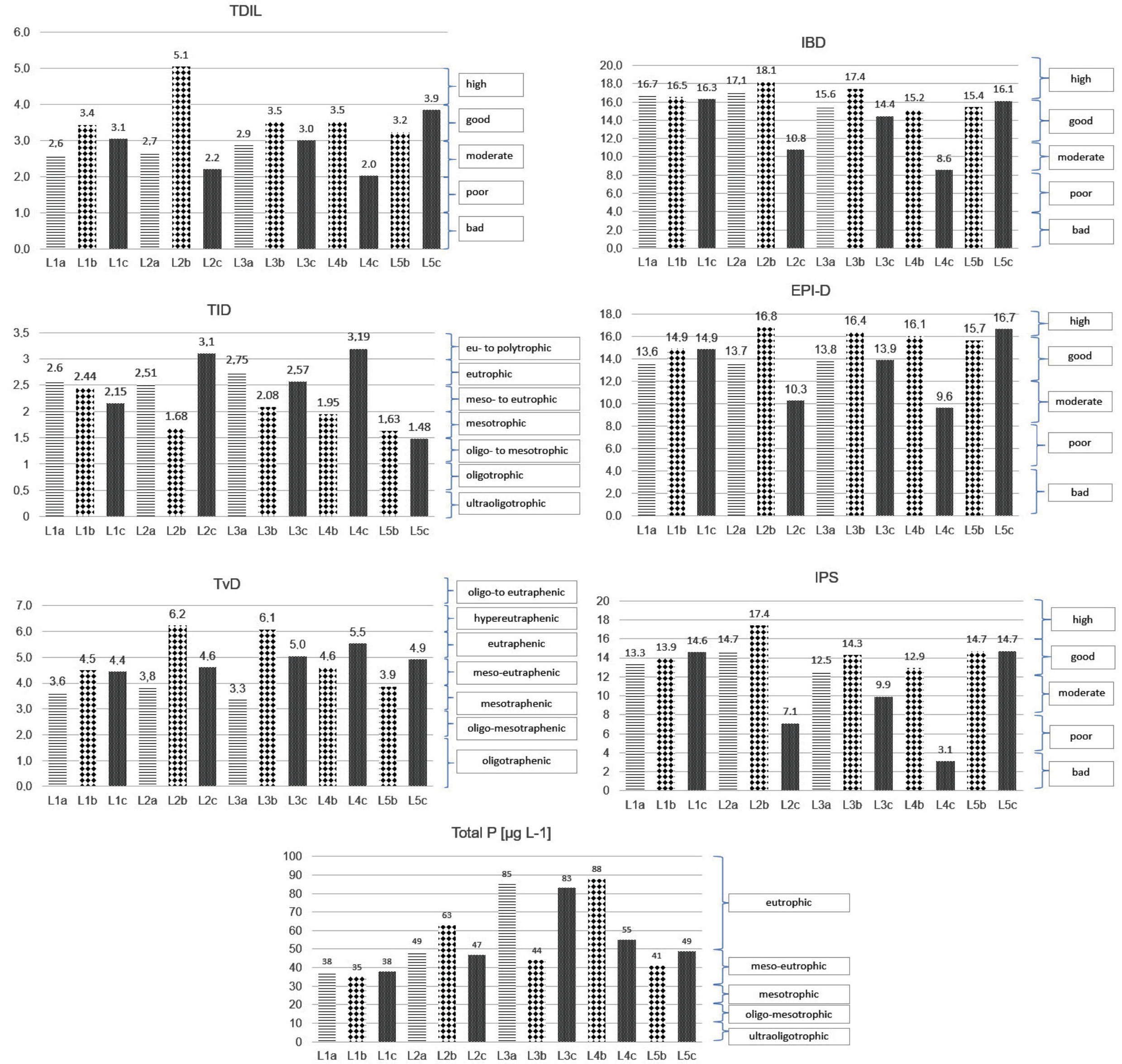

Figure 4. Trophic and ecological status of Lake Modrac per location assessed by 6 diatom indices and total phosphorus: TDIL - Trophic Diatom Index for Lakes; TID - Rott Trophic Index; TvD - van Dam Trophic Index; IBD - Biological Diatom Index; EPI-D - Eutrophication Pollution Index Diatoms; IPS - Pollution Sensitivity Index; Total P – total phosphorus.

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